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Daily application of post mortem computed tomography digital autopsy in a public mortuary

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Abstract

The digital autopsy has gained increasing attention in the past decade as post mortem computed tomography has become more widely available. Whether conducted with or without radiographic contrast, digital autopsies have been shown to be a valuable adjunct to invasive examinations in the investigation of natural and unnatural deaths. It has the potential to reduce the number of full invasive autopsies performed, allowing for more targeted limited invasive examinations. In certain deaths, the digital autopsy may obviate the need for an invasive examination entirely. This article considers the daily use of post mortem computed tomography in routine coronial autopsy practice in a busy public mortuary in England. The integration of the digital autopsy in to the investigation of natural deaths (including decomposing and embalmed bodies) is first considered before dealing with commonly encountered unnatural deaths due to surgery, industrial disease, trauma, drug overdose and suicides.

Key Words

Autopsy, Necropsy, Digital autopsy, PMCT

Introduction

In England and Wales, adults undergo autopsies for three broad reasons: the death is of interest to the Coroner but is not thought to be due to a crime (so-called Coroner's autopsies); the death is of interest to the police and the Coroner and may be due to a crime (so-called forensic autopsies); or the death is not of interest to the police or Coroner but the attending clinician has obtained consent for an autopsy from the relatives of the deceased (so-called hospital autopsy). Coroner's autopsies now comprise the largest group and form the focus of this article, whilst hospital autopsies have become extremely rare.[1 2]

Post Mortem Computed Tomography (PMCT) has been used sporadically in autopsy practice for the last 30 years.[3] Over the last 15 years technological advances, an increasing evidence base for the accuracy of PMCT, a shortage of autopsy pathologists and religious/cultural attitudes towards the invasive autopsy have resulted in PMCT being widely, but not universally, available around the world.[4-6] The MedicoLegal Centre in Sheffield, UK, first gained access to PMCT in 2013, and all adults coming to coronial autopsy since October 2017 have a PMCT as part of the internal investigation (except for those few patients whose bodies are too large (more than 200 kg) to enter the scanner).

It is generally recommended that PMCT should be undertaken once the pathologist has reviewed the clinical history/information regarding the circumstances leading to death and performed an external examination of the deceased.[5] The PMCT should be reported by a specially trained radiologist or a pathologist specially trained in the

interpretation of post mortem imaging.[5] Once the results of the PMCT are known the pathologist can then determine whether an invasive examination is required, and whether or not this can be limited to one or more body cavities. Due to constraints imposed by working practices, the procedure in our mortuary is somewhat different.[7] All adults coming to coronial autopsy have a PMCT which is reported by a consultant radiologist. Once the PMCT report is available, the pathologist reviews the available medical history and PMCT report at the same time, performs an external examination and then determines whether an invasive examination is required.

Autopsy practice is evolving. In the past, a full invasive examination coupled with extensive sampling for histology was by necessity the norm, as there were no other modalities of investigation available. With the advent of readily-available PMCT, our approach has changed from that of the traditional pathology approach to one that more closely mirrors a clinical approach used to diagnose patients in life. We consider the clinical history, examine the patient externally, review the PMCT report and synthesise that information in order to determine whether a cause of death can be issued, or whether some degree of invasive examination is required. Overall, we have found PMCT to be a useful adjunct to the invasive autopsy examination. Learning how to navigate this process, and determining when to perform invasive examinations has been challenging. Our learning curve was initially steep as we learnt how and when we could trust this imaging modality for visualising the internal organs. The combination of regular discussion of cases between pathologists coupled with audit comparing the findings of PMCT with invasive autopsy examinations[7] was crucial to our developing confidence in the use of PMCT.

One of the most challenging aspects of integrating PMCT into autopsy practice has been to determine which bodies need to be opened and the extent of the invasive examination that is required. Although the pathologists in our centre have different thresholds for when to open a body, the determining factor seems to be, in general, whether they consider that the combination of history, external examination and PMCT has provided them with sufficient information and evidence to answer the questions being posed by the Coroner and/or relatives and whether they consider that they will be able to defend their decision and cause of death if questioned in court. In addition, whilst a cause of death may be evident from the PMCT, it may, in some instances, be necessary to open the body to collect samples to support or refute future litigation, for example, when investigating the possibility that death was due to an industrial lung disease. Moreover a tissue sample or a microinvasive autopsy may be required to exclude other pathology, i.e., a cardiac cause when another cause of death is given but there was sufficient clinical history to prompt cardiac investigation (congenital heart pathology, etc).

This article aims to consider how PMCT can be utilised in modern routine general coronial autopsy practice in the investigation of deaths within the various organ systems before considering its utility in decomposing and embalmed bodies, post-operative deaths, deaths due to trauma, deaths due to drug use and suicides.

Using PMCT to investigate natural and unnatural deaths by organ system

Natural deaths may be due to a wide variety of causes mainly reflecting cardiac and/or respiratory diseases, localised and systemic infections, catastrophic vascular events (stroke, aneurysm rupture, etc.), disseminated malignancies and various causes of organ failure. The medical literature suggests that in the context of hospital autopsies, PMCT may identify the immediate cause of death in 70% of cases with accuracy superior to that of the clinical diagnosis.[8-10] It has therefore been suggested that PMCT may be used as an alternative approach to the conventional invasive autopsy examination in the investigation of deaths occurring due to presumed natural causes.[8]

High accuracy levels may be achieved in causes of death such as cardiac tamponade, haemorrhage, respiratory pathologies including chest infection and neoplasms. Discordance has been observed in those causes of death leading to liver failure, renal failure and multiple organ failure.[11 12]

Deaths due to cardiovascular causes

Ischaemic heart disease remains one of the commonest causes of death encountered at coronial autopsies in the UK. In the absence of post mortem coronary angiography, we use the degree of coronary artery calcification as measured at PMCT using the Agatston method[13] as a surrogate marker of severe coronary artery stenosis. We regard an Agatston score of 400 or more as indicating that a significant (i.e. life-threatening) coronary artery stenosis is likely to be present. In the absence of indications from the clinical history that death might be

due to another cause, and in the absence of other causes of death being evident on PMCT, we would regard this as being sufficient to indicate that death was (on the balance of probabilities) due to ischaemic heart disease. A previous history of ischaemic heart disease, or of risk factors such as hypertension, hypercholesterolaemia, etc, is helpful but not essential as sudden death may be the first manifestation of coronary artery atherosclerosis.

PMCT reaches higher levels of accuracy with the use of radiographic contrast compared with non-contrast PMCT alone.[12] However, even with the use of non-contrast-enhanced PMCT, a higher level of consistency is claimed between levels of confidence and accuracy of cause of death categorisation compared with conventional autopsy alone.[12] We accept that our method will not distinguish between coronary artery atherosclerosis, coronary artery dissection or coronary artery thrombosis and that sensitivity and specificity may be improved where PMCT with angiography is available. Where PMCT yields an Agatston score of less than 400 and no cause of death is evident, we tend to proceed to a limited invasive examination of the thoracic organs to complement this investigation. Very often this yields either severely stenosed but non-calcified coronary arteries or a pulmonary thromboembolus.

Pulmonary thromboembolism comprises a diagnostic pitfall for a PMCT and is often not diagnosed. In cases where no other cause of death is present and a possible pulmonary embolism is suspected a limited to the chest organs conventional autopsy is indicated.

It has been our experience that PMCT is not able to reliably diagnose cardiomyopathies. We have commonly encountered instances where PMCT indicates that the heart size is normal but invasive examination reveals marked cardiomegaly. Similarly we have encountered deaths where PMCT indicates that there is cardiomegaly but where the heart size and weight is normal. Consequently we do not rely on PMCT to determine the presence of cardiomegaly or cardiomyopathy. Where such conditions are suspected, a limited invasive examination of the thoracic organs, coupled with wider sampling as per Royal College of Pathologists guidelines is undertaken.

Haemopericardium is a frequent autopsy observation. It originates either from a vascular (typically aortic) rupture or from a ruptured transmural myocardial infarct. Both of these events result in bleeding into the pericardial sac. The underlying cause of the haemopericardium should be identified and this may require a conventional autopsy examination if the PMCT is equivocal, albeit one limited to the mediastinum.[14 15] In our experience, where there is an aortic dissection this is almost always evident on PMCT, even without contrast. Where a dissection is not seen but a haemopericardium and a haemothorax is visualised by PMCT this is, in the absence of a history of chest trauma, likely due to an aortic dissection. Consequently it is now generally our practice to often ascribe the cause of a haemopericardium to an aortic dissection if a dissection is revealed by PMCT or if there is a combined haemopericardium and haemothorax, and to a ruptured acute myocardial infarct if no aortic dissection is seen. The clinical history may be also prove valuable in this exercise.[16] Although their study is limited to a small number of cases, Filograna *et al*.[16] suggest that the use of PMCT is superior to the clinical

diagnosis of pericardial tamponade secondary to haemopericardium and when combined with the clinical history it reaches a high degree of accuracy.

PMCT without angiography may demonstrate calcific valvular heart disease but does not indicate the severity of the disease. It also does not demonstrate conditions such as infective endocarditis. Where a diagnosis of severe cardiac valvular stenosis or regurgitation has been confirmed by investigations in life, the PMCT finding of calcified valve leaflets may be sufficient to avoid invasive examination or limit it to the organs of the thorax.

Ruptured abdominal aortic aneurysm is readily identified by PMCT even in the absence of angiography and we regard this as sufficient to diagnose the cause of death without undertaking an invasive examination. In cases where there are concerns that aortic rupture may be the consequence of an inherited connective tissue disease or an infection, an invasive autopsy limited to the abdomen allows appropriate tissue samples to be collected.

Certain common cardiovascular causes of death such as pulmonary thromboembolism, acute myocardial infarct and other diseases causing cardiac failure may be difficult to identify using PMCT without angiography.[10 11 17] Whilst left ventricular aneurysms may be identified by PMCT, especially if calcified, acute myocardial infarcts attributed to soft coronary artery atheroma or a thrombus are not seen. Consequently, in such deaths a clear diagnosis of the cause of death may only be obtained using a conventional invasive autopsy.

Deaths due to respiratory causes

Deaths due to airways obstruction, for example due to an obstructing cancer or an inhaled foreign body, are rare in our practice. When combined with a clear clinical history, PMCT findings may demonstrate the obstruction and obviate the need for an invasive examination. We find little value in determining by dissection the exact nature of the obstructing food bolus PMCT can help to identify causes of the food aspiration, such as stroke, and samples can be collected percutaneously to determine the presence or absence of intoxicants. Not withstanding the above, there might be cases where airways obstruction by an inhaled food bolus may be secondary to a cardiac arrest. The latter may require a limited invasive examination to the chest depending on the circumstances.

Sohail *et al*.[11] found that PMCT is as effective as conventional autopsy when it comes to the diagnosis of natural causes of death such as chest infections. There are, however, pitfalls and difficulties in PMCT interpretation of the lungs. For example, pulmonary oedema of cardiac or non-cardiac origin is a frequent feature in post mortem imaging.[17] Pulmonary hydrostatic oedema may also occur secondary to an increase in vascular permeability due to drugs or transfusion reaction, water aspiration, trauma of central nervous system, diffuse alveolar damage secondary to infections, sepsis or massive fat embolism. These conditions should be considered within the clinical context and a careful approach is required when a differential diagnosis is given. Post mortem redistribution of gastric contents into the airways and lungs is common and is commonly misinterpreted on PMCT as aspiration

pneumonia. Aspiration pneumonia therefore remains a diagnosis that requires histopathological confirmation. Pulmonary oedema and hypostasis may be misinterpreted as lobar or bronchopneumonia. The pathologist must always consider the PMCT findings critically within the context of the clinical history.

We regularly receive requests to perform autopsy examinations to exclude or confirm the presence of an industrial disease (mostly lung disease) in our practice. Most commonly, these relate to possible asbestos induced diseases: pleural plaques, pulmonary fibrosis, lung cancers and malignant mesotheliomas. Concerns regarding possible coal-mining industrial lung disease, silicosis and other non-pulmonary industrial diseases are far less frequent. We have found PMCT to have utility in allowing an invasive examination to be limited. The pathologists routinely perform a limited invasive examination of the organs of the thorax in order to obtain samples for histopathological examination and, where indicated, mineral fibre or metal analyses. Invasive examination of the brain or other internal organs can be avoided, unless PMCT indicates that the cause of death lies within these organs.

In patients with lung masses revealed at PMCT, we consider whether invasive autopsy is indicated on a case-by-case basis after reviewing the PMCT in the context of the clinical history. Where a biopsy-proven diagnosis has been made in life, and where there are no concerns of possible industrial lung disease, there may be no need to undertake an invasive examination. Where the diagnosis has not been confirmed in life, we consider conducting either an invasive examination limited to the thorax (or hemithorax) to allow specimen collection for histopathological and/or

microbiological examination. Even this may not be required if a definitive alternate cause of death, such as a ruptured abdominal aortic aneurysm, is revealed by PMCT.

Deaths due to gastrointestinal tract and hepatobiliary causes

Deaths due to gastrointestinal tract and/or hepatobiliary pathology are uncommon. In patients with a perforated peptic ulcer, PMCT may reveal gas and free fluid in the upper abdomen, but typically the site of the perforation is not visualised. An invasive examination limited to opening the abdomen and examining the organs in situ may be sufficient to confirm the cause of death and to exclude other causes of gastric perforation such as gastromalacia.

Gastrointestinal tract cancers may be visualised on PMCT, particularly when they cause an obstruction but a definitive diagnosis is not always possible necessitating a limited invasive examination to differentiate, for example, between neoplasms and a benign ulcer/stricture. Where the PMCT raises the possibility of a malignancy in the gastrointestinal tract that may be of relevance to the cause of death, invasive examination can be limited to that body cavity. It may be possible to identity the cancer and collect tissue samples for histopathological examination without needing to eviscerate any organs.

We have found that PMCT is useful in suggesting a midgut infarct, when present, but is not infallible in making or refuting the diagnosis. Where bowel infarction is

suspected, this and the underlying pathology can be readily confirmed or excluded by opening the abdominal cavity and carefully inspecting the bowels and mesenteric tissues. Where no infarct is found, there may be no need to proceed with further invasive evisceration and examination. If an infarct is present, causes such as peritoneal bands, hernias and adhesions can be identified without evisceration. Where no cause is evident, evisceration of the organs of the torso can be undertaken to allow thrombo/embolic disease, atheromatous disease and vasculitis to be detected.

Fatty liver disease and cirrhosis of the liver may be identified on non-contrast PMCT. Where there is a known history of a particular risk factor, for example, alcoholism, there may be no need to investigate further. Samples for toxicology, histopathology and microbiology (for example, to exclude spontaneous bacterial peritonitis) can all be collected percutaneously or via a single incision to the abdominal wall. Small hepatocellular carcinomas may be missed, but the liver can be eviscerated through a subcostal incision for examination or limited tissue sampling if required.

Acute pancreatitis is readily appreciated on PMCT. The cause of acute pancreatitis may be evident in the clinical history (for example, a history of alcoholism or endoscopic retrograde cholangiopancreatography) or on the PMCT (for example, gallstones or an obstructing neoplasm). Where doubt regarding the underlying cause exists, an invasive examination limited to the abdominal cavity can be undertaken. Chronic pancreatitis is evident on PMCT as calcification and fibrosis of the pancreas.

Biliary sepsis is generally not evident on PMCT, but underlying causes such as gallstones, and sequelae such as hepatic abscesses can be detected. In general, when investigating a death that may be due to sepsis, the value of PMCT lies in excluding likely sites of origin, allowing the invasive examination and sample collection to be more targeted.

Deaths due to genitourinary causes

Deaths due to genitourinary causes are uncommon in our practise and generally centre around obstructive uropathies and urosepsis. Urinary tract obstructions such as prostate enlargement or urinary tract calculi, plus evidence of obstruction such as hydronephrosis and hydroureter can be identified, allowing any invasive examination to be limited to the abdominal cavity and pelvis.

Adult polycystic kidney disease and renal tumours are uncommonly encountered in our practice but can be identified by PMCT. Invasive autopsy can be targeted to the abdomen and pelvis to allow samples to be collected for histopathological examination. Our experience has been that PMCT is less able to detect bladder tumours.

Deaths due to endocrine causes

Deaths due to endocrine diseases are rare and this is reflected in our practice. PMCT may identify neoplasms in the endocrine organs, helping to target a limited

invasive autopsy. Given the possibility of multiple endocrine neoplasia syndromes, in such instances an invasive examination of the organs of the neck and torso may be required to collect samples for histopathological examination. Adrenal adenomas and metastases to the adrenals may be reliably identified by PMCT. In the case of metastatic disease, PMCT may help target any invasive examination to the site of the primary neoplasm. Similarly, adrenal haemorrhage, which may point to (particularly meningococcal) sepsis can be identified, allowing the invasive examination to be planned.

Deaths due to musculoskeletal causes

Deaths due to musculoskeletal disease are typically due to major trauma and these are considered later. The general utility of PMCT for the examination of this body system lies in the improved detection of bony resuscitation injuries, occult fractures, bony metastases and other bone pathologies such as osteoporosis and bony cysts that are not readily detected by conventional invasive examination. Sohail *et al.*[11] found that PMCT is more effective in identifying vertebral fractures and/or excluding trauma in the spine.

Deaths due to central nervous system causes

PMCT is helpful in identifying intracranial causes of death. Recent and old cerebral infarcts and cerebral haemorrhages can be readily identified, and in such instances PMCT can provide sufficient information to determine the cause of death. If there is

concern regarding the possibility of underlying diseases such as cerebral amyloid angiopathy, an invasive examination limited to the cranial cavity can be undertaken.

Whilst PMCT identifies skull fractures and subdural haematomas, when used without angiography it is less valuable in identifying subarachnoid haemorrhages and their underlying causes. PMCT artefacts may mimic subarachnoid haemorrhage and, in the absence of an intracerebral haemorrhage, an invasive examination limited to the cranial cavity is recommended to confirm the presence of subarachnoid haemorrhage and to identify its cause.

PMCT is not helpful in identifying deaths due to meningitis, encephalitis or sudden unexpected death in epilepsy, but may help to exclude other causes of death. Where there is a suspicion of these diagnoses, an invasive examination, which may be limited to the contents of the cranial cavity, is recommended.

Decomposing and embalmed bodies

Many pathologists find the autopsy examination of decomposing bodies to be unpleasant and unrewarding, rarely yielding a cause of death. Some pathologists in training find the experience so unpleasant that they are dissuaded from including autopsies in their future practice. Nevertheless, the careful examination of a decomposed body may yield useful information and a cause of death can usually be identified. Putrefactive decomposition gradually destroys the body as it progresses, and as such these bodies present a challenge to the pathologist.[18]

Changes due to putrefaction that are evident radiologically develop rapidly after death, with gas formation in the heart, vessels, hepatic parenchyma and body cavities. PMCT is sensitive in detecting these changes, but careful interpretation of the imaging is required to avoid diagnostic pitfalls.[18] We find that PMCT has utility as an adjunct in the examination of decomposing bodies and that there are instances where it allows an invasive examination to be dispensed with. Cartocci *et al.* have suggested that the benefit of PMCT in these cases lies in the detection of putrefactive gas,[18] but we disagree and consider this to be of no benefit. Rather, we consider that PMCT is helpful in identifying foreign bodies[19] such as pacemakers or other implanted devices, suggesting cardiac disease, and also plays a role in body identification. It also assists in limiting the scope of an invasive examination. Putrefactive dissolution of the brain removes the need to open the calvarium. Examination of semiliquid brain tissue does not permit macroscopic or microscopic diagnosis and does not contribute meaningfully to the autopsy. Similarly, if PMCT reveals that no organs are discernible within a body cavity there is likely little to be gained by opening the chest or abdominal cavity. Causes of death such as ischaemic heart disease (identified as heavily calcified coronary arteries), ruptured abdominal aortic aneurysm (identified by the presence of retroperitoneal blood coupled with a calcified aneurysm) and lobar pneumonia (with high radiological density) may still be identified on PMCT even when putrefaction is considerable.

In our practice, embalmed bodies are encountered where death has occurred overseas and the body has been repatriated for a funeral. Commonly, an invasive

autopsy has been performed prior to repatriation. The findings of the first autopsy examination are rarely known. These embalmed bodies pose a significant challenge. There is often little or no history of the events leading to death. Previous autopsy examination results in marked distortion of the internal organs, which have generally (but not always) been removed from their anatomical locations. The heart and/or other internal organs may be variably absent. Assessment of haemothorax, pneumothorax, pleural adhesions, pleural effusions and ascites are impossible. The collection of samples for microbiological examination is precluded by contamination with the gut microbiome and embalming materials. Embalming typically severely compromises the collection of samples for immunology and toxicology but may preserve tissues for histopathological examination. In such deaths is it is not uncommon for the autopsy examination performed in the UK to result in an unascertained cause of death. PMCT may yet still be a useful adjunct, as it may identify occult traumatic injuries, demonstrate what organs remain in the body and demonstrate where they are located, allowing the pathologist to plan an approach to the examination. If the brain has not been eviscerated, PMCT may still reveal the cause of death if due to a haemorrhagic stroke or brain tumour.

Post-operative deaths

Post-operative deaths refer to those that occur within 30 days of an operation, irrespective of the nature of the surgery, the anaesthetic and whether death was due to the diagnostic or therapeutic procedure. World-wide, post-operative deaths together form one of the commonest causes of death. Guidance on autopsy procedures for such deaths has recently been published by The Royal College of

Pathologists (London)[20] and in this journal.[21] Post-operative deaths merit careful scrutiny. Not only will the relevant medico-legal authority and relatives have an interest; the results of the autopsy examination will be of interest to the surgeons, anaesthetists, physicians, nursing and other staff who were involved in the care of the patient.

To date there have been few studies that have specifically focused on the use of PMCT in the investigation of post-operative deaths. There is, however, emerging evidence that it is a valuable adjunct to the conventional autopsy. When coupled with a careful review of the clinical history, a thorough external examination and angiography, PMCT may reveal sources of bleeding, vascular stenoses, mis-placement of drains and mis-placement of transcatheter aortic valve replacements.[21] [22] PMCT can be combined with minimally invasive techniques to allow the collection of samples for microbiology and toxicology if required.[4] [23] [24] It should be remembered that pulmonary thromboembolism is a not-uncommon cause of death in the post-operative period, and that PMCT without angiography is significantly worse than invasive autopsy in detecting them.[25]

The authors have found PMCT to be a valuable tool that frequently allows the invasive autopsy to be limited to the operative site. At present, we recommend that the operative site, particularly any anastomoses, should always be visualised directly. This also permits sampling for histopathological and, where relevant, microbiological examination. The need for wider examination, for example of the

entire torso, by conventional invasive means should be determined on a case-by-case basis after careful review of the clinical history and PMCT findings.

Deaths due to trauma

Deaths due to major trauma are regularly encountered by pathologists performing coronial autopsies and trauma is the leading cause of death in young adults.[26] Such deaths may be accidental, suicidal or homicidal, but here we will confine our attention to accidents and suicides. These deaths include road traffic deaths (drivers, passengers, pedestrians), rail deaths and falls from a height. Death may be due to significant head trauma, disruption of major blood vessels by deceleration injuries (for example, laceration or transection of the aorta), ruptured internal organs (for example, lacerated heart, liver, spleen), haemorrhage from multiple fractures or a combination of two or more of these mechanisms. Use of alcohol, illicit drug use and pre-existing co-morbidities may also contribute to the cause of death, and so sampling for toxicology is required. If there has been a period of survival, then infections and post-operative complications may also complicate the picture.

PMCT plays a valuable role in the investigation of traumatic deaths.[3 4 27] PMCT creates an observer-independent permanent record and can assist in planning any subsequent invasive examination.[4] Schmitt-Sody *et al.* found that PMCT performed within an hour of death following major trauma was able to identify the primary cause of death (as revealed by subsequent invasive autopsy) in 94.1% of cases.[26] PMCT was comparable to invasive autopsy in 52.9% of cases and superior to it in 5.8% of cases.[26] In the majority of those deaths where invasive autopsy was judged superior

to PMCT the PMCT revealed evidence of the cause of death (for example, haemothorax) but was unable to identify the underlying injury.[26] PMCT may be better in diagnosing skeletal[27] and soft tissue injuries than invasive examination.[3 26] It can certainly be used to replace the extremely invasive dissection of the limbs needed to demonstrate fractures in the long bones. PMCT is able to diagnose significant traumatic brain injuries, though small haemorrhages and contusions may be missed due to the resolution of PMCT imaging.[26] We have seen instances where a PMCT indicated that there was a subarachnoid haemorrhage but subsequent invasive examination revealed that no haemorrhage was present. This is a recognised PMCT artefact related to the composition of the tissues within the cranial cavity.

When investigating traumatic deaths, our practice is to conduct a careful external examination once the PMCT has been performed and reported by a radiologist. Invasive examination is mostly not required or is limited to the chest to examine for the presence of pre-existing cardiorespiratory disease. Samples for toxicology (blood, urine and vitreous humour) are obtained by needle puncture.[28] Recognising the possibility of erroneous PMCT diagnosis of subarachnoid haemorrhage, some of our colleagues would still routinely open the skull if this is the only abnormality demonstrated on PMCT.

Deaths due to illicit drug use

Deaths due to illicit drug use are common cases referred for medicolegal assessment in the UK, and their incidence is increasing. Such deaths are commonly accidental but suicides and homicides are encountered. PMCT of the deceased is

typically similarly unremarkable, usually revealing nothing more than pulmonary oedema, although some hypoxic changes may be evident in the brain. The absence of findings is beneficial to the pathologist, allowing a wide range of pathologies to be excluded. Unless there is cardiac disease (for example, as a result of repeated cocaine or amphetamine use) or liver disease due to viral hepatitis (for example, cirrhosis), invasive examination including histopathological examination is usually unrewarding and the diagnosis of the cause of death is based on the findings of a toxicological examination.

In our mortuary our practice when investigating such deaths varies between pathologists. Faced with a history of drug misuse, an unremarkable external examination and a negative PMCT, some colleagues will perform an invasive examination limited to the chest to allow the collection of samples of the major thoracic and abdominal organs for histological examination. (Samples of liver and kidney can be obtained through the diaphragm without the need to incise the skin of the abdomen. Samples of spleen or muscle can be similarly obtained for DNA extraction and analysis if required.) Samples for toxicology are collected percutaneously. Other colleagues do not perform an invasive autopsy examination in these circumstances, but rely on the history, external examination, PMCT and toxicology alone.

Rarely, these deaths are seen in individuals who have died whilst trafficking drugs within their person. Packets containing illicit drugs may be identified by PMCT within the body in drug traffickers. In such cases, the abdomen can be opened to allow the

drugs to be collected for toxicological examination and to be surrendered to the police.

Deaths due to suicide

The investigation of possible suicides is commonplace for the pathologist performing coronial autopsies in the UK. Common modes of suicide include hanging, therapeutic (or illicit) drug overdose, gas inhalation, falls from a height and other causes of major trauma (for example, jumping in front of a moving train or self-immolation). As with deaths due to major trauma and illicit drug use, these deaths may be suicidal, accidental or homicidal, but it is generally not possible to distinguish between these motivations at autopsy. Suicide notes and a past history of psychiatric illness are commonly absent but when present they act as a guide to the circumstances surrounding the death.

Hanging

Hanging is a popular suicide method globally and is the commonest means of suicide in the United Kingdom, continental Europe and most of Australasia. Death results from compression of the neck resulting in one or more of: occlusion of the vascular supply to and from the brain, vasovagal stimulation with reflex cardiac arrest, occlusion of the airway, cervical spinal cord injury or, in rare cases, decapitation. Accidental hanging, for example in auto-erotic asphyxiation “gone wrong” is uncommon and homicidal hanging is rare.

Typically there is a history that the deceased was found suspended or partially suspended by a ligature around the neck. It is not necessary for the body to be completely suspended above the ground. There may or may not be a history of mental illness or recent life events. External examination reveals a ligature mark, with or without an associated ligature, on the neck. Petechial haemorrhages may be present above the ligature but frequently are absent. The remainder of the external examination is typically unremarkable.

A rope around the neck with a corresponding ligature mark and no other injuries is a strong indication that death was, on balance of probability, due to hanging. Conventional wisdom holds that such deaths require a full invasive autopsy examination to exclude excessive bruising in the neck and hyoid/laryngeal fractures that might indicate a concealed manual strangulation homicide and to seek physical causes (for example, thyroiditis) of an altered mental state. Our anecdotal experience has been that such invasive examinations have an extremely low yield. After discussion with our coroner we have agreed that such deaths can be investigated using PMCT without the need for an invasive examination.

In deaths due to hanging the PMCT commonly reveals only non-specific findings, though fractures of the laryngeal cartilages, hyoid and cervical spine may be identified. Other recognised features of hanging, such as intimal tears in the carotid arteries and so-called Simon's bleedings (haemorrhages in the anterior spinal ligament over the lumbar vertebrae) that may be found on invasive examination are typically not seen with PMCT. We regard the presence of an appropriate ligature

mark around the neck, in the context of a relevant history regarding the discovery of the body (with or without a suicide note or psychiatric history), absence of other findings on external examination and a negative PMCT to be consistent with the diagnosis of hanging as the cause of death. We routinely collect samples of body fluids via percutaneous puncture for toxicological analysis in these cases.

Gas inhalation

Suicide due to the inhalation of a toxic or irrespirable gas is rarely encountered in our practice. Deaths due to suicidal carbon monoxide inhalation are now very rare, and in our practice most such suicides are due to the inhalation of helium (irrespirable but non-toxic) or hydrogen sulphide (toxic). Where death is due to inhalation of carbon monoxide, a characteristic cherry-red discolouration of hypostasis and the internal organs is seen. In deaths due to hydrogen sulphide inhalation there may be green discolouration of the tracheal mucosa and brain. Generally there are no other specific macroscopic findings. In all cases, PMCT would be expected to be negative beyond any pre-existing conditions such as coronary artery calcification, but has value in allowing an invasive examination to be limited to the chest, with specimen collection for histopathological and toxicological analysis.

Therapeutic drug overdose

As with deaths due to illicit drug use, external examination, PMCT and invasive autopsy examination typically are unremarkable. However, PMCT has value in excluding other causes of death. We have seen examples where PMCT has revealed radio-opaque tablet residues within the stomach, but this finding is rarely

present. PMCT has value in excluding other causes of death, allowing for an invasive examination limited to the thorax, with specimen collection for histopathological and toxicological examination.

Self-immolation

Suicide by self-immolation is only rarely encountered in our practice and is a rare suicidal method in the Western world. Most individuals who chose this method are found dead at the scene. Death occurs as a result of cutaneous burns and thermal injury to the airways and lungs and some would readily conclude the cause of death from the external examination findings and appearance of the lungs. External examination may reveal severe damage to the body. PMCT is a useful adjunct in the investigation of these deaths and has value in excluding the presence of natural pathology and projectiles within the body. A limited invasive examination of the chest, looking for burns and sooting in the large airways and the presence of soot within the lungs can then be undertaken to determine whether the deceased was alive when the fire started. Toxicology for alcohol, drugs and carboxyhaemoglobin is performed.

Conclusions

PMCT has become more widely available in the last decade, although it is not yet universally available in the UK or around the world. Incorporating such an investigative modality into autopsy practice comes with a steep learning curve, but PMCT has the potential to significantly reduce the need to perform full invasive autopsy examinations.

In certain natural and unnatural deaths, PMCT may mean that only a limited invasive autopsy examination is needed, or that the body need not to be opened at all. This is of importance to the families of the deceased who may be distressed by the thought of an invasive examination, and satisfies some faith groups. At a time of a global shortage of pathologists able and willing to engage in autopsy practice, it is also of benefit to pathologists trying to cope with workload pressures, as it permits focus of attention to those deaths that would most benefit from investigation by dissection.

PMCT is not without its pitfalls, and pathologists must consider the PMCT findings critically within the context of the available history of the events leading to death. Where there is incongruity between PMCT, the history, and external examination findings and/or where PMCT findings are equivocal or negative the conventional invasive autopsy examination remains the gold standard.

Practice Points

- Integrating PMCT into autopsy practice comes with a steep learning curve that is facilitated by frequent discussion of cases with colleagues and audit of PMCT findings versus findings of dissection.
- Post mortem computed tomography (PMCT) is a useful adjunct to the invasive examination undertaken in coronial autopsies and, on occasion, may replace invasive examination.

- PMCT is superior to invasive examination in the detection of bony injuries and foreign bodies.
- Invasive autopsy examination is superior to PMCT in the detection of pulmonary thromboemboli and soft tissue injuries.

Multiple Choice Questions

Q1. Which of the following is often not detected by PMCT?

A. Femoral neck fracture

B. Intracerebral haemorrhage

C. Lobar pneumonia

D. Pulmonary thromboembolus

E. Ruptured abdominal aortic aneurysm

Answer: D. Pulmonary thromboembolus

Q2. Which of the following is an advantage of using PMCT in the examination of decomposing bodies?

A. Detecting foreign bodies

B. Detecting maggots

C. Detecting Simon's bleedings

D. Detecting subcutaneous gas formation

E. Preventing the need for an external examination

Answer: A. Detecting foreign bodies

Q3. Which of the following findings may be detected by PMCT in the autopsy investigation of a hanging?

A. Carotid artery intimal tears

B. Laryngeal fractures

C. Petechial haemorrhages

D. Prinsloo-Gordon haemorrhages

E. Simon's bleedings

Answer: B – Laryngeal fractures

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