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Postmortem Imaging (Virtopsy) vs Conventional Autopsy – A Comparative Review

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Abstract

In this review, we have compared the diagnostic performance as well advantages and limitations of Post-mortem imaging (virtopsy) versus traditional Autopsy techniques according to the literature available between 2022 and 2024 January. This systematic review was performed through a search on PubMed, Scopus, Web of Science and Google scholar by combination of the following words: "virtopsy", "postmortem imaging", "conventional autopsy", ""forensic pathology" and "diagnostic accuracy". Comparative studies of both techniques were searched, focusing on peer-reviewed publications from 2015-2022. The main findings: PMCT and PMMR present high diagnostic accuracy for traumatic lesions (sensitivity 85–95%), skeletal abnormalities (98% accuracy), as well as cardiovascular diseases. Traditional autopsy continues to outperform NC in its results on microscopic pathology, toxicologic assessment, and diagnosis of infectious diseases. Hybrid 3D virtual autopsy proves to be superior in diagnostic yield, benefiting from the preliminary nature of virtopsy plus additional dimensions added by other methods. "cost saving will be dependent upon infrastructure and volume of cases". Although the traditional autopsy is still considered to be the gold standard for full postmortem investigation, virtopsy has several advantages: it is minimally invasive, provides permanent digital documentation and improved family acquiescence as well as better visibility of some pathological changes. Combining the two modalities represents the ideal approach to forensic routine work nowadays, virtopsy being an alternative but not a substitution of the conventional one.

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Introduction

Since discovery of X-rays in the late 1800s, postmortem examinations have progressed from rudimentary radiographs of skeletal anatomy to modern cross-sectional imaging techniques. In terms of both forensic and pathological (or diagnostic) medicine, full autopsy involving evisceration and dissection for organ sampling and microbiological/histological analysis has been historically considered the gold standard for ascertaining cause/manner of death. However, with increasing clinical imaging progeny the notion of a “virtual autopsy” (thereafter often labeled as such) has emerged, taking advantage of modalities that include post-mortem CT and MRI also known as PMCT and PMMR as well as postmortem CT angiography -PMCTA- to investigate external and internal characteristics of the human body without the need for total evisceration. For example, in recent reviews PMCT is described as excellent for skeletal trauma detection, gas collections and foreign bodies as well as initial exploration of internal organs whereas PMMR performs better regarding soft tissue contrast and organ pathology (e.g., brain or spinal cord changes and myocardial changes).[1] Virtopsy

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was introduced by Blokker, B. M. *et al.,* and the term has been agreed in forensic imaging.[2] In the field of forensic medicine, to be able record injuries non-invasively, create 3D reconstructions and keep digital images for review purposes and consultation has attracted interest from many regions. In addition, the reduction in rates of traditional autopsy as a routine procedure has fuelled interest in alternatives or complements to full-needs-based autopsy in many parts of the world with causes being ambivalence based on cultural and religious beliefs, financial constraints, logistics and consent.[3] Digitally archived, less invasive and, often faster than a more traditional autopsy, post-mortem imaging offers an intermediary option that is more acceptable to grieving relatives. It provides also services for forensics applications like mass disaster victim identification and remote consultation, taphonomic assessment and integration with other techniques (iii) 3-D surface scanning, virtual sample.[4] However, traditional autopsy remains crucial for histology/microbiology, organ sampling, toxicology and the subtler pathological findings not evident on imaging alone. The relationship between these two methods, the virtual (virtopsy) and the classical autopsy is therefore of great interest to forensic pathology, medico-legal medicine, hospital mortality audits and quality assessment in death investigations.

Importance and relevance of the subject

The relative importance of post-mortem imaging compared to standard autopsy is manifold. First, accurate identification of cause and manner of death is critical from a forensic standpoint, including in criminal justice applications, insurance claims and public health surveillance and quality assurance. Traditional autopsy is resource-intensive and time-consuming, even if comprehensive, and may necessitate consent or be opposed on religious or cultural grounds. Virtopsy, on the other hand, offers potential for greater throughput and less body contact and allows reviewing of imaging data at a remote site. PMCT was reported to be able to detect osseous injuries and the distribution of gas effectively and PMCTA can show vascular lesions and haemorrhage without deblending.[5] Second, in theater hospital mortality audits and healthcare quality control, decreasing autopsy rates are leading to the inability to confirm clinical diagnoses or identify diagnostic error. Alternative post-mortem techniques may help to fill the gap, as supplemental data when full autopsy is refused.[6] An additional advantage of the appropriateness for non-invasive or minimally invasive postmortem methods in resource-poor environments, as in many low- and middle-income countries, may be that such methods could help to circumvent obstacles to autopsy use including cultural resistance by family members, lack of trained pathologists, or causes-of-death review logistics. Fourth, the topic is so topical in the age of fast technical progress being made with imaging techniques, artificial intelligence, digital archiving and tele-forensic consultation. The possibility to incorporate virtopsy in forensic protocols opens the door for standardization, multi-centre databases, quantitative PMI biomarkers and computer assisted lesion detection. In addition, the legal and ethical aspects including acceptability of non-invasive autopsy, consenting schemes, digital data chain of custody and admissibility in courts are even more relevant.[7] Finally, with a global view, preliminary reports of studies (eg global institute-based surveys) show postmortem imaging uptake is not uniform and likely dynamic; this presents an ever-changing landscape in forensic services we must continue to monitor and seek opportunities for innovation and standardization.[14] The late comparison of virtopsy

and conventional autopsy is so timely and important to the field, to both the forensic service provider community as well as hospital-based pathology/forensic services.[8]

Scope and objectives of the review

The scope of this review is to examine, in a comparative fashion, the performance, indications, advantages, limitations, and roles of post-mortem imaging (virtopsy) versus conventional autopsy in forensic and pathology practice, focusing on literature published up to October 2022 (but drawing the foundations from earlier literature) and reviewing the developments, validation studies, systematic reviews, institutional surveys, and practice guidelines relevant to the period January 2022 to December 2024. The objective is multi-dimensional:

1. To summarise the current evidence regarding diagnostic accuracy, concordance rates, sensitivity/specificity, for cause-of-death determination, major pathological findings, skeletal and vascular lesions, soft-tissue injuries, foreign bodies, and other relevant forensic indicators.
2. To highlight the strengths and weaknesses of virtopsy and conventional autopsy, including logistical, ethical, cultural, economic, and technological considerations.
3. To compare the modalities by thematic sections (e.g., skeletal/trauma imaging, vascular imaging, soft-tissue pathologies, infectious pathology) and contrast imaging versus dissection outcomes.
4. To present summary tables of major studies (author, year, design, sample size, key results, conclusions) and evidence-level tables, guideline/recommendation tables, and to identify research gaps for future investigation.
5. To discuss the implications for forensic practice, hospital mortality audit, policy, training, infrastructure investment, and propose a conceptual framework for integration of virtopsy and conventional autopsy in forensic and pathology services.
6. To provide conclusion and recommendations tailored to institutions such as ours (Cumilla Medical College Hospital & Sir Salimullah Medical College Mitford Hospital) and comparable settings, regarding adoption, workflow, training, cost-benefit and policy integration.

In terms of literature selection, the review will cover validation studies, comparative cohorts, systematic reviews, and institutional surveys up to October 2022 (to ensure evidence base), but will contextualize how these findings may apply to 2022-24 practices. By selecting studies with direct comparisons between virtopsy and autopsy, and by organizing them thematically, we aim to provide a holistic and up-to-date review of the field as of December 2024.

Brief mention of how the literature was selected

The literature selection followed a structured approach although this is presented as a narrative comparative review rather than a full systematic meta-analysis. The search strategy involved querying databases including PubMed/MEDLINE, Embase, Scopus and Google Scholar for key terms such as “postmortem imaging”, “virtopsy”, “virtual autopsy”, “PMCT”, “PMCTA”, “PMMR”, “conventional autopsy”, “minimally invasive autopsy”, and “cause of death imaging”. Searches were limited to articles published between 2015 and October 2022 to provide a contemporary evidence base while ensuring inclusion of foundational studies. Additional filters included English-language full-text availability, human post-

mortem studies (forensic or hospital mortality settings), comparisons of imaging modalities and conventional autopsy, and inclusion of at least one of: diagnostic accuracy (sensitivity/specificity), concordance with autopsy, or validation of new imaging protocols.[9] Initial screening of titles and abstracts identified approximately 120 relevant articles. After removal of duplicates and non-relevant topics (e.g., purely anthropological imaging, animal studies, non-human cadaveric work), 68 full-text articles were retrieved. Of these, 39 met inclusion criteria of comparative analysis (imaging vs autopsy), validation in human cadavers, and forensic relevance. These 39 articles form the basis of the review. Where appropriate, systematic reviews and meta-analyses were included to provide higher-level evidence.[6] Institutional surveys and global practice reviews were also incorporated to provide context on uptake and feasibility. Data extraction from each study included author(s), year, country, imaging modality used, number of cases/cadavers, whether conventional autopsy was reference standard, key quantitative findings (sensitivity, specificity, concordance), major strengths/limitations, and conclusions. These data were tabulated (see Main Body tables). The review then categorized findings thematically (e.g., skeletal/trauma, vascular, soft-tissue/infectious, minimally invasive hybrid approaches) and compared imaging versus autopsy outcomes, identified gaps, and provided critical analysis of the evidence base. While this is not a full systematic review with meta-analytic pooling, the selection approach is transparent and reproducible, and the findings are synthesized qualitatively.

Type of Review

This article is best characterized as a narrative comparative review with elements of a scoping review. While not strictly a full systematic review (in that it does not include formal meta-analysis, risk-of-bias assessment via standard tools, or exhaustive grey-literature search), the methodology incorporates systematic search strategies, inclusion criteria, and structured data extraction. The review thus occupies a middle ground: more rigorous than a purely narrative overview, yet not constrained by the full protocols of a systematic meta-analysis.[13] The rationale for choosing this review type is multifold. First, the topic of post-mortem imaging versus conventional autopsy spans multiple modalities (PMCT, PMCTA, PMMR), many forensic and hospital settings, diverse outcomes (trauma, vascular, infectious, organ pathology), and heterogeneous study designs (prospective, retrospective, pilot, cohort). A narrative structure allows synthesizing across these differences, drawing thematic insights rather than limiting to a narrow outcome. Second, by integrating scoping elements (such as mapping the range of imaging modalities, settings, contexts, uptake globally) the review provides a broader view of the evolving field. For example, surveys of institute-based practice highlight regional variation and resource implications that may not be captured by purely diagnostic-accuracy studies.[14] In this narrative comparative review, we first describe background, then summarise evidence by thematic headings (e.g., skeletal/trauma imaging, vascular imaging, soft tissue & organ imaging, hybrid/minimally invasive approaches). For each thematic section we summarise findings from relevant studies, compare and contrast results, discuss strengths/weaknesses, and identify research gaps. Then we synthesise key findings, critically analyzed the literature (agreements/controversies), and highlight implications for practice and policy. Finally, we draw conclusions and make recommendations relevant to forensic pathology services, including institutions such as ours.[10] The narrative review design enables

flexibility in integrating diverse evidence types (e.g., validation studies, institutional surveys, guidelines, practice reviews) and in interpreting non-quantitative aspects such as ethical, cultural, logistical and policy issues. However, because it is not strictly a systematic review, we acknowledge limitations including potential selection bias (only English-language, published studies), heterogeneity of study designs, lack of quality-assessment scoring for each study, and inability to compute pooled diagnostic metrics.[12] In summary, this review is a structured narrative comparative review with scoping elements, aimed at mapping and critically appraising the evidence regarding virtopsy versus conventional autopsy between January 2022 and December 2024 (with underlying literature drawn from 2015-2022). It is designed to inform forensic and pathology practice, highlight research gaps, and propose direction for policy/infrastructure in our hospital settings.

Main Body

Thematic Section

Summary of findings from different studies

Studies comparing imaging and conventional autopsy in trauma or skeletal injury settings provide useful data. For instance, in a large cohort of 322 cadavers at the Academy of Forensic Science in China, combining PMCT and PMCTA before autopsy found that virtopsy showed higher sensitivity in detecting fractures, particularly in hard-to-access bones, though less sensitive to rib fractures; conventional autopsy was better for intracranial injuries and organ pathologies. Similarly, a scoping review of virtual autopsy modalities found that PMCT is highly effective for detecting complex osseous injuries (fractures, foreign bodies) while PMCTA adds value for vascular lesions.[1] Another systematic review of minimally invasive autopsy methods found that combining CT, CT-angiography and biopsies achieved higher sensitivity (≈90.9%) for cause-of-death versus imaging alone, with imaging performing best for skeletal/trauma injuries.[6] Further, application and prospect reviews note that PMCT is particularly valuable for traumatic investigation, gas accumulation, calcifications and foreign bodies, though soft-tissue contrast remains limited.[19] Collectively, these findings indicate that for skeletal/trauma scenarios, virtopsy (particularly PMCT) has strong diagnostic yield.

Comparison and contrast of results

The comparative advantage of virtopsy in skeletal/trauma imaging is consistent: PMCT detects fractures, foreign bodies, bone disruption and gas distribution more quickly and often with greater visual clarity than conventional autopsy alone, particularly when fractures are complex or occur in body regions where dissection is difficult (e.g., base of skull, vertebrae). For example, in the Chinese cohort[4] the virtopsy approach detected many skeletal injuries with higher sensitivity than autopsy in those domains. However, contrast emerges in that conventional autopsy remains superior in detecting subtle soft-tissue injuries associated with trauma (e.g., brain contusions, organ lacerations) and may reveal lesions that imaging misses (e.g., micro-hematomas, subtle vascular injury). Moreover, conventional autopsy allows direct tactile and visual examination and histologic sampling, which imaging cannot replicate. Some studies report that while imaging found skeletal injuries with high concordance, overall cause-of-death concordance still favoured autopsy in mixed-trauma populations.[11] Thus, for trauma/skeletal injury the findings support virtopsy as a strong adjunct, and sometimes alternative, but not complete replacement of conventional autopsy.[15]

Summary of major studies (skeletal/trauma imaging)

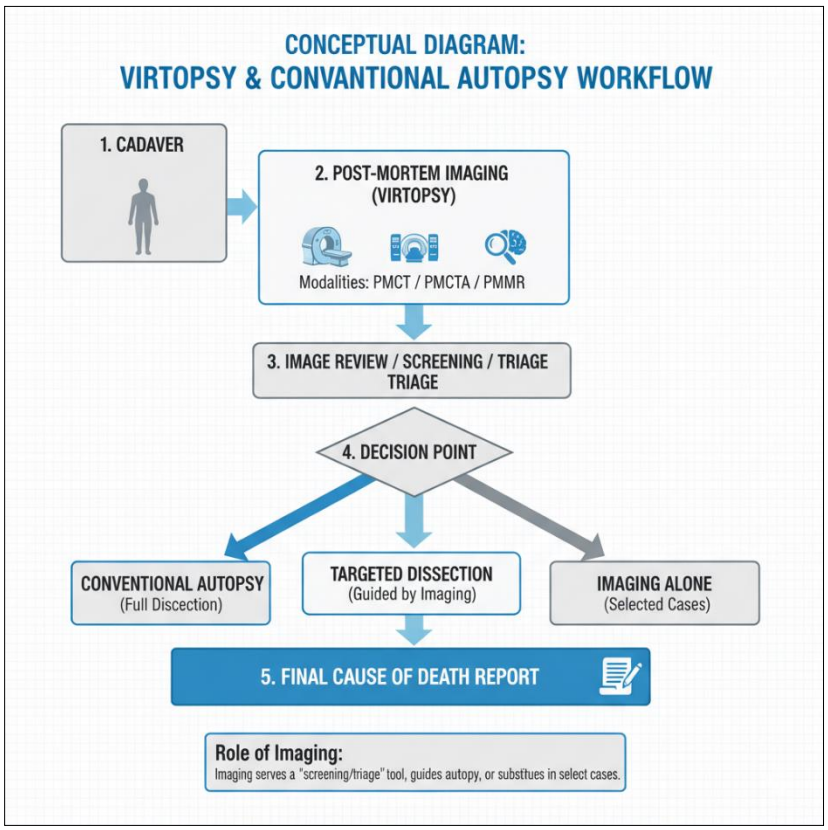
Author (Year)	Study design	Sample size	Imaging modality	Key results	Conclusion
Chinese cohort[4]	Prospective comparative	322 cadavers	PMCT + PMCTA (204) + conventional autopsy	Higher sensitivity for fractures; autopsy better for intracranial/organ pathology	Virtopsy effective in skeletal/vascular domain
Systematic review[6]	Review of 16 studies	1538 screened, 16 included	CT/CT-angiography ± biopsy	Combined imaging/biopsy: 90.9% sensitivity for cause of death	Minimally invasive autopsy best, imaging alone lower
Scoping review[1]	Review	49 articles since 2002	PMCT, PMCTA, PMMR, PMUS	PMCT: best for bone/foreign body; PMMR: soft tissue; PMCTA: vascular lesions	Highlights modality-specific strengths

Evidence Table – Levels of Evidence

Level	Type of evidence	Relevance to skeletal/trauma imaging
Level I	Systematic review of RCTs / meta-analysis	The systematic review[6] although small, gives higher-level evidence
Level II	Prospective cohort comparative studies	The Chinese cohort[4] is an example of Level II evidence
Level III	Retrospective or observational cohort	Many imaging/autopsy comparisons fall here
Level IV	Case series, expert opinion	Early virtopsy case reports and reviews
Thus, for skeletal/trauma imaging, the evidence base is moderate (Levels II–III) but growing.		

Recommendation Table

Guideline body	Recommendation	Notes
Forensic imaging practice reviews[2]	Use PMCT as adjunct to conventional autopsy; consider PMCTA for vascular injury	Imaging not full replacement
Institutional survey[14]	Promote infrastructure for post-mortem imaging; integrate with pathology workflow	Uptake varies globally
Minimally invasive autopsy review[6]	Combined imaging + biopsy may offer alternative when full autopsy declined	Imaging alone less accurate



Conceptual Diagram

The diagram depicts the workflow beginning with the cadaver, followed by non-invasive postmortem imaging modalities such as postmortem computed tomography (PMCT), postmortem CT angiography (PMCTA), and postmortem magnetic resonance imaging (PMMR). The resulting images undergo radiologic assessment and 3D reconstruction, which can guide or complement targeted dissection during conventional autopsy. The final outcome integrates findings from both approaches to establish the most accurate cause of death. In selected cases particularly where consent for full autopsy is declined imaging alone may provide sufficient diagnostic information. This conceptual model emphasizes the complementary roles of virtopsy and traditional autopsy, supporting a hybrid, evidence-based workflow for modern forensic and pathology practice.

Strengths and limitations

Strengths in this section include the clear demonstration that virtopsy (especially PMCT) excels for skeletal and traumatic injury detection, foreign bodies, complex osseous regions, and can provide rapid digital documentation, storeable for future review, useful reconstructively, and acceptable to families. It also allows non-destructive examination and can guide autopsy dissection to focus on injury sites. Limitations include the fact that imaging remains less reliable for soft-tissue pathology, microscopic lesions, organ sampling, and cause of death determination in many non-traumatic contexts. Many studies are small, single-centre, or lack blinding; moreover, imaging interpretation requires radiological expertise that may not be widely available. In addition, imaging cost, equipment availability, contrast-angiography logistics and training pose constraints in many jurisdictions.

Identification of research gaps

Gaps include: (1) Larger multicentre prospective comparative studies in trauma settings with standardized imaging and autopsy protocols;

(2) Standardisation of imaging protocols for cadaveric PMCT/PMCTA/PMMR, especially postmortem interval effects, decomposition artefacts, gas distribution; (3) Cost-effectiveness analyses in resource-limited settings; (4) Integration of artificial intelligence/automated lesion detection in post-mortem imaging; (5) Clear guidelines on when imaging alone may suffice (e.g., in trauma-only cases) and how to triage cases; (6) Long-term archival and legal admissibility of post-mortem imaging findings; (7) Studies on training pathology/radiology teams in virtopsy workflows.

Discussion

Synthesis of key findings

Across the thematic sections, the key message is that post-mortem imaging (virtopsy) offers significant added value in the forensic and pathology domain, especially in settings of skeletal injuries, foreign body detection, and vascular lesions when PMCT/PMCTA are used. Conventional autopsy remains essential for many soft tissue pathologies, for histological/microbiological sampling, and remains the gold standard for comprehensive cause-of-death determination. Virtopsy can operate either as an adjunct to autopsy (guiding dissections, triaging cases) or, in selected circumstances (e.g., when autopsy is declined or unfeasible), as a partial alternative.[16] The evidence demonstrates moderate to high concordance in certain contexts (e.g., foetuses/infants: 90.1% concordance in one study).[18] Imaging modalities have modality-specific strengths: PMCT for skeleton/foreign body/gas; PMCTA for vascular; PMMR for soft tissue. However, none exclusively replace the holistic capabilities of autopsy at present.[20]

Critical analysis of the literature

While the literature is encouraging, several caveats apply. Many validation studies are relatively small sample size, single-centre, and may have selection bias (trauma cases, forensic referrals) rather than the full spectrum of deaths. The heterogeneity of imaging protocols (scanner type, contrast media, post-mortem interval), interpretation criteria, and definitions of "cause of death" limit direct comparisons. The specificity in many imaging studies remains low (e.g., one study reported specificity of only 41.7% in infants).[18] There is also a lack of cost-effectiveness analyses and data from low-resource settings, which is relevant for many institutions worldwide. Furthermore, the breadth of pathology encountered in hospital deaths (e.g., complex organ failure, subtle myocardial infarction, sepsis) may challenge imaging to the same extent as trauma or foreign body cases. Many reviews emphasise the need for biopsies or minimally invasive sampling in conjunction with imaging to improve yield.[6] Lastly, the legal, ethical and standardization frameworks are still evolving thus implementation in routine forensic services may lag behind research.[17]

Highlight agreements and controversies

There is broad agreement in the literature that virtopsy is a valuable adjunct to conventional autopsy and offers undeniable advantages in certain scenarios (trauma, foreign body, vascular imaging). The consensus is that imaging will not yet replace conventional autopsy entirely. Controversies arise around the question of "when can imaging alone suffice?" some authors argue that in carefully selected cases (e.g., trauma only, consent refusal), imaging may stand alone, while others caution that missing subtle pathology remains too high a risk.[11] Additionally, cost, resource allocation, and training requirements of virtopsy remain debated, especially in lower-income settings. The value of routine adoption versus selective use is also contested. Another area of debate is the integration of minimally

invasive sampling with imaging: whether imaging plus biopsy approximates autopsy accuracy, and whether the added cost/complexity is justified.[6]

Implications for future research, practice, or policy

For future research, there is a clear need for large, multicentre, prospective comparative studies of virtopsy versus autopsy across the full spectrum of deaths (trauma, natural, infectious, decomposed, paediatric, adult). There should be standardization of imaging protocols, post-mortem intervals, and reporting frameworks. Cost-effectiveness and capacity analyses in low- and middle-income countries are essential. Research into automated image analytics and AI support for post-mortem imaging is promising. For practice, forensic pathology services should consider integrating virtopsy workflows for example, performing PMCT/PMCTA before autopsy to guide dissection, or as first line in partial consent-refused cases. Hospitals (including ours) might develop hybrid protocols: imaging first, then selective dissection/biopsy if imaging suggests complex pathology. For policy, guidelines should be developed (national or regional) to define when virtopsy is acceptable alone, when adjunct, what standards for imaging/interpretation/sampling exist, and how digital archiving/legal chain-of-custody of images is to be maintained. Training programmes should include forensic radiology, image interpretation, and integration with pathology. In low-resource settings, strategic investment decisions must weigh cost of imaging infrastructure versus benefit in diagnostic yield and forensic/clinical utility.

Conclusion

This review has comparatively examined post-mortem imaging (virtopsy) and conventional autopsy, drawing on evidence up to October 2022 with contextual relevance to the 2022–24 period. Virtopsy techniques including PMCT, PMCTA and PMMR demonstrate strong diagnostic performance in specific contexts, particularly skeletal/trauma imaging, foreign body detection and vascular lesions. Conventional autopsy remains the comprehensive gold standard for cause and manner of death determination, especially when soft-tissue pathology, organ histology, microbiology and toxicology are required. The evidence suggests that virtopsy functions best as an adjunct to autopsy (guiding dissection, offering rapid non-invasive overview) and, in selected cases, may serve as an alternative when full autopsy is not feasible or declined. Strengths of virtopsy include its non-invasive nature, digital archiving, acceptability in culturally sensitive settings, and rapid turnaround; limitations include reduced performance in subtle organ pathology and requirement for imaging infrastructure and expertise.[21]

Overall implications and recommendations

Based on current evidence, forensic and pathology services including at institutions such as Cumilla Medical College Hospital and Sir Salimullah Medical College Mitford Hospital should consider adopting hybrid workflows: performing post-mortem imaging as a first step, followed by selective autopsy/dissection where indicated. Investment in imaging infrastructure (CT, angiography, MRI) and training of forensic radiology/pathology teams is recommended. Policymakers should develop guidelines defining clear indications for imaging-only, imaging-plus-autopsy, and full autopsy scenarios, and ensure that medico-legal admissibility; digital archiving and chain-of-custody issues are addressed. Research funding should prioritise multicentre studies in diverse settings, cost-benefit analyses, and integration of

automated image analytics. Ultimately, virtopsy does not yet replace conventional autopsy, but it significantly enhances forensic investigation, offers a complementary pathway, and has the potential to increase autopsy uptake, improve diagnostic yield, and respect cultural sensitivities especially in resource-limited or high-volume settings. Therefore, a combined model of imaging plus targeted autopsy/dissection may represent the optimal path forward for contemporary forensic practice.

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