Introduction of postmortem CT increases the postmortem examination rate without negatively impacting the rate of traditional autopsy in daily practice

Introduction of postmortem CT increases the postmortem examination rate without negatively impacting the rate of traditional autopsy in daily practice: an implementation study

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ABSTRACT

Aim The aim of this implementation study was to assess the effect of postmortem CT (PMCT) and postmortem sampling (PMS) on (traditional) autopsy and postmortem examination rates. Additionally, the feasibility of PMCT and PMS in daily practice was assessed.

Methods For a period of 23 months, PMCT and PMS were used as additional modalities to the autopsy at the Department of Internal Medicine. The next of kin provided consent for 123 postmortem examinations. Autopsy rates were derived from the Dutch Pathology Registry, and postmortem examination rates were calculated for the period before, during and after the study period, and the exclusion rate, table time, time interval to informing the referring clinicians with results and the time interval to the Multidisciplinary Mortality Review Board (MMRB) meeting were objectified to assess the feasibility.

Results The postmortem examination rate increased (from 18.8% to 32.5%, p<0.001) without a decline in the autopsy rate. The autopsy rate did not change substantially after implementation (0.2% decrease). The exclusion rate was 2%, the table time was 23 min, and a median time interval of 4.1 hours between PMCT and discussing its results with the referring clinicians was observed. Additionally, more than 80% of the MMRB meetings were held within 8 weeks after the death of the patient.

Conclusions Our study shows that the implementation of a multidisciplinary postmortem examination is feasible in daily practice and does not adversely affect the autopsy rate, while increasing the postmortem examination rate.

INTRODUCTION

Identification of the correct cause of death is important for the evaluation of diagnostic and therapeutic procedures. Therefore, a postmortem examination is an essential tool for quality control and education.[1–5] Additionally, the correct cause of death and identification of comorbidities are important for national registries and the reliability of death certificates as well as for making health policy decisions.[6 7] Knowing the cause of death is of value to the next of kin, at the very least because they may share risk factors (eg, genetic predisposition). It is often assumed that the cause of death is known based on the antemortem clinical information. But even in the era of advanced diagnostic methods, the percentage of major discrepancies between clinical and (traditional) autopsy diagnosis is as high as 50%.[8–14] Despite the need for a correct cause of death and the known discrepancies between the clinical cause of death and the cause of death according to the autopsy, the number of clinical autopsies is declining worldwide.[15–21] The reason for this decline is a combination of factors, such as the overconfidence in the diagnostic procedures, financial and religious reasons, fear of mutilation, workload issues and a fear of litigation.[22–24]

As a response to the declining autopsy rates, other modalities for postmortem examination should be considered as well. The application of postmortem imaging has been growing since its introduction and plays an increasing role in postmortem examinations.[25 26] Postmortem imaging uses imaging modalities routinely used in clinical medicine, such as postmortem CT (PMCT) and postmortem MR (PMMR) imaging. Excellent visualisation of skeletal trauma, presence of air configurations and metal has already proven the value of imaging in the field of forensic and trauma cases.[27–30] In addition to postmortem imaging, methods of the minimally invasive autopsy have been introduced. These methods include the use of thoracoscopy, laparoscopy and postmortem sampling (PMS) by taking image-guided biopsies to enable a macroscopic and histological examination in a less invasive manner than the conventional autopsy.[31–35]

Although postmortem imaging was initially introduced in forensic medicine, it seems that clinical medicine can profit from these developments as well.[34 36] PMCT and PMS were implemented in daily clinical practice as an additional postmortem examination, with the main goal to contribute to the quality and completeness of the postmortem workup, without the purpose of replacing autopsy. With the use of these non-invasive and minimally invasive techniques (eg, PMCT and PMS, respectively), this study aimed to evaluate the effect on the rate of autopsies and postmortem examinations and assess its feasibility in daily clinical practice.

MATERIALS AND METHODS

Study design and setting

PMCT and PMS were introduced in the context of a prospective study, to expand the current single-modality examination (autopsy) to a multidisciplinary examination. This required the collaboration of multiple departments with a shared vision and approach. This implementation study identified the effect of implementation on the autopsy and postmortem examination rates before, during and after implementation. Additionally, the feasibility of PMCT and PMS was assessed. The diagnostic performance was not determined in this study. The institutional ethics committee examined the research protocol and subsequently confirmed that the Medical Research Involving Human Subjects Act (WMO) does not apply to this study and that an official approval of this study by the committee was not required.

Inclusion and logistics

Adult patients who died in the internal medicine wards were eligible for inclusion. Patients were included when consent for PMCT, possibly in combination with other examinations, was obtained. Consent for a postmortem examination was obtained from the next of kin by the treating clinician. In order to encourage consent for autopsy, consent for autopsy was discussed first, then in descending order of invasiveness, PMS and PMCT were discussed. Any combination of postmortem examinations could be agreed on, including traditional autopsy only, or PMCT and PMS only. However, unconventional scenarios such as PMCT and traditional autopsy without PMS were not recommended to the next of kin by the clinician conducting the consent process. Additionally, because PMS was CT guided, it was not performed in the absence of PMCT. A workshop was provided to prepare clinicians for this consent procedure. When consent for PMCT was obtained, the treating clinician filled out an application form and informed the radiology technician on duty (24/7 service) to plan the PMCT for the next workday or at the weekend if possible. The form included patient identification, the postmortem examinations for which consent was provided, and the clinical cause of death with relevant clinical information and questions (see the online supplement 1; application form). The request form remained with the corpse at all times. Between examinations, corpses were returned to the morgue for temporary storage at 4°C, unless the examinations could be performed consecutively. Patients were excluded only when autopsy took place before PMCT (due to miscommunication) or when the corpse was picked up by the funeral director before PMCT was performed. The clinical autopsy was performed according to the normal clinical protocol. The cause of death based on macroscopic results was communicated directly after the autopsy and summarised in a preliminary report within 48 hours. The final cause of death based on autopsy and histology analysis was usually provided after 5–6 weeks.

Implemented interventions

Imaging was performed with a SOMATOM Definition Flash (Siemens Healthineers, Forchheim, Germany) or a Brilliance 64-slice CT scanner (Philips, Best, the Netherlands). The standardised full-body scan protocols (proximal femur—head) are shown in table 1. The corpse was placed in the supine position with the hands beside the body if possible (rigour mortis). Imaging was performed by the radiology technicians and reported by general radiologists with experience in forensic or postmortem radiology using a structured report template. This template consisted of the main anatomical regions (head and neck, thorax, abdomen and the extremities) and their corresponding anatomical structures with a scoring system for severity of the pathology (see the online supplement 2; report template).

CT-guided biopsies were performed after PMCT imaging. Three standard full-core biopsies were obtained, one of the livers and one of each inferior lung lobe. The main considerations for the locations were easy accessibility and the expected yield of histopathology. The radiologist was present when the corpse was scanned to identify any additional locations for PMS (eg, tumour, fluid collection and enlarged lymph node). Biopsies were taken with a 15G introducer needle and soft tissue Tru-Cut biopsy needle (H.S. Hospital Services S.p.A, Aprilia, Italy). Additional biopsies or fluid aspirations were performed only if indicated and consent was provided. Tissue samples were sent to the Department of Pathology in separate containers labelled with the patient's details and biopsy location. A pathologist reviewed the biopsies without knowledge of the autopsy results.

No changes were made to the traditional autopsy protocol for the purpose of this study. According to this protocol, the autopsy of the brain was only performed when explicit consent was provided. In this study, the term 'autopsy' will refer to the traditional autopsy performed in a clinical setting.

Data storage

The imaging data were sent to a picture archiving and communication system (AGFA Impax V.6.6; Agfa, Mortsel, Belgium) that enabled the radiologist to view the acquired PMCT, correlate the findings with any antemortem imaging and prepare the PMCT report in the normal workflow. Once the radiology report was finalised, it was visible in the patient's electronic medical records (SAP NetWeaver V.7.30; SAP SE, Walldorf, Germany) and available to the treating clinicians and pathologists.

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	–
Philips Brilliance 64							
Head/neck	Helical	120	400	64*0.625	0.291	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	–

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

Multidisciplinary Mortality Review Board

The multidisciplinary approach, with radiologists, clinicians and pathologists present, was considered to be the cornerstone for the postmortem workup. Besides reaching a consensus on the cause of death, integration of the results by the Multidisciplinary Mortality Review Board (MMRB) sought answers to relevant questions about the provided care. This is instrumental for the identification of missed diagnoses, suboptimal treatment and inadequate protocols, thereby enabling healthcare improvement. Short-term feedback of the postmortem examination results was considered to be essential, because treating clinicians have a more recent memory of the deceased patient, enabling correlation with the clinical information in greater detail. Also, residents (who provided most of the referrals) usually spend a limited period of time at a single department before they rotate to another department. The MMRB took place consecutively to the morning report of the Department of Internal Medicine. The clinician who clinically treated the patient introduced the case and discussed the medical history, reason for hospitalisation, clinical course and suspected cause of death based on the clinical assessment. Consecutively, the radiologist showed and discussed the radiological findings of PMCT. If a pathological examination was performed, the pathologist then shared their results based on macroscopic, histopathological and possibly molecular examinations. Lastly, the interpretation of all the results took place to formulate a unanimous final cause of death. MMRB was discontinued after the study period. However, traditional autopsy results are still discussed during meetings by the Department of Internal Medicine and Pathology, in the absence of radiologists, as they were before the study period.

Outcome measures

Several outcome measures were defined for the process evaluation and assessment of the implementation. The autopsy data were retrieved from the histopathology system (Delphic AP, Sysmex, Epsom, New Zealand), which is linked to the nationwide histopathology and cytopathology data network and archive (PALGA).[37] The autopsy and postmortem examination rates were determined for several periods: before (44 months), during (23 months) and after implementation (17 months). The periods before and after the study period were determined by data availability and the study period itself was determined by the available research budget. The postmortem examination rate was defined as the total number of patients with a postmortem examination (PMCT, PMS and/or autopsy) divided by the total number of deceased patients on the internal medicine wards. The autopsy was the only available postmortem examination in the periods before and after implementation. Additionally, the number of autopsies requested by the Department of Internal Medicine as a percentage of the total number of autopsies performed hospital-wide was determined for the same time periods. This percentage is referred to as the relative autopsy rate. Additionally, the mean time intervals from death to the MMRB meeting were compared between cases with and without autopsy (autopsy vs non-autopsy group).

To evaluate feasibility in daily practice, several objective outcome measures were assessed. (1) The rate of exclusion (indicative of interference with autopsy and funeral preparations). (2) The table time, defined as the time in minutes between the first and last images captured during PMCT imaging, including CT-guided biopsies, if indicated. (3) The time interval between PMCT imaging and informing the referring clinician of the cause of death based on radiological findings. (4) The time interval between death and the MMRB meeting.

Methods of analysis

For descriptive purposes, variables were presented as mean (±SD) or median with IQR as appropriate. 2×2 Contingency tables were created to perform χ^2 tests to compare autopsy, postmortem and relative autopsy rates observed before, during and after the study period. A comparison of mean interval times was performed with the independent t-test. Statistics were calculated using SPSS (IBM SPSS Statistics for Macintosh, V.24, IBM Corp.). A p value <0.05 was considered to be statistically significant.

RESULTS

Participants

During a period of 23 consecutive months (September 2015 until August 2017), PMCT and PMS were offered an additional postmortem examination. A total of 456 patients died in the internal medicine wards during this period. Consent for PMCT was provided in 123 of these cases. Three patients were excluded because PMCT could not be performed (in two cases, the corpse had already been collected by the funeral service, whereas in the remaining case, autopsy had already been performed). A total of 120 patients underwent PMCT during the study period (73 male 47 female individuals; mean age 69±13.9 years; range 71 years). A combination of PMCT and PMS was performed in 103 cases. Additional biopsies or fluid aspirations were collected in 51 cases (maximum of three additional biopsies besides the standard biopsies). In 57 cases, autopsy was performed. The mean table time of PMCT in combination with PMS was 23 min (SD ±1, range 56 min, n=103). A flowchart of the selection process is shown in figure 1. No changes in the protocol were made during the study, and no events occurred during PMCT or PMS that could have adversely affected the autopsy results.

PMCT was performed at a median interval of 16.8 hours after death (IQR: 10.9–28.7). Radiological findings and cause of death were discussed by telephone with the referring clinician at a median of 4.1 hours (IQR: 1.7–8.0) after PMCT was

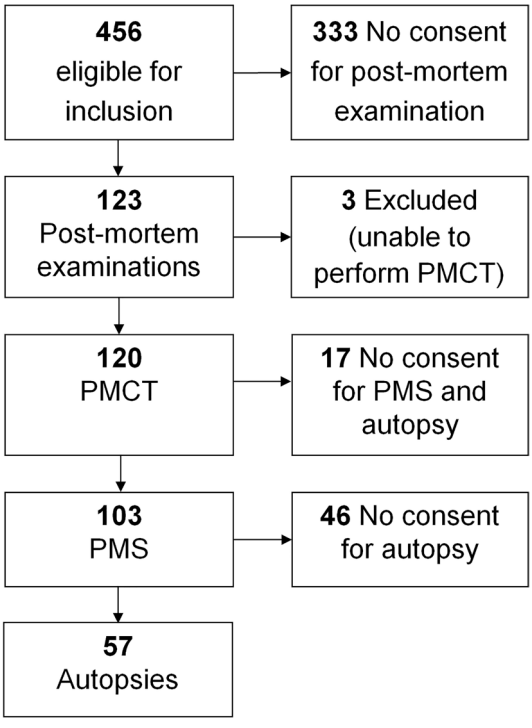

Figure 1 Inclusion flowchart. PMCT, postmortem CT; PMS, postmortem sampling.

Table 2 The autopsy rates, postmortem examination rates and relative autopsy rates of the Department of Internal Medicine are shown for the periods before, during and after the study period

	Before the study period	During the study period	Difference before and during the study period (p value)	After the study period	Difference during and after the study period (p value)
Autopsy rate	18.8% (146/778)	18.6% (85/456)	−0.2% (0.956)	14.1% (49/348)	−4.7% (0.856)
Postmortem examination rate	18.8% (146/778)	32.5% (148/456)	13.7% (**<0.001**)	14.1% (49/348)	−18.4% (**<0.001**)
Relative autopsy rate	28.2% (146/517)	34.4% (85/247)	6.2% (0.082)	32.2% (49/152)	−2.2% (0.655)

Differences between before and during the study period, and during and after the study period are also shown with associated p values. Statistically significant p-values (<0.05) are marked in bold.

performed. An autopsy was performed at a median of 1 day after the death (IQR: 1–2).

Autopsy and postmortem examination rates

The autopsy rate, postmortem examination rate and the relative autopsy rate before, during and after the study are shown in table 2. During the study period, 148 patients underwent a postmortem examination, 63 with only imaging, 28 with only autopsy and 57 with imaging and autopsy combined. The autopsy rate showed no substantial decline during the study period (18.8%–18.6%). Only after the study period, it dropped to 14.1%. The postmortem examination rate increased with 13.7% ($p<0.001$) after implementation. The relative autopsy rate is at its highest during the study period, indicating that the autopsy rate of other departments decreased, whereas the autopsy rate at the Department of Internal Medicine did not.

Time interval to MMRB meeting

The mean time interval between the day of death and MMRB meeting was 6.87 (±1.92) and 3.62 (±2.19) weeks in the autopsy and non-autopsy groups, respectively. There was a statistically significant difference between the two groups ($p<0.001$). The MMRB meeting was held within 8 weeks in 82% of all cases (98/120).

DISCUSSION

Our results show that the introduction of additional postmortem examinations at the Department of Internal Medicine led to a statistically significant increase in the postmortem examination rate. The autopsy rate was not substantially affected by the introduction of PMCT and PMS. A decrease in the autopsy rate was only observed after the study period. This study also demonstrates that implementation was feasible in daily practice.

Although declining autopsy rates are well described globally, no literature is available on the autopsy rate or postmortem examination rates when alternative postmortem examinations are available.[15–19] This makes our study the first to show the effects of the implementation of PMCT and PMS on these rates. Although it is clear that the postmortem examination rate increased during the study period, the effect of implementation on the autopsy rate is more difficult to assess. This is due to fluctuations in the number of autopsies on departmental, regional, national and global scales. The autopsy rate might also be affected by the increased awareness for postmortem examinations during the study period, the diagnostic performance of autopsy and other postmortem examinations, the presence of an elaborate MMRB with in-depth discussions and a relatively short time interval to the MMRB meetings. This may have resulted in a bias towards obtaining consent for an autopsy. Likewise, autopsy and postmortem examination rates after the study period might have been affected by the absence of these advantages that were then no longer available, much like a rebound effect. It would be of interest to conduct a similar study with a larger patient population or in a multicentre setting in which these fluctuations and determinants can be identified. Strengths of this study were the novelty of the outcome measures and the reliable data collection from the national pathology network and archive.[37]

Several studies have made statements with respect to the feasibility of PMCT.[38–40] The term feasible is not defined consistently in the current literature, as no standard criteria are available. Feasibility was assessed by the evaluation of multiple objective measures as defined in the Materials and methods section of this study. The results showed that a low exclusion rate was achieved (2%) and the mean table time was 23 min for PMCT in combination with PMS. PMCT results were discussed with the referring clinician at a median of 4.1 hours, and more than 80% of the MMRB meetings were held within 8 weeks after the death of the patient. We, therefore, conclude that the incorporation of PMCT and PMS in daily practice is feasible. However, costs and benefits are equally important. In this study, the internal hospital costs of a PMCT were equal to clinical CT imaging of four body regions. The cost of PMS was also equal to CT imaging of four body regions, independent of the number of biopsies that were taken.

In this prospective study, PMCT and PMS were implemented as an additional examination, not as a replacement of autopsy. The autopsy rate remained fairly unchanged during the study period and decreased only after PMCT and PMS were no longer available. It is important to pursue a postmortem examination with all available modalities as every modality has its strengths and weaknesses. More comprehensive imaging and more biopsies will increase the total yield of diagnoses and, therefore, add to the completeness of the postmortem examination, as was shown by Blokker *et al*.[41] However, this comprehensive method consisted of PMMR, PMCT and PMS with an average

Take home messages

- Despite the need for a correct cause of death and the known discrepancies between the clinical cause of death and the cause of death according to the autopsy, the number of clinical autopsies is declining worldwide.
- Postmortem CT (PMCT) and postmortem sampling (PMS) were introduced in the context of a prospective study to expand the current single-disciplinary examination (traditional autopsy) to a multidisciplinary examination.
- The introduction of additional postmortem examinations at the Department of Internal Medicine led to a statistically significant increase of the postmortem examination rate, and a decrease in the autopsy rate was only observed after the study period.
- Implementation of PMCT and PMS was feasible in daily practice.

of 16 biopsies, which resulted in a mean procedure time of 6.28 hours.[41] It is more likely that such a method will interfere with the daily workflow, as opposed to the method presented in the Materials and methods section, which took 23 min for PMCT in combination with PMS. Similarly, additional techniques such as angiography and lung ventilation pose as interesting new fields for future research, but may also affect the feasibility in a similar manner.[42–45]

In conclusion, our study shows that the implementation of a multidisciplinary postmortem examination does not adversely affect the autopsy rate while increasing the postmortem examination rate. Additionally, PMCT and PMS were feasible in daily practice.

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Contributors FCHB, CM, RJMWR, BGHL and PAMH carried out the implementation. All authors were consulted for conceptualising of the study design. MJL and MGM were responsible for the data acquisition. MGM performed the data analysis and was responsible for writing the manuscript. All authors were involved in the final approval of the submitted version.

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