Efficacy of postmortem CT and tissue sampling in establishing the cause of death in clinical practice

Efficacy of postmortem CT and tissue sampling in establishing the cause of death in clinical practice: a prospective observational study

Max Guillaume Mentink ,[1] Bart G H Latten,[2,3] Frans C H Bakers,[1] Casper Mihl,[1,4] Faysal Benali,[1] Patty J Nelemans,[5] Roger J M W Rennenberg,[6] Richard P Koopmans,[6] Dennis C J J Bergmans,[7] Bela Kubat,[2] Paul A M Hofman[1]

[1]Radiology & Nuclear Medicine, Maastricht Universitair Medisch Centrum+, Maastricht, Netherlands
[2]Pathology, Maastricht Universitair Medisch Centrum+, Maastricht, Netherlands
[3]Pathology, Netherlands Forensic Institute, Den Haag, Netherlands
[4]CARIM school for Cardiovascular Diseases, Maastricht University, Maastricht, Netherlands
[5]Epidemiology, Maastricht University, Maastricht, Netherlands
[6]Internal Medicine, Maastricht Universitair Medisch Centrum+, Maastricht, Netherlands
[7]Intensive Care, Maastricht Universitair Medisch Centrum+, Maastricht, Netherlands

Correspondence to
Max Guillaume Mentink, Radiology & Nuclear Medicine, Maastricht Universitair Medisch Centrum+, Maastricht, Limburg, Netherlands; maxmentink92@gmail.com

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ABSTRACT

Aims The aim of this study is to evaluate whether agreement with autopsy-determined cause of death (COD) increases by use of postmortem CT (PMCT) or PMCT in combination with postmortem sampling (PMS), when compared with clinical assessment only.

Methods This prospective observational study included deceased patients from the intensive care unit and internal medicine wards between October 2013 and August 2017. The primary outcome was percentage agreement on COD between the reference standard (autopsy) and the alternative postmortem examinations (clinical assessment vs PMCT or PMCT+PMS). In addition, the COD of patient groups with and without conventional autopsy were compared with respect to involved organ systems and pathologies.

Results Of 730 eligible cases, 144 could be included for analysis: 63 underwent PCMT without autopsy and 81 underwent both PMCT and autopsy. Agreement with autopsy-determined COD was significantly higher for both PMCT with PMS (42/57, 74%), and PMCT alone (53/81, 65%) than for clinical assessment (40/81, 51%; p=0.007 and p=0.03, respectively). The difference in agreement between PMCT with PMS and PMCT alone was not significant (p=0.13). The group with autopsy had a significantly higher prevalence of circulatory system involvement and perfusion disorders, and a lower prevalence of pulmonary system involvement.

Conclusion PMCT and PMS confer additional diagnostic value in establishing the COD. Shortcomings in detecting vascular occlusions and perfusion disorders and susceptibility to pulmonary postmortem changes could in future be improved by additional techniques. Both PMCT and PMS are feasible in clinical practice and an alternative when autopsy cannot be performed.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Postmortem CT is a well-established imaging technique as adjunct to a medicolegal autopsy in many countries. However, its role in the non-forensic clinical practice remains unclear.

WHAT THIS STUDY ADDS

⇒ This study shows the added value of postmortem CT to a clinically diagnosed cause of death and identifies postmortem sampling as a potential adjunct to CT. Additionally, shortcomings of postmortem CT are illustrated by the results and possible solutions are discussed.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ We hope that our results inspire clinicians to consider this non-invasive technique to further improve their diagnostic accuracy in times of declining autopsy rates.

INTRODUCTION

The first autopsies were performed to create an understanding of the normal anatomy and physiology by detailed observations, a search aspired by Hippocrates' naturalistic view who favoured natural causes over the divine and supernatural.[1] Nowadays, however, autopsy plays an irreplaceable role in quality control and education.[2–6] In an era of growing accuracy and accessibility of antemortem diagnostics, however, waning interest in postmortem examination has resulted in steadily declining autopsy rates worldwide.[7–12] The most important reason to forego autopsy is the assumption that the cause of death (COD) was reliably derived from clinical observations and antemortem diagnostic procedures.[2 13] Other factors are the fear of revealing medical errors or increasing the suspicion of such even when none were made, the presupposition that family members will oppose conventional autopsy because of its invasive character, religious beliefs or because they feel the deceased has suffered enough.[11 13] This decline in postmortem examinations is potentially detrimental: in the current era of high-tech medicine, postmortem examinations still reveal diagnostic errors and change the COD in a significant number of patients.[14–17] Postmortem imaging with or without postmortem tissue sampling (PMS) could decrease the persistent trend of declining autopsy rates, possibly by an increased awareness for postmortem examinations.[18]

Postmortem imaging has gained popularity over the past decade, and may provide a solution for accurate determination of COD despite declining postmortem examination rates. Postmortem CT (PMCT) and postmortem MRI (PMMR) have been introduced into the field of forensic medicine and both show promising results compared with traditional autopsy.[19–22] However, systematic use of

these alternative techniques is not common, and their role in clinical practice remains undefined.

Few studies have been published regarding the diagnostic performance of PMCT combined with PMS in a non-forensic population.[23–28] These studies find 64%–97% agreement on the COD with autopsy, depending on imaging techniques, number of biopsies, definition of agreement and number of radiologists involved in reporting. However, none of the studies evaluate whether PMS with CT-guided biopsy has an added diagnostic value in establishing the COD when compared with clinical assessment only.

The aim of the current prospective observational study is to assess the additional diagnostic value of PMCT and PMS in establishing the COD. This study is carried out in a setting that reflects clinical practice, with single reader reporting, a limited number of biopsies and minimised examination time. The hypothesis is that, in this setting, PMCT will show a better agreement with conventional autopsy on the COD than a clinical assessment, and that adding PMS will improve agreement even further.

MATERIALS AND METHODS

Study design

This single-centre, prospective, observational study included consecutive deceased patients at the Maastricht University Medical Centre who underwent a postmortem examination. The index tests, PMCT and standardised biopsy PMS, were implemented as part of standard care. The primary outcome was the percentage agreement on the COD between the alternative postmortem examinations (clinical assessment, PMCT and PMCT+PMS) and the reference standard (autopsy). The percentage agreement was calculated as follows: number of cases in agreement with the reference standard divided by the total number of cases × 100. In addition, in order to identify shortcomings of PMCT in absence of autopsy, deceased with autopsy were compared with those with only alternative examinations in a secondary analysis. This secondary analysis did not include a comparison of diagnostic accuracy, as the reference-standard (autopsy) was not available in all cases.

Participants

Adult patients that either deceased in the intensive care unit (ICU) between October 2013 and December 2014, or the department of internal medicine (DIM) between September 2015 and August 2017, were eligible for inclusion. Consent from the next of kin was required. Consent was provided for every examination separately (PMCT, PMS and autopsy) to the wishes of the next of kin. Therefore, some deceased underwent all examination, yet others underwent only PMCT, or PMCT with PMS, without autopsy. Deceased were excluded if postmortem imaging could not be performed although consent was acquired.

Postmortem examinations

The COD was determined directly after death by the treating clinicians. To determine the COD, clinicians had full access to medical records, including patient reports, vital parameters, antemortem imaging, laboratory test results and microbiological studies, as in daily practice. PMCT, PMS or autopsy had not yet been performed at the time of determining the clinical assessment COD. Clinicians could, therefore, not have been biased by PMCT or autopsy results. Clinicians filled out a standardised request form for postmortem imaging, including the COD as determined by their clinical assessment. PMCT was carried out within the first workday after death. A Somatom Definition Flash (Siemens Healthineers, Forchheim, Germany) or a Brilliance 64 (Philips, Best, the Netherlands) CT scanner was used, with an unenhanced full-body protocol (see details in table 1).

Images were interpreted once by one of two board-certified abdominal radiologists (FB and CM) with 6 years' and 3 years' experience in forensic and postmortem radiology. Findings were recorded on a structured report template including the most probable COD. The radiologist was blinded to tissue sampling and autopsy results (not available at the time of PMCT reporting), but not to clinical information or ante-mortem imaging.

PMS was performed by standardised full-core (CT-guided) biopsies from the liver and both inferior lobes of the lungs, using a 15G introducer and a soft-tissue Tru-Cut biopsy needle (H.S. Hospital Services S.P.A., Aprilia, Italy). Easy access and expected histopathology yield were the main considerations for the determined biopsy sites. Additional histological samples (CT guided) were obtained if warranted by PMCT findings or clinical indication. Tissue samples were reviewed by a pathologist blinded to autopsy results. PMS was not performed in patients from the ICU.

The autopsy was performed according to standard procedure, including a thorough internal examination of the pelvic, thoracic and abdominal organs. The brain was only examined if additional consent from the next of kin was obtained. The autopsy included a macroscopic and microscopic (histological) assessment of all major organs, as well as microbiological studies when appropriate. Additional toxicological and biochemical analysis were not performed. Autopsy was performed by a pathology resident, supervised by a pathologist. In accordance with clinical practice, pathologists were not blinded to information from clinical records and the results of all postmortem examinations.

Table 1 Scan and biopsy control CT parameters

	Mode	Tube voltage (kV)	Tube current (mAs_{eff})	Acquisition (mm)	Pitch	Slice (mm)	Reconstruction increment
Siemens Somatom definition Flash							
Head/neck	Helical	120	400	128 * 0.6	0.55	1	0.7
Thorax/abdomen	Helical	140	500	128 * 0.6	0.6	1	0.7
Biopsy control	Sequential	120	200	12 * 1.2	–	2.4	–
Phillips Brilliance 64							
Head/neck	Helical	120	400	64 * 0.625	0.891	1	0.7
Thorax/abdomen	Helical	120	400	64 * 0.625	0.891	1	0.7
Biopsy control	Sequential	120	250	12 * 1.25	–	2.5	–

mAs_{eff}, effective tube current scan time product.

Determining and classifying the COD

The COD was defined as the acute pathological process leading to the death of a patient. The COD was determined for every deceased, one for each type of postmortem examination performed (clinical assessment, PMCT, PMCT in combination with PMS and autopsy). If available, autopsy was taken to be the reference standard for COD (the 'autopsy' group), if not, a consensus COD was held as the final COD ('non-autopsy' group). Consensus COD was established by a multidisciplinary mortality review board (MMRB), consisting of the referring physician, radiologist and pathologist. To this end, the MMRB evaluated all clinical data including results of postmortem examinations.

The International Classification of Diseases coding was applied to each COD and used for statistical analysis.[29] The COD was also categorised per organ system and main pathology according to Sonnemans *et al*[25] and Roberts *et al*[26]: organ systems were classified as pulmonary, circulatory, gastrointestinal, haematologic, genitourinary or nervous; main pathologies were classified as infection, haemorrhage, perfusion disorder or other (eg, hydrothorax, liver transplant failure). Any underlying disease (diagnosed before death) was categorised as malignancy, cardiac failure, respiratory disease, unknown or other. ICD codes were not used to determine agreement or disagreement on the COD. This was determined by a case-per-case review by the researcher and a radiologist. All cases with disagreements were discussed with a pathologist before statistical analysis. For the purpose of this study, no findings other than the COD (eg, additional findings indicating comorbidities) were analysed.

Statistical analysis

For the primary analysis, the difference in percentage agreement in COD between autopsy and alternative examinations was tested for significance using the two-sided McNemar test for paired proportions. For the secondary analysis, the differences between the autopsy and non-autopsy groups in the distribution of antemortem underlying diseases, involved organ systems and type of pathology were tested using the two-sided χ^2 test and Fisher's exact test for unpaired samples. All statistical analyses were performed using SPSS (IBM SPSS Statistics for Macintosh, V.24.0.0.0., 2016, IBM). A $p<0.05$ was considered to indicate statistical significance.

RESULTS

Participants

A total of 730 deceased were eligible for inclusion (figure 1). Consent for postmortem examination by next of kin was obtained in 148 cases (25 ICU and 123 DIM). Four of these patients (one ICU and three DIM) were excluded because PMCT could not be performed (in one case the deceased had already been transferred to the funeral home, in the other three cases autopsy had already been performed). No statistically significant differences were found between included and non-included patients in male to female ratio (1.5 vs 1.4; p=0.423), mean age (69.3 vs 69.9 years; p=0.669) or mean length of hospitalisation until death (7.7 vs 8.4 days; p=0.681).

Of the remaining 144 deceased (figure 1), no consent for autopsy was given in 63 cases (all DIM). Autopsy was performed in the remaining 81 cases (24 ICU, 57 DIM; 51 males, 30 females; mean age 67±12 years, range 57 years, minimum 33-maximum 90). No significant differences in patient demographics, underlying disease, involved organ system or main pathology of the COD were found between ICU and DIM deceased (table 2). PMCT was performed at a median interval of 12 hours after death (IQR: 6–17, n=81). In 57 of the 81 autopsy group cases (all DIM), standardised PMS was performed prior to autopsy; additional biopsies were performed in 27 of these 57 cases. No adverse events occurred during PMS that could have affected autopsy results.

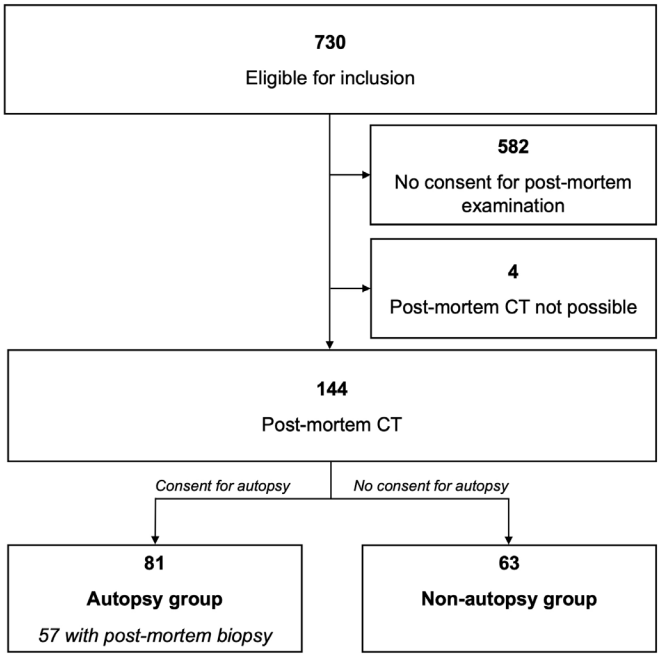

Figure 1 Inclusion flow chart.

Agreement with autopsy COD (autopsy group)

Percentage agreement with autopsy-determined COD was 51% (40/81) for clinical assessment, 65% (53/81) for PMCT alone and 74% (42/57) for PMCT combined with PMS. The differences with agreement for clinical assessment were significant for both PMCT and PMCT with PMS (p=0.03 and p=0.007, respectively) (figure 2). The difference in agreement between PMCT with PMS and PMCT alone was not statistically significant (p=0.13).

Twenty-eight discrepancies between autopsy and PMCT determined COD were found (35%). The COD as determined by clinical assessment, PMCT, PMCT in combination with PMS and autopsy of these discrepancy cases are described in table 3. In 18 of these 28 cases, the COD determined by PMCT involved the pulmonary system. Remarkedly, autopsy determined the COD to be related to the circulatory system, rather than the pulmonary system, in 12 of 18 cases.

Distribution of involved organ systems and pathology (autopsy vs non-autopsy group)

Differences in categorisation of COD into involved organ system and main underlying pathology between the autopsy (n=81) and non-autopsy (n=63) group are shown in table 4. Four statistically significant differences were found: COD involving the pulmonary system (36% vs 63%, p<0.001), COD involving the circulatory system (46% vs 21%, p=0.002), perfusion disorders (26% vs 6%, p=0.002) and other type of pathology (27% vs 51%, p=0.004). The mean age of patients in autopsy group was 67 years and significantly lower than the mean age of 72 years in the non-autopsy group (p=0.04).

Table 2 Characteristics of deceased from the department of internal medicine and intensive care unit included in the autopsy group

	Internal medicine n=57	Intensive care unit n=24	P value
Demographics			
Male (%)	39 (68)	12 (50)	0.12
Mean age (±SD)	67 (±13)	68 (±10)	0.59
Underlying disease			
Malignancy (%)	25 (44)	8 (33)	0.38
Cardiac failure (%)	7 (12)	7 (29)	0.67
Respiratory disease (%)	2 (4)	3 (13)	0.12
Unknown or other (%)	23 (40)	6 (25)	0.19
Organ system of the COD			
Pulmonary (%)	23 (40)	6 (25)	0.19
Circulatory (%)	23 (40)	14 (58)	0.14
Gastrointestinal (%)	7 (12)	3 (13)	0.98
Haematologic (%)	0 (0)	1 (4)	0.29
Genitourinary system (%)	1 (2)	0 (0)	>0.99
Nervous system (%)	3 (5)	0 (0)	0.55
Type of pathology of the COD			
Infectious (%)	21 (37)	11 (46)	0.45
Haemorrhage (%)	5 (9)	1 (4)	0.47
Perfusion disorder (%)	13 (23)	8 (33)	0.32
Other (%)	18 (32)	4 (17)	0.17

COD, cause of death.

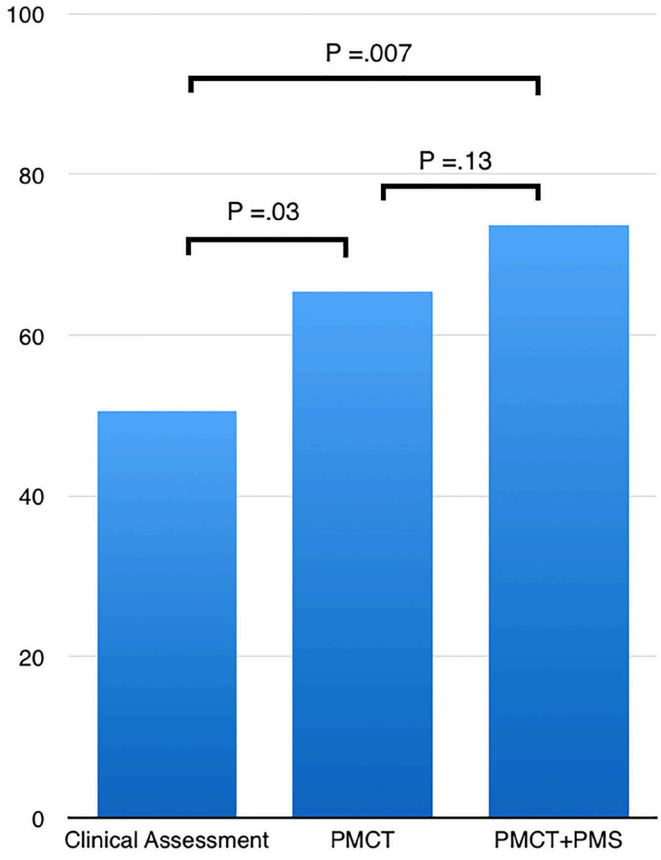

Figure 2 Percentage agreement on cause of death, with autopsy as the reference standard. PMCT, postmortem CT, PMS, postmortem sampling.

DISCUSSION

Agreement with autopsy-determined COD was significantly higher for both PMCT combined with PMS (74%) and PMCT alone (65%) than for clinical assessment (51%). The 9% difference in agreement between PMCT combined with PMS and PMCT alone was not statistically significant. In 43% of discrepancies between PMCT and autopsy, PMCT determined a pulmonary system-related COD, whereas the COD according to autopsy was circulatory system related. Finally, the autopsy group had a significantly higher prevalence of both circulatory system involvement and perfusion disorders, and a lower prevalence of pulmonary system involvement. A statistically significant age difference was also found between the autopsy and non-autopsy group. This effect of age on the autopsy rate has been recognised and described before in literature.[12]

In this study, the COD according to clinical assessment agreed with the autopsy COD in just over half the cases, which is comparable to findings published in literature and illustrates the continued necessity of comprehensive postmortem examinations.[16 17 24 25 30–32] Agreement with autopsy improved by 14% when using PMCT. Other studies reporting on the value of postmortem imaging include a variable combination of postmortem examinations such as PMCT, PMMR and PMS. Consequently, these studies vary substantially in their materials and methods, which is reflected in the reported range in percentage agreement with autopsy (64%–97%).[23–27] The results of the current study reflect clinical practice, with one reader, no postmortem angiography and a limited number of biopsies, and still fall within the published range.

To the best of our knowledge, this is the first study to evaluate the added value of PMS, more specifically CT-guided biopsy, to unenhanced PMCT. Several studies and case reports describe a combination of postmortem imaging and tissue sampling.[33] These studies include unguided, ultrasound-guided, CT-guided and CT fluoroscopic controlled biopsy as method of PMS. However, the added value of PMS (a specific comparison of the performance of PMCT without PMS and PMCT with PMS) is not described in any of these studies. In the current study, agreement with autopsy-determined COD increased from 65% to 74% when PMCT was combined with PMS. Even though not statistically significant, probably due to the limited sample size (n=57), an increase of 9% in agreement could be deemed clinically relevant. The diagnostic performance of postmortem imaging and sampling depends on the way these imaging techniques are implemented and the materials and methods used for sampling. For instance, the total number and core diameter of these biopsies could affect the evaluability and limit the risk of sampling error. Wagensveld *et al* demonstrated that diagnostic utility and yield are highest when PMCT, PMMR and PMS are combined.[34] Although the highest diagnostic yield can be sought, feasibility, time-efficiency and costs should be taken into account, especially if costs of alternative examinations threaten to exceed those of autopsy.[34]

Some literature suggests that the degree of agreement also depends on the study population. A forensic multicentre study found that in cases of polytrauma PMCT revealed a higher proportion of essential additional findings compared with cases of natural death.[35] Furthermore, a recent forensic study established superiority of PMCT to autopsy in the detection of facial and cervical fractures, as well as in the detection of intraventricular haemorrhage and pneumocephalus in neurotrauma victims.[36] It is therefore plausible that including patients from different departments (emergency vs internal medicine) or even

Table 3 Discrepancy cases between PMCT COD and autopsy COD

Case #	Sex, age	Clinical assessment	PMCT	PMCT+PMS	Autopsy
Internal medicine					
1	♂ 60–65	Sepsis, unspecified	Sepsis, unspecified	Sepsis, unspecified	Sepsis by pneumonia (candida)
2	♂ 60–65	Respiratory insufficiency	Pulmonary haemorrhage	Pulmonary haemorrhage	Haemophagocytic syndrome
3	♂ 50–55	Respiratory insufficiency	Sepsis by pneumonia	Sepsis by pneumonia	Acute pulmonary embolism
4	♀ 65–70	Sepsis, unspecified	Sepsis by pneumonia	Sepsis by pneumonia	Acute pancreatitis
5	♀ 65–70	Shock, Hypovolaemic	Respiratory insufficiency	Respiratory insufficiency	Shock, Hypovolaemic
6	♂ 70–75	Shock, septic	Respiratory insufficiency	Acute myocardial infarction	Acute myocardial infarction
7	♂ 70–75	Sepsis, unspecified	Respiratory insufficiency	Respiratory insufficiency	Sepsis, unspecified
8	♂ 70–75	Sepsis by pneumonia	Pneumonia, pleural effusion	Sepsis by pneumonia	Sepsis secondary empyema
9	♀ 30–35	Shock, tuberculous pneumonia	Respiratory tuberculosis	Respiratory tuberculosis	Acute myocardial infarction secondary to miliary tuberculosis
10	♂ 50–55	Suspicion of acute myocardial infarction	Pulmonary findings consistent with mycobacterial infection	Mycobacterial infection	Acute transmural myocardial infarction, secondary to mycobacterial infection
11	♀ 70–75	Metastasised neoplasm, unknown origin.	Pleural carcinomatosis	Identified new sites of metastasised neoplasm.	Diffuse metastasised neoplasm, breast cancer.
12	♀ 35–40	Respiratory insufficiency	Pneumonia	Pneumonia	Interstitial fibrosis with findings consistent with acute respiratory distress syndrome
13	♂ 80–85	Viral pneumonia	Pulmonary oedema (cardiac decompensation), unknown cause	Pulmonary oedema (cardiac decompensation), unknown cause	Acute myocardial infarction
14	♀ 50–55	Cardiomyopathy, unspecified	Respiratory insufficiency	Respiratory insufficiency	Diffuse metastasised neoplasm, urothelial carcinoma
15	♂ 70–75	Sepsis, unspecified	Sepsis, unspecified	Sepsis, unspecified	Acute pancreatitis
16	♂ 75–80	Unknown	Aspiration pneumonitis	Aspiration pneumonitis	Acute endocarditis
17	♂ 80–85	Respiratory insufficiency	Respiratory insufficiency	Respiratory insufficiency	Acute myocardial infarction
18	♀ 50–55	Gastrointestinal haemorrhage	Sepsis by pneumonia	Sepsis by pneumonia	Gastrointestinal haemorrhage
19	♂ 65–70	Liver transplant failure	Liver transplant failure	Acute hepatitis	Acute myocardial infarction
ICU					
20	♀ 80–85	Sepsis, unspecified	Respiratory insufficiency (pleural fluid, atelectasis)	No PMS	Bronchopneumonia
21	♀ 75–80	Sepsis, unspecified	Suspicion pulmonary embolus	No PMS	Cardiac failure
22	♀ 70–75	Sepsis by pneumonia	Respiratory insufficiency (pleural fluid, atelectasis)	No PMS	Sepsis by pneumonia
23	♂ 75–80	Respiratory insufficiency	Respiratory insufficiency	No PMS	Acute peritonitis
24	♂ 55–60	Left ventricular heart failure	Acute hepatic failure	No PMS	Sepsis by pneumonia
25	♂ 60–65	Ischaemia of the colon	Ischaemia of the colon	No PMS	Opportunistic mycoses
26	♂ 70–75	Respiratory insufficiency	Suspicion cardiac failure, unspecified	No PMS	Acute myocardial infarction
27	♀ 65–70	Shock, cardiogenic	Pulmonary haemorrhage	No PMS	Bronchopneumonia
28	♀ 60–65	Respiratory insufficiency	Heart failure, unspecified	No PMS	Acute and subacute hepatic failure

COD, cause of death; ICU, intensive care unit; PMCT, postmortem CT; PMS, postmortem sampling.

hospitals (academic vs non-academic) will result in differences in efficacy of PMCT.

The secondary analyses showed a higher prevalence of circulatory system involvement in the autopsy group compared with the non-autopsy group, in combination with a lower prevalence of pulmonary system involvement and a higher prevalence of perfusion disorders as the main pathology. These findings illustrate two shortcomings of unenhanced PMCT. First, in absence of intravascular contrast is it impossible for PMCT to detect vascular occlusions and perfusion disorders (ie, coronary stenosis or occlusion), a type of pathology that is frequently observed during autopsy and often deemed as the COD. A possible solution for this limitation is the application of PMCT angiography and PMMR as these techniques are more sensitive to cardiovascular pathology.[35 37–40] Second, postmortem changes can affect interpretation of pulmonary findings, as the lungs are particularly sensitive to the redistribution of fluids.[41 42] Studies exploring postmortem ventilation show promising results with regard to reversibility of pulmonary postmortem changes and state that ventilated PMCT might enhance diagnostic ability of PMCT for lung pathologies.[43 44] The overall percentage of COD involving the pulmonary system of all 144 cases is 60% (87/144), which is consistent with the non-autopsy group (63%). Other studies show a variable percentage of pulmonary related COD, ranging from 5% to 62%. The wide range of reported pulmonary COD underlines the difficulty of interpretation of pulmonary findings related to the COD and raises questions hopefully answered by future research.[21 23 24] These shortcomings of PMCT emphasise the importance of autopsy and illustrate why consent for autopsy should always be sought.

A limitation of this study is the sample size, which was determined by the patient care budget and the relative low autopsy rate. This led to insufficient data for a sensitivity and specificity analysis of the pathology and organ system subgroups. A remark

Table 4 Characteristics of autopsy and non-autopsy groups

	Autopsy group n=81	Non-autopsy group N=63	P value
Male (%)	51 (63)	34 (54)	0.28
Mean age (±SD)	67 (±12)	72 (±14)	**0.04**
Underlying disease			
Malignancy (%)	33 (41)	28 (44)	0.66
Cardiac failure (%)	15 (19)	5 (8)	0.34
Respiratory disease (%)	4 (5)	2 (3)	0.70
Unknown or other (%)	29 (36)	28 (44)	0.29
Organ system of the COD			
Pulmonary (%)	29 (36)	40 (63)	**<0.001**
Circulatory (%)	37 (46)	13 (21)	**0.002**
Gastrointestinal (%)	10 (12)	4 (6)	0.27
Haematologic (%)	1 (1)	2 (3)	0.58
Genitourinary (%)	1 (1)	1 (2)	>0.99
Nervous (%)	3 (4)	3 (5)	>0.99
Type of pathology			
Inflammatory (%)	32 (40)	25 (40)	0.98
Perfusion disorder (%)	21 (26)	4 (6)	**0.002**
Haemorrhage (%)	6 (7)	2 (3)	0.47
Other (%)	22 (27)	32 (51)	**0.004**

Statistically significant results are expressed in bold (p<0.05).
COD, cause of death.

must be made on the autopsy performing pathologists, whom were not blinded to the results of prior postmortem examinations results. This introduces a potential incorporation bias, as results were accessible through the electronic patient files. However, in practice, results were not actively shared with pathologists, and pathologists did not consult the PMCT reports for the interpretation of autopsy results. Strengths of this study are the reproducibility of the study design, the realistic clinical practice-oriented setting and the use of a well-accepted reference standard (autopsy). Although currently considered the reference standard for determining COD, limitations of autopsy have been described (ie, limited to the examined anatomical structures and cavities, the lack of consent for brain autopsy and difficulties with the identification of abnormal gas collections). These limitations provide sufficient grounds for seeking to improve the current reference standard, possibly through the introduction of a multimodality postmortem examination. The pathophysiological process leading to death can be seen as a cascade of events. Thus clinician, radiologist and pathologist may each identify a different event with their own modality (clinical parameters and the setting of death, whole body cross-sectional imaging based on X-ray attenuation and macroscopy and microscopy of tissues). Multimodality postmortem examination could therefore be more suitable for establishing the COD than a single modality. Within the field of forensic radiology, PMCT has already proven its added value and is readily used complimentary to the medicolegal autopsy.[45] We hope that the current results will stimulate others to investigate the added value of postmortem biopsies and help to define the optimal role of PMCT in clinical practice.

In conclusion, PMCT confers additional diagnostic value in establishing the COD, which is increased with the addition of PMS. Shortcomings in detecting vascular occlusions and perfusion disorders and in susceptibility to pulmonary postmortem changes could be improved by adaptations such as ventilated PMCT and PMCT angiography. Both PMCT and PMS are feasible in clinical practice and provide an alternative in situations where autopsy cannot be performed.

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ORCID iD
Max Guillaume Mentink http://orcid.org/0000-0002-0733-9029

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