DR SUSAN CHENG SHELMERDINE (Orcid ID : 0000-0001-6642-9967)
DR THOMAS S JACQUES (Orcid ID : 0000-0002-7833-2158)

Article type : Original Article

**Title:**

# British Neuropathological Society and International Society of Forensic Radiology and Imaging Expert Consensus Statement for Post-mortem Neurological Imaging

**Shortened running title:**

BNS/ISFRI Consensus Statement for Post-mortem Neurological Imaging

**Authors:**

Susan C. Shelmerdine[1,2], John Ciaran Hutchinson[1,2], Safa Al-Sarraj[3], Nat Cary[4], Tim Dawson[5], Daniel Du Plessis[6], Paul G Ince[7], Siobhan McLaughlin[8], Liina Palm[1], Colin Smith[9], Neil Stoodley[10] , Rick van Rijn[11], Owen J Arthurs [1, 2], Thomas S Jacques [1, 2] .

On behalf of the British Neuropathological Society and International Society of Forensic Radiology and Imaging

**Affiliations:**

1. Great Ormond Street Hospital for Children NHS Foundation Trust, London, UK
2. Great Ormond Street Institute of Child Health, UCL, London, UK
3. Department of Clinical Neuropathology, Kings College Hospital, London, UK
4. Forensic Pathology Services, Wantage, Oxfordshire, UK
5. Department of Neuropathology, Lancashire Teaching Hospitals NHS trust, Preston, UK
6. Department of Neuropathology, Salford Royal Hospital, Stott Lane, Greater Manchester, UK
7. Sheffield Institute for Translational Neuroscience, Sheffield University, Sheffield, UK

This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record. Please cite this article as doi: 10.1111/nan.12482

8. Edinburgh Forensic Radiology and Anthropology Imaging Centre, Royal Infirmary of Edinburgh, Edinburgh, UK
9. Academic Department of Neuropathology, Centre for Clinical Brain Sciences, University of Edinburgh, Edinburgh, UK
10. Department of Paediatric Neuroradiology, Frenchay Hospital, Bristol, UK.
11. Department of Radiology, Academic Medical Center, Emma Children's Hospital, Amsterdam, The Netherlands

**Corresponding Author:**

Dr. Susan Shelmerdine,

Paediatric Radiology Research Fellow,

Department of Clinical Radiology, Great Ormond Street Hospital, London, UK WC1N 3JH

susan.shelmerdine@gosh.nhs.uk

**Keywords (up to 8):**

Postmortem, neuroimaging, radiology, brain, neurology, Magnetic Resonance Imaging (MRI), Computed Tomography (CT), Autopsy

**Funding Sources:**

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). OA is funded by a National Institute for Health Research (NIHR) Clinician Scientist Fellowship (NIHR-CS-012-002), and TJ is funded by The Brain Tumour Charity, Children with Cancer UK, Great Ormond Street Children's Charity, Olivia Hodson Cancer Foundation and NIHR.

The authors receive funding from the Great Ormond Street Children's Charity and the Great Ormond Street Hospital NIHR Biomedical Research Centre. 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.

**Conflicts of Interest:**

The authors in this article have no conflicts of interest to disclose.

**Author Contributions:**

Authors contributed to the following aspects of the manuscript including project design (SCS, JCH, OJA, TSJ), contribution to the consensus statement discussions and data analysis (all authors - SCS, JCH, SAS, NC, TD, DDP, PGI, SM, LP, CS, NS, RvR, OJA, TSJ), manuscript preparation and submission (SCS, JCH, OJA, TSJ). All authors have approved the final version of the manuscript.

**Ethical Approval:**

Ethical approval was not required for this expert consensus statement article which does not use any clinical data.

**British Neuropathological Society and International Society of Forensic Radiology and Imaging Expert Consensus Statement for Post-mortem Neurological Imaging**

**Abstract:**

**Aims:** To develop an expert consensus statement regarding appropriate clinical and forensic post-mortem neurological imaging.

**Methods:** An expert panel of clinicians were recruited from registered members of the British Neuropathological Society (BNS) and the International Society of Forensic Radiology and Imaging (ISFRI) with post-mortem expertise. Following a focus group meeting, 16 core statements were incorporated into an online modified Delphi survey and each panellist was asked to score their level of agreement. Following the first iteration, two statements that failed to reach consensus were modified and re-rated. Consensus was predefined as 75% agreement across responders.

**Results:** 17 experts joined the panel and 12 (70.6%) attended the focus group meeting. 14 (82%) completed both iterations of the survey. Consensus was reached for need of adequate clinical history, multidisciplinary discussion, establishment of special interest groups to discuss cases, gathering

further evidence to inform imaging choices, establishment of methods for quality assessment in reporting standards and adequate funding for imaging services. The panel agreed that pathologists should be responsible for neuroimaging referrals, collating results of ancillary tests, and producing the final post-mortem report. Areas requiring further discussion include the impact of double reporting, indications for neuroimaging, and utilities of 3D printing.

**Conclusion:** The BNS / ISFRI statement represents current views of an expert panel of health professionals engaged in post-mortem neuroimaging. We hope this provides a working guideline for less experienced operators, stimulates discussion, and highlights the most pressing clinical and research questions.

**Abbreviations:**

3D – Three-dimensional

BNS - British Neuropathological Society

CT – Computed Tomography

ISFRI - International Society of Forensic Radiology and Imaging

MDT – Multidisciplinary team

MRI – Magnetic Resonance Imaging

PM – Post-mortem

PMCT - Post-mortem Computed Tomography

PMMR – Post-mortem Magentic Resonance imaging

**INTRODUCTION**

Post-mortem imaging techniques are increasingly being used across the world [1,2] both as an alternative to autopsy or an adjunct in elucidating the cause of death. The decline in autopsy rates [3,4], the increased availability of imaging equipment and shorter imaging times, as well as obviating the need for 'opening the body' all make post mortem imaging an attractive technique at autopsy.
In post-mortem neuroimaging, an added benefit over autopsy includes the lack of disturbance to the underlying neuroanatomy. This allows a reliable assessment of neuroanatomy even in cases of advanced putrefaction [5] and maceration [6] - information which may be lost during dissection. Whilst

expected normal post-mortem changes over time have been well documented on both post-mortem CT and MRI [7,8, 9], diagnostic accuracy rates for the identification of neuropathology in adults are lacking, with the majority of findings described in small case reports and series and mostly utilising CT. Comparatively, in children, the diagnostic accuracy for identification of the presence of pathology in the nervous system at post-mortem MRI (PMMR) is higher than that for post-mortem CT (PMCT) with estimated sensitivity and specificity rates of 88.4% and 95.2% [10] compared to 60.9% and 85% respectively [11].

Neuroimaging may be useful in disaster victim identification [12,13,14], determining the presence of skull fractures and intracranial haemorrhage in non-accidental injury [15], crime scene reconstruction [16] or in the investigation of an unexpected and otherwise clinically unexplained death [17]. Nevertheless, robust evidence based studies and comprehensive guidelines specifically for post-mortem neuroimaging are lacking.

With increasing demand for imaging from bereaved families, coroners and referring clinicians, there is a risk that variations in practice may arise from differences in referral rates and caseload, whereas national guidelines are preferable. The objective of this study was therefore to develop practical, consensus based statements based on expert guidance within the field of post-mortem neurological imaging. In publishing the consensus statement, we hope to stimulate discussion, highlight the most pressing research questions, and elucidate what experts believe to be contributory in different clinical scenarios.

**METHODS**

Ethical approval was not required for this study. No funding sources were sought in the development of this review. We are grateful to the British Neuropathological Society for sponsoring the study meetings.

**Selection of Experts**

Our panel of experts were recruited primarily through an invitation email to registered members of the British Neuropathological Society (BNS) and the International Society of Forensic Radiology and Imaging (ISFRI). The BNS and ISFRI societies were chosen as they are clinically relevant societies and include both academics with an interest in post-mortem work and practicing clinicians within the relevant field (i.e. pathologists and radiologists, who both undertake forensic and clinical work). In addition, representatives from forensic pathology (NC) and paediatric and perinatal pathology (LP) were invited to join the group.

**Survey Development**

An expert panel focus group meeting was held on the topic of post-mortem neurological imaging in January, 2017 in London, UK. Following the meeting, the lead and supervising authors (SCS, JCH, OJA, TSJ) summarised the key themes into 16 relevant statements. These were incorporated into an online survey, for rating by the panel on a 5 point Likert scale (1 – strongly disagree, 2 – disagree, 3 – neither, 4 – agree, 5 – strongly agree). Optional free-text feedback boxes were also provided for each statement where an expert may wish to elaborate on their response.

Prior to dissemination of the survey, 'consensus' was predefined as 75% agreement (i.e. score 4 or 5) or disagreement (i.e. score 1 or 2) for any statement by the expert panel. Any statement rated as 'neither' (i.e. score 3) was not counted in the 'agreement' or 'disagreement' summation. A 75% consensus rating was used as it represents the median percentage threshold in a large systematic review of Delphi surveys in the scientific literature[18].

**Data Collection**

The online survey was created in Google Forms (https://www.google.co.uk/forms/about). An email containing a link to the first iteration of the survey was sent in May 2017. A reminder e-mail was sent out 3 weeks later, and the total time available to respond was 4 weeks (May – June 2017).

After the results were analysed, a second iteration was compiled and redistributed to the expert panellists in June 2017. This was a shortened version which included only two statements that did not reach consensus by the panel. These two statements were re-worded to reflect feedback received in

the first iteration, and panellists were asked to reflect on the amended statements in the same manner. A reminder e-mail was sent out 3 weeks later, and the total time available to respond was again 4 weeks (June – July 2017).

All panellist responses were anonymised in this study, known only to the authors collecting the data, but not to each other.

## RESULTS

17 expert panellists expressed their interest in partaking in the study. Of the 17 panellists, 12 (70.6%) attended the initial focus group meeting in January 2017. The first iteration of the online survey was completed by 14/17 (82%) expert panellists (this included all 12 members who attended the focus group meeting). The second iteration was completed by the same 14 panellists who responded to the first iteration. Three experts who had initially expressed an interest did not result in partaking in the survey at any stage.

The 14 panellists who responded to both iterations comprised of 5 neuropathologists, 3 paediatric radiologists, 2 paediatric pathologists, 1 general radiologist, 1 neuroradiologist, 1 paediatric neuropathologist, 1 forensic pathologist.

The headings for the different key themes examined by our panel and the statements relating to these themes are listed and discussed below. All reference to the term 'post-mortem imaging' refer specifically to the imaging of the nervous system, unless otherwise stated. A summary of these results are provided in Table 1 and Figure 1.

### Referrals for Post mortem Neurological Imaging

1. *Adequate and accurate clinical patient history should be provided prior to post-mortem imaging.*

There was 100% (14/14) agreement of this statement in the first iteration, although the panel raised the possibility that clinical patient history may not always be available, may be misleading or the circumstances may be unknown. Nevertheless, in all cases, a relevant clinical question should be provided.

2. *Referrals for post-mortem imaging should be initiated through the pathologist responsible for the case.*

There was 78.5% (11/14) agreement for this statement. It was argued that this strongly depended on the clinical situation and that more importance should be placed upon who has oversight of the final integrated post-mortem report rather than who initiates the imaging referral. Where families only wish for post-mortem imaging for their relative/child (but no autopsy), it was discussed that the pathologist may not be involved in the case unless further tissue sampling was required, but should still have a part to play in integration of the antemortem and post-mortem findings.

In the focus group discussion, there was discussion regarding whether only clinicians at consultant level should be allowed to make imaging referrals to prevent potential overuse and / or abuse of the post-mortem imaging service.

**Type of Imaging Modality and Relevant Indication for Imaging**

3. *The modality of imaging should be determined by liaison between pathology and radiology.*

There was a 78.5% (11/14) agreement for this statement. The panellists believed that ideally there should be discussion between a radiologist and a pathologist, but free text comments suggested that the panel felt this was mostly the radiologist's domain. This was particularly felt to be the case in situations where with the procedure would involve only imaging, without subsequent autopsy. Panel members felt that in this scenario, choice of imaging modality should be made by a radiologist, or a pathologist with sufficient experience of post-mortem imaging.

.

4. *Post-mortem imaging is indicated in the following situations:*

*The panellists were offered six different potential neuroimaging indications and asked to rank their agreement. In three situations, there was >75% consensus agreement for imaging which included:*

a) Major trauma cases (inclusive of ballistic injuries and road traffic accidents) to determine pattern of fractures, trajectory and number of bullets/weapons and crime scene reconstruction. (92.8%, 13/14 agreement)

b) To provide sanitised images to present to a jury in medicolegal proceedings (78.5%, 11/14 agreement)

c) In terminations of pregnancies or perinatal cases where the brain may be autolysed and damaged from the extraction process (85.7%, 12/14 agreement)

*For the other three situations, there was < 75% consensus for the indication to image:*

a) For disaster victim identification, such as airline crashes or road traffic accidents
71.4% (10/14) agreement, 21.4% (3/14) neutral, 7.1% (1/14) disagreement

b) Cases with a suspected vascular pathogenesis (i.e. vertebral dissection or stroke)
71.4% (10/14) agreement, 21.4% (3/14) neutral, 7.1% (1/14) disagreement
It was suggested that in such cases post-mortem CT angiography should also be considered as a technique because a diagnosis of stroke can be difficult to make on unenhanced post-mortem CT, especially if the time between death and imaging is prolonged.

c) In all specialist neuropathological examinations
50% (7/14) agreement, 28.6% (4/14) neutral, 21.4% (3/14) disagreement

There was the argument that if ante-mortem imaging had already been performed shortly prior to death, there may not be any additional value of re-imaging in the post-mortem setting, so this should be situation dependent rather than a blanket imaging statement for every case.

As medical evidence regarding specific indications for neuroimaging is still emerging, statements that did not reach consensus from this question were not reworded in the second survey iteration.

5. *Even where not currently indicated, the use of post-mortem imaging should be considered all neurological autopsies and follow a pragmatic and evidence-gathering approach until further evidence becomes available.*

There was 85.7% (12/14) agreement for this statement, as it has potential to build a strong baseline upon which to base future decisions. Some panellists disliked the word 'all', but did believe imaging should be considered where possible (such as suspected gross pathology e.g. stroke, trauma) and that an evidence based approach for gathering diagnostic accuracy information was a reasonable suggestion.

For cases where the imaging may be performed without clear indication, it should be made clear to parents and relatives that this is the case, and ideally the results should be collated into a large prospective cohort study to enable an evidence base to be collected.

**Imaging Reporting, Analysis and Quality Control**

6. *The impact of 3D printing should be assessed prior to offering this service to assist in legal proceedings.*

In the first iteration, the panel were asked to rate the statement '3D printing from post-mortem imaging should be offered to assist in legal proceedings'. For this, there was only 57.1% (8/14) agreement, 35.7% (5/14) neutral and 7.1% (1/14) disagreement. The lack of consensus lay in part from knowing who would fund this service, and where the facilities exist for this to be routinely offered. It was felt by the panellists that the impact of having a 3D printed model on the judge/jury should be assessed before offering this as a routine service in case it significantly changed perceptions of injuries within criminal cases.

For the second iteration, the statement was amended to include a comment pertaining to 'the impact of 3D printing'. This revised statement garnered 92.9% (13/14) agreement. Whilst responders agreed that the impact should be assessed, one panellist felt that in straightforward situations, such as depiction of a skull fracture, the method may not require a formal method of assessment.

7. *Where post-mortem imaging is conducted, provisions should be made for a joint pathology and radiology multidisciplinary team (MDT) meeting to prevent cases being interpreted in isolation without a full clinico-pathological context.*

There was 92.8% (13/14) agreement for this statement. The allocation of a joint MDT meeting was felt to be critical by the majority of responders. One panellist believed that to provide such a meeting to discuss all cases would cause more complexity and expense, and perhaps pre-selection of cases for review would be more appropriate.

8. *The pathologist and radiologist should refrain from issuing an authorised final report on cases prior to an interdisciplinary team meeting.*

There was a 78.5% (11/14) agreement for this statement. It was felt that some form of discussion should occur, although a formal MDT may not be necessary, particularly if a one-to-one discussion was more appropriate and convenient. If a discrepancy was discovered between the tests then the results should be discussed. It was acknowledged that in certain forensic situations, it may not be possible to finalise the radiology report until the pathology report is available to review.

9. *Any centre offering post-mortem imaging should have a formal mechanism for Quality Assessment.*

There was complete (14/14) agreement for this statement, although the actual logistics of this was questioned. In a small field without an established formal training programme or registration standards it would be difficult to establish how high or low a quality standard bar should be set. There was the suggestion that this should be led by the radiology department.

10. *Any centre offering post-mortem imaging should have a formal mechanism for Quality Assessment comparable to those used in pathology services e.g. external quality assessment schemes, external accreditation.*

There was 92.8% (13/14) agreement for this statement, although it may be difficult to establish a UK based mechanism given the current small number of radiologists who report post-mortem imaging.

11. *The impact and feasibility of double reporting of post-mortem imaging by two radiologists should be assessed prior to suggesting blanket implication for all cases.*

In the first iteration, this statement originally read '*Double reporting of post-mortem imaging cases by two radiologists should be encouraged for a) training and b) quality assessment purposes.'* This achieved a 71.4% (10/14) agreement, 14.3% (2/14) neutral, and 14.3% (2/14) disagreement. Reasons for lack of consensus included the perception that the specialty field is too small for such an endeavour, that it would require more time in order to perform this, and there would not be any remuneration for taking part. In addition, it was argued that work in the living is not routinely double reported, and therefore there is no reason why it should be performed in the dead.

Therefore the statement was reworded for the second iteration to include a comment relating to 'impact and feasibility of double reporting'. For this, there was 92.9% (13/14) agreement. Again, concerns were raised regarding the logistical difficulties for this until a greater number of reporting radiology consultants were engaging in post-mortem imaging. However, other panellists argued in favour of this revised statement saying that a second report need not be performed at the same time, but could be done as a 'safety net' and for reflective/teaching purposes.

12. *Regional or national post-mortem imaging specialist interest group meetings should be established to build collective expertise.*

There was complete (14/14) agreement for this statement and no additional comments were given.

**Lead Clinician for Post Mortem Cases**

13. *The pathologist (regardless of whether the situation calls for a neuropathologist/ forensic pathologist) should remain the lead clinician in charge of the case.*

There was 92.8% (13/14) agreement for this statement. One panellist stated that the instruction to undertake a PM examination is usually (although not necessarily) made by HM Coroner to a pathologist, so the pathologist should remain the lead clinician regardless of what other ancillary tests are undertaken.

14. *The pathologist (regardless of whether the situation calls for a neuropathologist/ forensic pathologist) should remain the lead clinician in charge of the case even in situations where the brain is not extracted at autopsy and only imaging was performed.*

There was 92.8% (13/14) agreement for this statement. If an autopsy is planned then panellists believed that the pathologist should remain the lead clinician. One panellist stated that imaging in death does not differ from those of the living, in that the imaging report forms one part of the larger jigsaw puzzle, and the main clinician (i.e. pathologist) puts the pieces together with help of toxicology, histology and clinical findings.

**Post-mortem Imaging Funding**

15. *Funding for post-mortem imaging needs to be addressed in addition to current payment for forensic pathology.*

There was complete agreement (14/14) amongst panellists that funding should be addressed, however the best mechanism for this was debatable. It was argued that there may not be a role for this service in healthcare systems where funding difficulties exist, but unless funding is nationalised then the use of post-mortem imaging may remain a local 'pet project' by some centres and not others. It was also suggested that introducing a specialist neuroradiology assessment would increase complexity of the reporting and the added value was questionable given additional expense.

16. *Funding for post-mortem imaging should be independent of reporting positive results.*

There was 92.9% (13/14) agreement for this statement. Panellists believed that any medicolegal system must be able to display independence from financial gains per result.

**Additional Comments**

Additional comments by the panel were encouraged at the end of both iterations. One panellist believed that post-mortem neuroimaging should be reserved to when consent is not given for an autopsy to confirm expected brain pathology although there was a fear that imaging may miss crucial pathology that would otherwise be detected at an autopsy. Another panellist felt that hospital governing bodies should re-introduce and provide funding for a post-mortem service for relatives and families. There was also a suggestion to introduce a specialised 'forensic neuropathologist medical examiner' post for pathologists who had an interest in the field to supervise the post-mortem investigative process, including the issues surrounding the neuroimaging.

**Discussion:**

In this study, consensus agreement was reached for the need for adequate clinical history, multidisciplinary discussion, establishment of a special interest group to discuss cases, gathering further evidence to inform imaging choices, establishment of methods for quality assessment in reporting standards and adequate funding for imaging services.

The notion of performing post-mortem neuroimaging to establish an evidence base in scenarios where robust evidence is lacking was agreed, and therefore, unsurprisingly, what constituted a strong clinical indication for neuroimaging was debated. The panel agreed that the pathologist should be responsible for referral for neuroimaging, collating results of ancillary tests, and producing the final post-mortem report. Areas to explore further prior to integration into guidelines include the impact of double reporting, indications for neuroimaging, and potential utilities of 3D printing.
Of the six potential indications for neuroimaging proposed to the panel, three achieved consensus (trauma/ballistic injuries, for medicolegal proceedings and for confirmation of brain anomalies in terminations of pregnancies). Of these, there is evidence that PMCT can provide additional information to the autopsy for the identification of facial fractures, air embolism, pneumencephalon and firing range for gunshot fatalities [19]. There is also data describing that PMMR can yield useful information in approximately 53% of fetuses where the brain was too autolysed for assessment at autopsy [20].

Of the three indication statements that did not achieve consensus (disaster victim identification (DVI), vascular pathogenesis and in all neuropathological examinations), reasons given by the panellists included uncertainty of benefit given lack of experience in DVI reporting, potential lack of ability to diagnose post-mortem cerebrovascular accidents on PMCT (without obtaining post-mortem CT angiography (PMCTA)) and the fact that post-mortem imaging may not need to be performed for all neuropathology cases if an ante-mortem study had been performed. Recent evidence from a large cohort of 210 subjects where PMCTA was performed [21], has shown that this imaging modality was better than autopsy for assessment of haemorrhage and trauma ($p = 0.008$), although the cases were not specific to neuropathology and none of the subjects were found to have suffered from a cerebrovascular incident. Nevertheless a cause of death was established by imaging in 92% of

coroner referred cases. Whilst our panel did not reach consensus on imaging for DVI, a positional statement advocating the usage of PMCT has already been published by ISFRI [22] and provides detailed information regarding information required by Interpol in such circumstances. As medical evidence regarding specific indications for neuroimaging is still emerging, statements regarding indications that did not reach consensus from this question were not reworded in the second survey iteration, but these could be re-examined in future.

In terms of running a post-mortem imaging service, it was agreed that some form of quality assessment should be implemented and funding issues should be addressed, although the best method for this was not established. The impact of double reporting and 3D printing from post-mortem studies are areas requiring further consideration and did not reach consensus in the first iteration of our survey. Whilst double reporting already occurs for the assessment of skeletal surveys in the setting of suspected non-accidental injury in children [23] and may reduce diagnostic errors [24], it is not routine clinical practice and would be resource intensive. Although double reporting forms a method for quality assessment, less labour intensive methods for achieving this may need to be considered. 3D printing can be performed on PMCT data and provide a sanitised method of demonstrating injuries and pathologies to relatives or a jury in a court of law [25], but is also not routine practice in many imaging centres and may incur additional labour, cost and expertise.
There were several limitations to our study. The Delphi method of investigation is subjective in nature and lack robust scientific validity. However, where expertise is rare and no conclusive medical evidence is available, combining shared knowledge and opinion can provide a helpful framework for other clinicians with less experience. In addition, by performing our survey online and preserving the anonymity and responses by each panellist, individual views were maintained and we believe each panellist was given more freedom to express their true opinions.

We acknowledge the limited number of expert panellists included, and the possibility that a different panel composed of a different mix of subspecialties may have generated different key themes and issues for debate whilst reaching differing conclusions. Nevertheless, we believe our results still provide a structure and outline of topics that will generate discussion, contribute to guidelines and ideas for future research.

**Conclusion**

The BNS / ISFRI statement on post mortem neurological imaging is a contemporary consensus based statement based on current views of an expert panel, designed to provide a practical guideline. In publishing the consensus statement, we hope to provide a working guideline for less experienced operators, stimulate discussion, and highlight the most pressing clinical and research questions.

**Figure Legends:**

**Figure 1:**

A flowchart depicting a summary of consensus statements in a 'service flow' structure. Only statements that reached consensus agreement are presented.

## References:


[1] Dirnhofer R, Jackowski C, Vock P, Potter K, Thali MJ. VIRTOPSY: minimally invasive imaging guided virtual autopsy. Radiographics. 2006. 26(5): 1305-1333

[2] Saunders SL, Morgan B, Raj V, Rutty GN. Post-mortem computed tomography angiography: past, present and future. Forensic Sci Med Pathol. 2011. 7(3):271-277

[3] Blokker BM, Weustink AC, Hunink MGM, oosterhuis JW. Autopsy rates in the Netherlands: 35 years of decline. Plos One. 2017 Jun 15;12(6):e0178200

[4] Oluwasola AO, Fawole OI, Otegbayo JA, Ayede IA, Ogun GO, Ukah CO, Bamigboye AE. Trends in clinical autopsy rate in a Nigerian tertiary hospital. Afr J Med Sci. 2007 Sep; 36(3):267-72

[5] Tschui J, Jackowski C, Schwendener N, Schyma C, Zech WD. Postmortem CT and MR brain imaging of putrefied corpses. Int J Legal Med. 2016 Jul; 130(4):1061-8

[6] Arthurs OJ, Thayyil S, Pauliah SS, Jacques TS, Chong WK, Gunny R, Saunders D, Addison S et al. Diagnostic accuracy and limitations of post-mortem MRI for neurological abnormalities in foetuses and children. Clin Radiol. 2015 Aug; 70(8); 872-80

[7] Kobayashi T, Shiotani S, Kaga K, Saito H, saotome K, Miyamoto K, Kohno M, Kikuchi K, Hayakawa H, Homma K. Characteristic signal intensity changes on post-mortem magnetic resonance imaging of the brain. Jpn J Radiol. 2010. Jan; 28(1):8-14

[8] Sieswerda-Hoogendoorn T, Beenen LF, van Rijn RR. Normal cranial post-mortem CT findings in children. Forensic Sci Int. 2015; 246; 43-49

[9] Ishida M, Gonoi W, Okuma H, Shirota G, Shintani Y, Abe H, Takazawa Y, Fukayama M, Ohtomo K. Common post-mortem computed tomography findings following atraumatic death: differentiation between normal post-mortem changes and pathologic lesions. Korean J Radiol. 2015 Jul-Aug; 16(4): 798-809

[10] Arthurs OJ, Thayyil S, Pauliah SS, Jacques TS, Chong WK, Gunny R, Saunders D, Addison S et al. Diagnostic accuracy and limitations of post-mortem MRI for neurological abnormalities in foetuses and children. Clin Radiol. 2015 Aug; 70(8); 872-80

[11] Arthurs OJ, Guy A, Thayyil s, Wade A, Jones R, Norman W, Scott R, Robertson NJ, Jacques TS, Chong WK, Gunny R, Saunders D, Olsen OE, Owens CM, Offiah AC, Chitty LS, Taylor AM, Sebire NJ. Comparison of diagnostic performance for perinatal and paediatric post-mortem imaging: CT versus MRI. Eur Radiol. 2016. 26: 2327-2336

[12] Morgan B, Alminyah A, Cala A, O ′Donnell C, Elliott D, Gorincour G et al. Use of post-mortem computed tomography in Disaster Victim Identification Positional statement of the members of the Disaster Victim Identification working group of the International Society of Forensic Radiology and Imaging. J Forens Radiol Imaging. 2014. 2(3):114–116

[13] Rutty GN, Alminyah A, Cala A, Elliot D, Fowler D, Hofman P et al. Use of radiology in disaster victim identification: positional statement of the members of the disaster victim identification working group of the international society of forensic radiology and imaging. J Forens Radiol Imaging. 2013. May (4):218

[14] Ruder TD, Kraehenbuehl M, Gotsmy WF, Mathier S, Ebert LC, Thali MJ, Hatch GM. Radiologic identification of disaster victims: A simple and reliable method using CT of the paranasal sinuses. Eur J Radiol. 2012. 81: e132-138

[15] Proisy M, Marchand AJ, Loget P, Bouvet R, roussey M, Pele F, Rozel C, Trequier C, Darnault P, Bruneau B. Whole body post-mortem computed tomography compared with autopsy in the investigation of unexpected death in infants and children. Eur Radiol. 2013. Jun; 23(6): 1711-9.

[16] Brough AL, Morgan B, Rutty GN. Postmortem computed tomography (PMCT) and disaster victim identification. Radiol. Med. 2015. 120: 866-873

[17] Ishida M, Gonoi W, Okuma H, Shirota G, Shintani Y, Abe H, Takazawa Y, Fukayama M, Ohtomo K. Common post-mortem computed tomography findings following atraumatic death: differentiation between normal post-mortem changes and pathologic lesions. Korean J Radiol. 2015 Jul-Aug; 16(4): 798-809

[18] Diamond IR, Grant RC, Feldman B, Pencharz PB, Ling SC, Moore AM, Wales PW. Defining consensus: A systematic review recommends methodologic criteria for reporting Delphi studies. J Clin Epidem. 2014. 67: 401-409.

[19] Makhlouf F, Scolan V, Ferretti G, Stahl C, Paysant F. Gunshot fatalities: correlation between post-mortem multi-slice computed tomography and autopsy findings: a 30 months retrospective study. Leg Med (Tokyo). 2013. May; 15(3): 145-8

[20] Arthurs OJ, Thayyil S, Pauliah SS, Jacques TS, Chong WK, Gunny R, Saunders D, Addison S et al. Diagnostic accuracy and limitations of post-mortem MRI for neurological abnormalities in foetuses and children. Clin Radiol. 2015 Aug; 70(8); 872-80

[21] Rutty GN, Morgan B, Robinson C, Raj V, Pakkal M, Amoroso J, Visser T, Saunders S, Biggs M, Hollingbury F, McGregor A, West K, Richards C, Brown L, Harrison R, Hew R. Diagnostic accuracy of post-mortem CT with targeted coronary angiography versus autopsy for coroner-requested post-mortem investigations: A prospective, masked, comparison study. Lancet 2017; 390: 145-54

[22] Morgan B, Alminyah A, Cala A, O ′Donnell C, Elliott D, Gorincour G et al. Use of post-mortem computed tomography in Disaster Victim Identification Positional statement of the members of the Disaster Victim Identification working group of the International Society of Forensic Radiology and Imaging. J Forens Radiol Imaging. 2014. 2(3):114–116

[23] Society and College of Radiographers and The Royal College of Radiologists. The radiological investigation of suspected physical abuse in children. London: The Royal College of Radiologists, 2017.

https://www.rcr.ac.uk/system/files/publication/field_publication_files/bfcr174_suspected_physical_abuse.pdf. Accessed 29/09/2017

[24] Sahni VA, Khorasani R. Radiology double reads. BMJ Quality Saf. 2016. Aug; 25(8):569-71

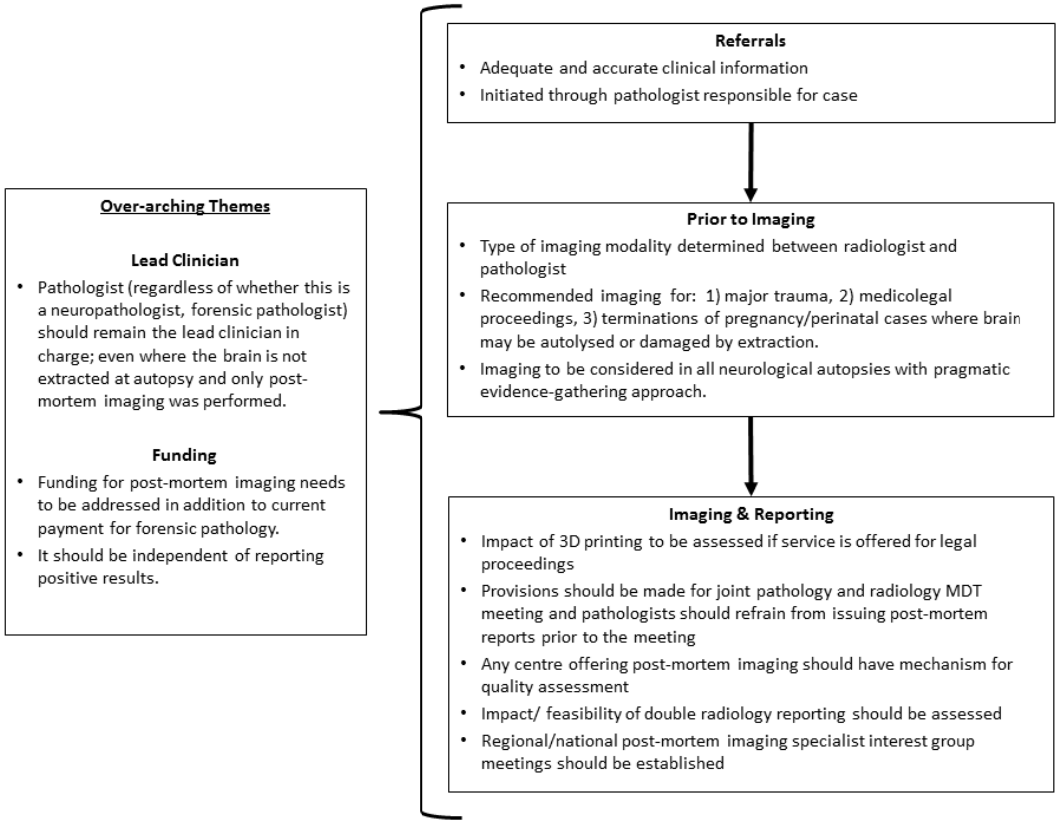
[25] Arthurs OJ, Hutchinson JC, Sebire NJ. Current issues in postmortem imaging of perinatal and forensic childhood deaths. Forensic Sci Med Pathol. 2017; 13 (1): 58-66

**Table 1.**

Summary of consensus statements generated and agreed upon by an expert panel regarding the use of post-mortem imaging for the nervous system. Statements that did not reach consensus agreement are not presented in this table.

| Statement Theme | Consensus Statement | Agreement (%) |
|---|---|---|
| **Referrals** | 1. Adequate and accurate clinical patient history should be provided prior to post-mortem imaging. | 100 |
| | 2. Referrals for post-mortem imaging should be initiated through the pathologist responsible for the case. | 78.5 |
| **Type and Indication for Imaging** | 3. The modality of imaging should be determined by liaison between pathology and radiology. | 78.5 |
| | 4. Post-mortem imaging is indicated in the following situations:<br>a) Major trauma cases (inclusive of ballistic injuries and road traffic accidents) to determine pattern of fractures, trajectory and number of bullets/weapons and crime scene reconstruction. | 92.8 |
| | b) To provide sanitised images to present to a jury in medicolegal proceedings | 78.5 |
| | c) In terminations of pregnancies or perinatal cases where the brain may be autolysed and damaged from the extraction process. | 85.7 |
| | 5. Even where not currently indicated, the use of post-mortem imaging should be considered all neurological autopsies and follow a pragmatic and evidence-gathering approach until further evidence becomes available. | 85.7 |
| **Imaging Reporting, Analysis and Quality Control** | 6. The impact of 3D printing should be assessed prior to offering this service to assist in legal proceedings. | 92.9 |
| | 7. Where post-mortem imaging is conducted, provisions should be made for a joint pathology and radiology multidisciplinary team (MDT) meeting to prevent cases being interpreted in isolation without a full clinico-pathological context. | 92.8 |
| | 8. The pathologist and radiologist should refrain from issuing an authorised final report on cases prior to an interdisciplinary team meeting. | 78.5 |

| | | |
|---|---|---|
| | 9. Any centre offering post-mortem imaging should have a formal mechanism for Quality Assessment. | 100 |
| | 10. Any centre offering post-mortem imaging should have a formal mechanism for Quality Assessment comparable to those used in pathology services e.g. external quality assessment schemes, external accreditation. | 92.8 |
| | 11. The impact and feasibility of double reporting of post-mortem imaging by two radiologists should be assessed prior to suggesting blanket implication for all cases. | 92.9 |
| | 12. Regional or national post-mortem imaging specialist interest group meetings should be established to build collective expertise. | 100 |
| **Lead Clinician** | 13. The pathologist (regardless of whether the situation calls for a neuropathologist/ forensic pathologist) should remain the lead clinician in charge of the case. | 92.8 |
| | 14. The pathologist (regardless of whether the situation calls for a neuropathologist/ forensic pathologist) should remain the lead clinician in charge of the case even in situations where the brain is not extracted at autopsy and only imaging was performed. | 92.8 |
| **Funding** | 15. Funding for post-mortem imaging needs to be addressed in addition to current payment for forensic pathology. | 100 |
| | 16. Funding for post-mortem imaging should be independent of reporting positive results. | 92.9 |


Over-arching Themes
Lead Clinician
Pathologist (regardless of whether this is a neuropathologist, forensic pathologist) should remain the lead clinician in charge; even where the brain is not extracted at autopsy and only post-mortem imaging was performed.
Funding
Funding for post-mortem imaging needs to be addressed in addition to current payment for forensic pathology.
It should be independent of reporting positive results.
Referrals
Adequate and accurate clinical information
Initiated through pathologist responsible for case
Prior to Imaging
Type of imaging modality determined between radiologist and pathologist
Recommended imaging for: 1) major trauma, 2) medicolegal proceedings, 3) terminations of pregnancy/perinatal cases where brain may be autolysed or damaged by extraction.
Imaging to be considered in all neurological autopsies with pragmatic evidence-gathering approach.
Imaging & Reporting
Impact of 3D printing to be assessed if service is offered for legal proceedings
Provisions should be made for joint pathology and radiology MDT meeting and pathologists should refrain from issuing post-mortem reports prior to the meeting
Any centre offering post-mortem imaging should have mechanism for quality assessment
Impact/ feasibility of double radiology reporting should be assessed
Regional/national post-mortem imaging specialist interest group meetings should be established