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Review article

Effects of decomposition on the cardiovascular system: A systematic review

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ABSTRACT

Objective: Postmortem decomposition poses significant challenges in forensic pathology, particularly in the evaluation of the heart and coronary arteries. Putrefactive processes may alter or mask cardiac pathology, complicating the interpretation of cause of death. This systematic review aims to evaluate the literature on decomposition-related alterations of the heart and vessels, focusing on their forensic impact.
Method: A systematic literature review was performed across PubMed, Scopus, and Web of Science, including studies from 1970 onward. Articles were screened according to predefined criteria, and duplicates were removed using *Rayyan software*. After initial screening and full-text evaluation, seven original research articles and one forensic guideline were included in the final analysis.
Results: The review confirmed a significant lack of focused studies on cardiac decomposition. Calcified atherosclerotic plaques remained detectable in various stages of decomposition, including skeletal remains, and may serve as reliable postmortem indicators. In contrast, myocardial histology was often unreliable due to autolysis and bacterial overgrowth. Postmortem computed tomography angiography (PMCTA) showed some capacity to visualize vascular calcifications but was hindered by postmortem gas and fluid artifacts. Mummification and adipocere cases demonstrated improved preservation of cardiac morphology, particularly of coronary arteries, though valvular structures remained difficult to assess.
Conclusion: The current literature provides limited guidance on the forensic evaluation of decomposed cardiac tissues. Despite this, certain features such as vascular calcifications may retain diagnostic value. Further controlled studies are needed to develop standardized protocols for assessing postmortem cardiac pathology.

1. Introduction

Postmortem changes in the human body represent a crucial aspect of forensic pathology, as they significantly influence the evaluation of the cause and time of death [1]. Among these processes, putrefaction plays a key role in tissue degradation, progressively altering the structural and histological integrity of organs, including the heart and coronary arteries [2]. Forensic interpretation of cardiac findings in decomposed bodies presents challenges, as putrefactive phenomena can mask or mimic pathological conditions, potentially leading to misdiagnoses. One of the critical aspects in forensic pathology is distinguishing true antemortem cardiovascular pathology from postmortem artifacts, particularly in cases of advanced decomposition [3]. Previous studies have demonstrated that myocardial necrosis can still be detected in putrefied cardiac tissue through specific immunohistochemical techniques. In particular, deposition of complement complex C5b-9 and neutrophilic markers like NP57 may localize ischemic injury, even in tissues affected by autolysis or bacterial proliferation, due to their relative resistance to decomposition [4]. These markers tend to accumulate at sites of pre-mortem hypoxia and allow differentiation from postmortem artifacts when evaluated with appropriate staining protocols. [5]. The heart is frequently the focus of forensic investigations due to its central role in sudden and unexplained deaths, particularly those linked to ischemic heart disease, myocardial infarction, and thrombotic events. According to established autopsy protocols, such as those described by Ludwig [6], coronary arteries should be evaluated for calcification and tortuosity prior to dissection, and angiographic techniques must be performed before vessel sectioning or fixation. In decedents younger than 30 years

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without cardiac causes of death, longitudinal opening of the coronary arteries may be appropriate, while in other cases, cross-sectional cuts at 3–5 mm intervals are recommended. Heavily calcified arteries that cannot be sectioned with a scalpel should be stripped and decalcified before analysis. Additionally, within approximately 24 h after death, the relaxation of rigor mortis can result in ventricular dilation and wall thinning, potentially mimicking dilated cardiomyopathy—a crucial interpretative pitfall in forensic cardiac evaluation. Yet, the specific decomposition-related alterations of the myocardium and coronary vessels are still insufficiently described in the forensic literature. Structural modifications, including arterial delamination, tissue liquefaction, and histological disorganization, can obscure preexisting pathological features, making it difficult to differentiate between premortem coronary atherosclerosis, thrombotic events, and postmortem artifacts. Furthermore, the postmortem interval (PMI) represents a critical variable in forensic interpretation, as the timing of decomposition-related changes directly influences the preservation of tissue morphology. Accurate estimation of PMI is essential to contextualize autopsy findings and to assess the progression of putrefactive alterations affecting the heart and vasculature, this information is crucial for understanding the timing and progression of decomposition. The challenge is further exacerbated by environmental factors such as temperature, humidity, and burial conditions, which significantly influence the rate and pattern of decomposition, thereby impacting forensic assessment. Despite the growing interest in postmortem cardiovascular pathology, no standardized forensic methodology currently exists to reliably differentiate decomposition artifacts from antemortem cardiac pathology. The existing literature is highly fragmented, with forensic investigations often limited to case reports rather than controlled experimental studies capable of systematically assessing the effects of decomposition on cardiac tissues. Additionally, radiological and histopathological assessments are significantly hindered by putrefaction-induced degradation, making it difficult to establish clear forensic criteria for the interpretation of decomposed cardiac findings. This systematic review aims to analyse and synthesize the available scientific literature on the postmortem decomposition of the heart and its vascular structures. Specifically, this study seeks to provide forensic pathologists with a clearer framework for distinguishing postmortem artifacts from true pathological findings, ultimately improving the accuracy of cause-of-death determinations in decomposed bodies. By addressing the current gaps in forensic cardiovascular pathology, this review aims to highlight the limitations of existing forensic techniques and lay the groundwork for future research aimed at improving diagnostic reliability in decomposed cases.

2. Materials and methods

2.1. Search strategy

A systematic literature review was made following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 criteria [7], using PubMed, Scopus and Web of Science as search engines. In the identification phases, all studies from 1970 onward, written in English, were included in the analysis. The keywords and Boolean operators used for the search are listed in Table 1. At least one keyword from each field had to be present in the title or abstract for inclusion. 4188 studies were found in PubMed, 4597 in Scopus and 4341 in Web of Science, amounting to a total of 13,126 records. Duplicate articles were automatically removed using Rayyan, a web-based systematic review management tool, resulting in the exclusion of 3556 duplicated entries. The first screening phase involved reviewing titles and abstracts, where studies that did not meet the inclusion criteria were excluded. Specifically, review articles were removed to focus exclusively on original research, while studies involving animals or plants were excluded, as they did not pertain to human forensic pathology. Articles that did not explicitly indicate the postmortem interval (PMI) or did not describe putrefactive changes were also eliminated, along with those focusing on organs other than the heart. Although the selected studies addressed postmortem decomposition, the extent of it was often described in qualitative terms (e.g., "advanced putrefaction", "skeletonized", or "mummified") without the application of standardized classification systems. When the level of decomposition was explicitly stated, it was reported in Table 2 accordingly. This variability underscores the lack of uniformity in reporting decomposition stages across the literature, which limits direct comparisons between studies. This initial filtering process led to the exclusion of 7932 studies, leaving a total of 90 articles for full-text evaluation. Each of these 90 studies was reviewed to assess their relevance. During this phase, 75 articles were excluded as they were not directly related to the research question or did not provide sufficient data to aid the research. Among the remaining 15 articles, 7 could not be retrieved in full text despite attempts through institutional access and were therefore excluded from detailed analysis but acknowledged in the reference list [8–14]. Ultimately, 7 original research articles and 1 guideline report were included in the systematic review. A detailed summary of the study selection process is presented in Fig. 1, following the PRISMA flowchart (see Fig. 1).

Table 1
Keywords used for the search.

FIELD 1	FIELD 2	FIELD 3
Heart OR cardiac OR myocardium OR coronary AND	Decomposition OR putrefaction OR postmortem OR exhumation OR autopsy AND	Atherosclerosis OR calcification OR plaque OR vascular changes OR arterial changes OR arterial calcification

3. Results

The literature analysis revealed that data on the decomposition of the heart and coronary arteries remain extremely limited, with only a few forensic studies directly addressing postmortem changes in cardiac structures. One consistent finding across the selected studies was that calcified atherosclerotic plaques in coronary and major arteries tend to persist despite decomposition, making them one of the few identifiable features in advanced postmortem stages [15,16]. A detailed summary of the selected literature - including decomposition state, cardiac findings, and diagnostic techniques - is provided in Table 2. These plaques, particularly in the aorta and coronary ostia, have even been observed in skeletonized remains, suggesting their forensic utility in assessing pre-existing cardiovascular conditions [16,17]. Conversely, histological assessment of decomposed cardiac tissue was found to be severely compromised. Most studies reported extensive bacterial overgrowth, loss of cellular architecture, and tissue liquefaction, making it difficult or impossible to distinguish pre-existing ischemic damage from postmortem artifacts [17]. Notably, putrefaction-induced myocardial wall thinning may mimic dilated cardiomyopathy, a phenomenon that could lead to misinterpretation of the cause of death [18]. This underscores the forensic challenge of differentiating true pathological conditions from decomposition artifacts, especially when assessing cardiomyopathies in decomposed bodies. Postmortem radiological studies, including computed tomography angiography (PMCTA), have been explored as potential tools for assessing vascular integrity in decomposed bodies. However, findings indicate that decomposition - related artifacts - such as gas accumulation, intravascular collapse, and fluid leakage - can significantly impair the visualization of coronary arteries [19]. Nevertheless, in certain cases, such as mummification, PMCTA has successfully identified vascular calcifications even in ancient mummies, some dating back thousands of years [20]. This suggests that, under specific conditions, vascular calcifications persist beyond soft tissue degradation, providing a potential postmortem marker of chronic cardiovascular disease. Mummified cardiac structures exhibited delayed decomposition

Table 2
Summary of the selected studies.

Title	Author(s)	Journal	Year	State of Decomposition	Cardiac Findings	Notes
Approach to the autopsy examination of an adult decomposing body	Burton J.	Diagnostic Histopathology	2023	Advanced putrefaction	Myocardial wall thinning can mimic cardiomyopathy	Highlights interpretative pitfalls in decomposed cardiac structures
Atherosclerosis: a medicolegal tool in exhumed decomposed bodies	Puschel K.	Forensic Science International	2004	Exhumed, advanced decomposition	Calcified plaques preserved in coronaries and aorta	Calcifications used to infer pre-existing cardiovascular disease
Diagnostic yield and characteristic features in a series of decomposed bodies subject to coronial autopsy	Byard R. et al.	Forensic Sci Med Pathol	2007	Advanced putrefaction	Cardiac findings still possible in many cases	Demonstrated usefulness of autopsy even in decomposed bodies
PMCTA in decomposed bodies – A feasibility study	Franckenberg S. et al.	J Forensic Radiol Imaging	2015	Putrefied bodies	Coronary visualization feasible in 6/10 cases	Artifacts present, but feasible for vascular visualization
Survival of Atherosclerotic Calcifications in Skeletonized Material	Biehler-Gomez L. et al.	J Forensic Sci	2018	Skeletonized	Atherosclerotic plaques identifiable	Plaques can survive and be recognized in dry bone
The mummified corpse in a domestic setting	Campobasso C. P. et al.	Am J Forensic Med Pathol	2009	Mummified	Heart reduced to a shrunken mass	Internal organs grossly unremarkable
What can ancient mummies teach us about atherosclerosis?	Wann S., Thomas G.	Trends Cardiovasc Med	2014	Ancient mummies	Vascular calcifications seen in 34 % of cases	CT shows preserved vascular calcifications over millennia
Guidelines on autopsy practice: the decomposing cadaver	Swift B. et al.	RCPath Guidelines	2023	Putrefaction, mummification, adipocere	Variable, depends on preservation	Detectability of calcified plaque in decomposed or mummified human remains

compared to putrefied tissues, leading to better preservation of anatomical features [21]. However, even in mummified cases, cardiac valves, chordae tendineae, and papillary muscles were no longer identifiable, whereas coronary arteries could still be recognized, showing distinct areas of calcification. Despite this relatively better preservation, histological evaluation of these tissues remained unreliable due to severe autolytic changes, limiting their diagnostic potential in forensic analysis. While the literature offers limited guidance, vascular calcifications remain among the few features that can persist postmortem, providing potentially valuable diagnostic clues.

4. Discussion

The findings of this review highlight the complexity of postmortem cardiac decomposition and its implications in forensic pathology. A key insight from the selected studies is that vascular calcifications, particularly in the coronaries and aorta, may persist even in severely decomposed or skeletonized remains, reinforcing their role as stable forensic markers. [15,16]. This suggests that vascular calcifications could serve as a reliable marker of chronic cardiovascular pathology, allowing forensic pathologists to infer preexisting conditions even in highly decomposed remains. In some cases, coronary and aortic plaques were still identifiable in skeletonized bodies, reinforcing the forensic utility of these findings [16,17]. It should be noted that coronary calcification, although frequently detectable even in decomposed or skeletonized remains, does not in itself confirm a cardiac cause of death, but rather indicates the presence of chronic vascular disease that must be interpreted in context with other autopsy findings. The rapid autolysis of myocardial tissue severely limits the reliability of traditional histological techniques, necessitating alternative approaches in forensic cardiac evaluations [18]. This aligns with previous forensic observations indicating that autolysis, bacterial proliferation, and tissue liquefaction severely alter myocardial architecture, often preventing the identification of antemortem ischemic damage [22]. Additionally, myocardial thinning due to putrefaction can mimic dilated cardiomyopathy, introducing a significant risk of diagnostic misinterpretation [19]. This finding underscores the forensic challenge in distinguishing true pathological conditions from decomposition-related artifacts, a fundamental issue in forensic cardiac pathology. Another major challenge is the high variability of decomposition processes, which depends on multiple extrinsic and intrinsic factors. Environmental elements such as temperature, humidity, and exposure to air or water influence the rate and pattern of putrefaction, leading to heterogeneous postmortem changes in cardiac structures [21]. Furthermore, special decomposition processes, including maceration, saponification, and mummification, introduce additional variability in tissue preservation. In mummified cases, for example, the preservation of coronary arteries and their calcifications was significantly better compared to putrefied tissues [20]. Despite the delayed decomposition, valvular structures, chordae tendineae, and papillary muscles were unidentifiable, indicating that mummification does not necessarily preserve all cardiac components. The variability in decomposition conditions limits the possibility of establishing standardized forensic criteria for assessing postmortem cardiovascular pathology. PMCTA has demonstrated some diagnostic utility in select cases, but its efficacy is often compromised by decomposition artifacts, highlighting the need for optimized imaging protocols tailored for postmortem application [20]. Nevertheless, its forensic applicability remains controversial due to decomposition-induced artifacts—such as gas formation, vessel collapse, and intravascular fluid shifts—which significantly impact image interpretation [19]. In addition, histological techniques remain unreliable in decomposed cases, as conventional staining methods fail to differentiate between true ischemic lesions and postmortem alterations [18]. A potential alternative, as suggested by Ortmann et al., is the use of immunohistochemical markers (C5b-9, NP57), which appear to resist degradation and may offer a more reliable postmortem assessment of myocardial ischemia [4]. Although promising, the forensic applicability of these methods is still hindered by the absence of standardized protocols and their limited implementation in routine casework. Developing validated and reproducible methodologies for postmortem cardiovascular evaluation remains essential to enhance diagnostic precision and ensure consistency across forensic investigations.

4.1. *Forensic implications and future directions*

The ability to assess cardiac pathology in decomposed remains is crucial for forensic investigations, particularly in cases of sudden and unexplained deaths where cardiovascular disease is suspected. Despite the severe tissue degradation caused by putrefaction, the findings of this review suggest that forensic pathologists can still extract valuable diagnostic information from vascular calcifications, which persist long after the degradation of soft tissues [15,16]. This reinforces the importance of performing autopsies even in cases of advanced decomposition, as relevant pathological markers may still be identifiable. However,

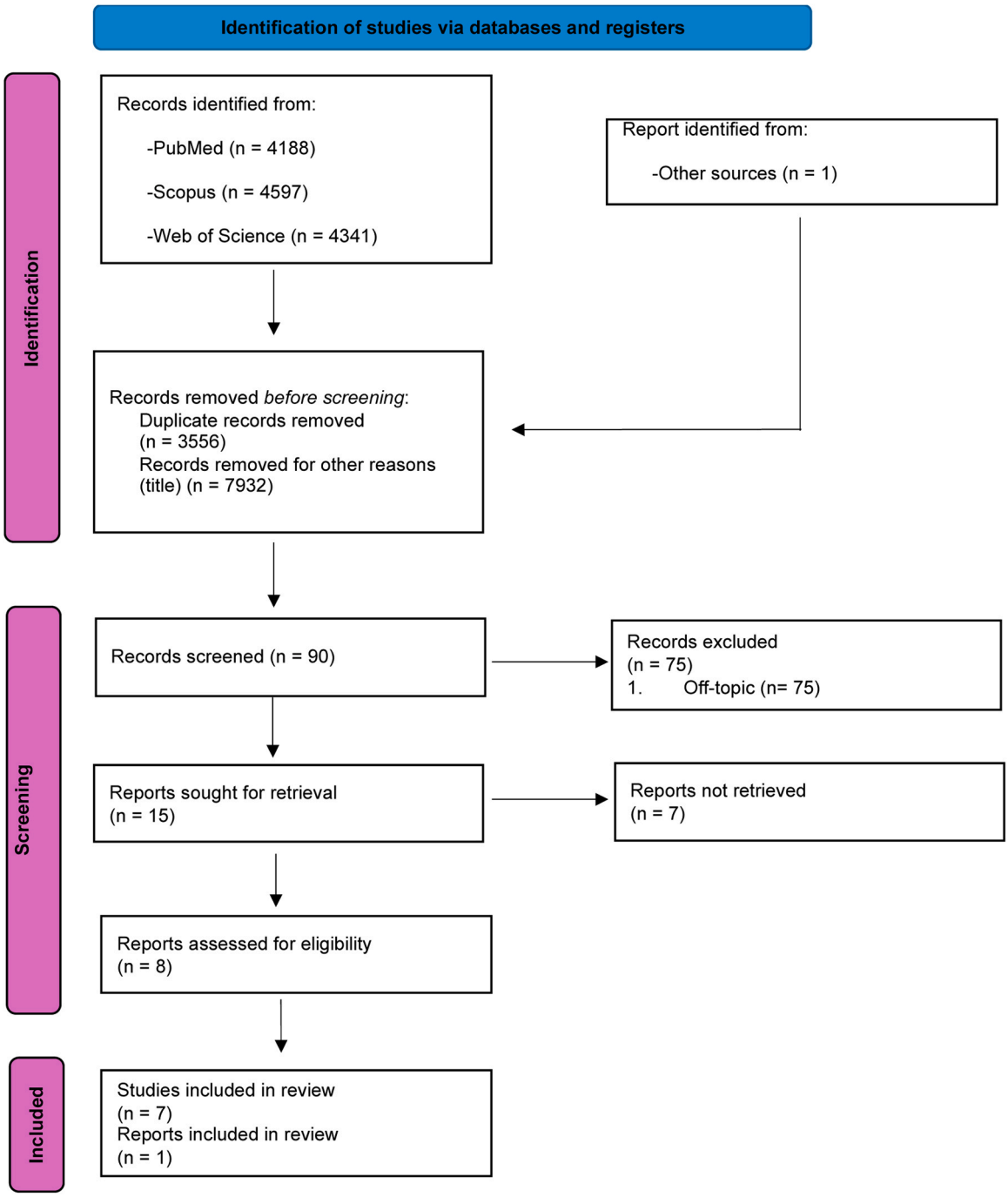

Fig. 1. PRISMA 2020 flow diagram illustrating the study selection process. prisma 2020 flow diagram for new systematic reviews which included searches of databases, registers and other sources.

current forensic methodologies lack a standardized approach for evaluating decomposed cardiac structures, and existing techniques (histology, PMCTA, immunohistochemistry) require further validation before they can be systematically integrated into forensic practice. Given the significant variability in postmortem decomposition, future research should focus on controlled experimental studies to systematically assess how different environmental factors impact cardiac degradation. These studies could help define forensic reference models for differentiating antemortem pathology from postmortem artifacts. Additionally, integrating advanced imaging techniques and molecular pathology methods could enhance the reliability of forensic cardiac investigations, particularly in cases where traditional histological evaluation is no longer feasible.

5. Conclusions

Based on the available data, some preliminary considerations can be proposed. Coronary calcifications are among the most stable findings and may serve as indirect markers of chronic disease. Conventional histology is often unreliable in decomposed myocardium, whereas ancillary techniques such as PMCTA or immunohistochemical staining (e.g., C5b-9, NP57) may provide additional diagnostic value. However, further validation through controlled studies is necessary before such features can be adopted as standardized forensic criteria. The available literature on the effects of decomposition on the heart and coronary arteries remains extremely limited, with no standardized forensic methodology for distinguishing antemortem cardiac pathology from

postmortem artifacts. Despite extensive tissue degradation, forensic autopsies retain diagnostic value even in advanced decomposition stages, as calcified atherosclerotic plaques persist when other cardiac structures are no longer identifiable. These findings, supported by both forensic and anthropological studies, reinforce the role of vascular calcifications as a key forensic marker of preexisting cardiovascular disease. Postmortem imaging techniques, particularly computed tomography angiography (PMCTA), may offer additional insights into vascular integrity. However, decomposition artifacts often limit its applicability, emphasizing the need for improved diagnostic approaches. Given the high variability of decomposition processes, controlled experimental studies are necessary to develop forensic methodologies capable of accurately assessing postmortem cardiovascular alterations. To address this gap, we will conduct a dedicated experimental study to analyze decomposition - related changes in the heart under controlled conditions, with the goal of developing standardized forensic protocols for cardiovascular pathology. Establishing such criteria will enhance forensic interpretations in cases of advanced decomposition, ensuring that critical diagnostic evidence is not overlooked.

6. Limitations

This review is limited by the scarcity of available studies specifically addressing the decomposition of the heart and coronary arteries. The limited number of available studies, as well as their heterogeneity in methodology, significantly restricts the ability to draw definitive forensic conclusions. Most of the included studies are based on case reports or retrospective observations rather than controlled experimental research, limiting the generalizability of the findings. Additionally, the exclusion of non-English articles and inaccessible studies may have led to the omission of relevant findings.

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Giovanni Cecchetto: Writing – review & editing, Methodology. **Biagio Solarino:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Gianmarco Argentiero:** Writing – original draft, Formal analysis, Conceptualization. **Matilde Talamo:** Formal analysis. **Federica Amirante:** Formal analysis.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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