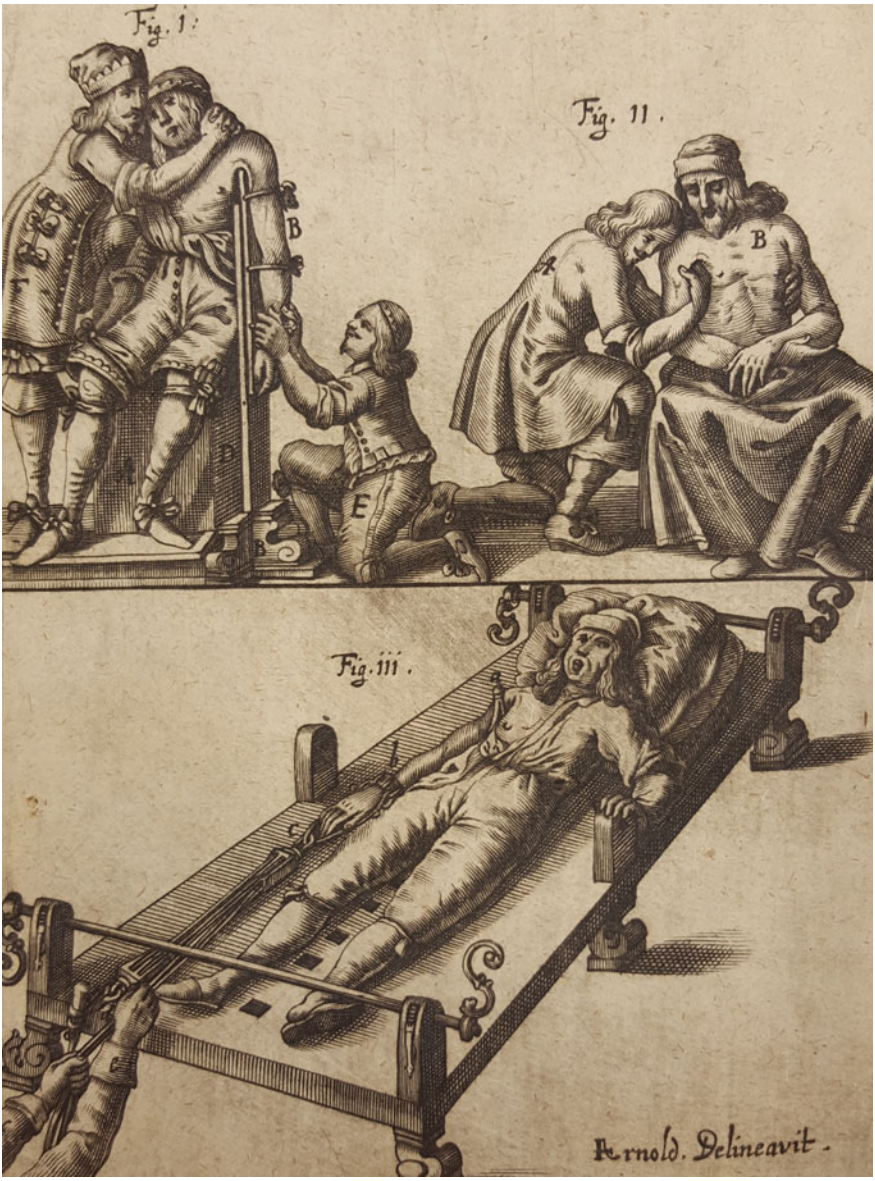

Schultes, Johann 1595–1645, Armamentarium Chirurgicum. Francofurti: sumptibus viduae Joan. Gerlini, Bibliop. Ulm. typis Joannis Gerlini, 1666

Chapter 38
Future Evidence in Forensic Imaging

Guy N. Rutty and Bruno Morgan

Abstract The idea that the traditional autopsy can no longer be considered the "gold standard" and should be combined with or replaced, if necessary, by the radiological study (post-mortem cross sectional imaging—PMCSI) is slowly gaining ground, despite the presence of opposing currents thought. To encourage the application of PMCSI it is necessary to concentrate resources in three key areas: (1) Research, to improve its incisiveness, reducing its costs and keeping in mind possible applications in clinical settings; (2) formation of a "necroradiologist", with guaranteed specialist skills in the interpretation of radiological images of cadavers; (3) achievement of the standard, to ensure the quality of the results and give credibility to a still vulnerable field exposed to possible errors with catastrophic repercussions on its development and on the judiciary system. In the near future PMCSI will become the praxis in the study of the cadaver; however, for this purpose, it is necessary to promote research and a hyper-specialized training, to ensure the quality of results.

38.1 Introduction

Since 1983 when Kranz et al. first reported the use of computed tomography (CT) as an adjunct to autopsy investigation [1], the world has been undergoing slow but steady change in autopsy practice. This change has not been accepted easily, which is often the case in medicine when the traditional and longstanding "gold standard" of practice is challenged. To put it bluntly; medicine does not like change.

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Historical examples of resistance to change in medicine include the introduction of post-surgery antibiotic therapy or the introduction of keyhole surgery. More recently within the field of imaging itself, the use of CT for routine cancer staging was at first met with resistance and yet today is standard practice. When you add the police and the legal system into the mix then there is a significant mountain to climb!

The sequences of the change process is well recognised and in relation to post-mortem cross sectional imaging can be seen to have occurred over the last 35 years. The world is slowly coming to terms with the fact that the traditional invasive autopsy can no longer be viewed as the gold standard for death investigation [2, 3]. We are, as yet, not there yet in terms of the process of transformation, but we are nearing the top of the curve, somewhere between integration of the new "status quo". However, even when a new "status quo" is reached, what is certain is that there will still be invasive autopsies, but with routine post-mortem cross sectional imaging as an integral part of the autopsy practice.

Looking back over the last 35 years it is easy to identify why change has been so long in coming. After all the invasive autopsy has been around for a very long time; in essence why fix something that isn't broken? The most often quoted driver for change is the perception of the publics' dislike and religious objection to the invasive autopsy. Although this is in part correct, in one of the few studies to consider this matter Rutty and Rutty identified that it was not necessarily the public who were the main objectors to the invasive autopsy, but rather the medical profession's perception of the publics' attitude, or even the medical profession's own objection [4]. This explains in part the loss of the so-called "hospital" (non medico-legal) autopsy from modern medical practice. Thus, if both the public and medicine itself do not like the concept of the invasive autopsy, why has change been so slow in coming?

In fairness to autopsy pathologists, attempts have been made previously to try and seek alternatives to the full invasive autopsy [5]; needle biopsy autopsies, laparoscopic autopsies, limited and molecular autopsies have all been reported. In the case of deaths due to natural causes, if one undertakes an external examination and then, based on the past medical history and clinical presentation, suggest on a "balance of probabilities" that the death was due to ischaemic heart disease, the commonest cause of natural death in the western world, one will be correct in approximately 70% of case [6, 7]. So it is not for a want of trying that change has been slow in coming.

An alternative situation is where we do not wish to reduce the number of autopsies as such, but seek an alternative in order to actually increase the number of post-mortem investigations, for example in regions where autopsies are rarely performed. A good example of this is in Japan where they have probably the lowest invasive autopsy rate in the developed world. By seeking a culturally acceptable alternative, in this case cross sectional post mortem imaging, they have been able to increase and enhance their death investigation processes, without the need for invasive autopsies.

The main obstacles to the development of post-mortem cross sectional imaging are much simpler to identify. First there is the imaging technology. It has taken years for the scanners and computational software to develop to enable the living, let alone the dead to be imaged in the ways we know today. Then there is the access to scanners. Those who have been lucky enough to place scanners into their mortuaries will reap the benefits of 24-h access to imaging technology [8]. There is then the imaging enhancements such as post-mortem computed tomography angiography (PMCTA), including targeted coronary angiography [9], and ventilated post-mortem computed tomography (VPMCT) [10], all of which have had to be developed to enable diagnostic imaging of the dead to be able to provide a cause of death without the need for an invasive autopsy. However, the main hurdle currently is cost; cost of the equipment/facility and cost of the service. Post-mortem cross sectional imaging is perceived to be more expensive than the traditional invasive autopsy at a time of continuing global recession.

In 1994 Donchin et al. [11] proposed that some cases of trauma related death could be examined by sole use of post-mortem computed tomography (PMCT), as it later became known [12]. They were correct, although they lacked a research derived evidence base to support this pioneering suggestion. The world also lacked an autopsy imaging specific educated workforce to deliver this proposal to the medico-legal world. Finally, the processes of quality assurance, audit and standards of practice, which are so important within the criminal justice world, were all lacking. It is these three key areas i.e. research, education and standards, rather than the how and why, which remain to be addressed to allow forensic imaging to truly become integrated globally into medico-legal autopsy practice.

38.2 What Is the Question?

When looking to the future use of post-mortem cross sectional imaging (PMCSI) one first has to ask oneself "*what is the question we are trying to answer in investigating this death*"? To start with, for any medico-legal investigation there are usually 4 questions to be answered; *who* the person was, *where*, *when* and by *what* means, which is usually shortened to the simple terms '*how*' did the person come by their death? You need to know what the question is, before knowing if and how PMSCI can assist in the investigation. The question should not be asked in isolation but rather as a series of sequential questions (triage) so that when one has answered all the questions, to the burden of proof required for the relevant legal enquiry, the investigation stops. If these are all answered prior to PMSCI (view and grant system) then imaging is not required. If the question(s) are answered by PMSCI then there is no need to proceed to invasive autopsy. If PMSCI does not or cannot answer the question(s) then limited or full invasive autopsy is required.

If the question is solely or partly '*who*', can PMCSI assist with or address this question on its own? Well, when combined with an external examination of the body, and personal possessions, the answer is yes, to a certain extent. PMCT has

been reported to be used for both odontology [13] and anthropology [14] identification, although further research is required to consider larger ethnic, age and gender data sets. As with the invasive autopsy PMCSI cannot tell where the person died. There are a number of publications considering the use of PMCSI for estimating a post-mortem interval but the field is too young for it to be considered more than a research interest currently [15]. As for '*how*', although there is a growing evidence base for its use in both natural and unnatural death, Morgan recently pointed out that there are large discrepancies currently between papers considering this question due to having different measures as to the required effect [16]. Due to changing context, different biases and inconsistent study comparators and end-points, it is very difficult to compare or apply published study findings to different areas of practice.

38.3 Research

When a new imaging technique is developed it needs to be tested to assess efficacy, effectiveness and efficiency. Efficacy and effectiveness are the extent to which the technique influences a favourable outcome, but are different. Efficacy is a technical term—does the test actually work, whereas effectiveness concerns the extent to which this 'efficacy' actually brings about the desired effect in the real world. For example an imaging test may accurately diagnose a condition, but this has no "effectiveness" if the diagnosis is untreatable or unimportant. So not only must the imaging test identify abnormalities and make the diagnosis, they must also displace or improve on other tests, contribute to service delivery and improve on outcomes for the whole population.

Not surprisingly, most diagnostic tests have good evidence for "efficacy" but often very little for their "effectiveness" [17]. Focusing purely on this technical performance can lead to failure to address the bigger picture and to incorrect assumptions about the new test. Therefore, when reviewing research or planning it, we must be a very clear about what effect we want. Put simply, if we ask the wrong question we will often get the wrong answer! [16].

These issues are particularly important in research into the relatively new discipline of post-mortem cross sectional imaging. Papers on technical performance abound with radically different conclusions. For example, we can argue that imaging is very poor at diagnosing the cause of natural death [18, 19] or actually very good [20].

These arguments cannot currently be satisfactorily resolved because the evidence suffers from a combination of changing context, different biases, and inconsistent study comparators and end-points. This makes it very difficult to compare and even apply study findings to work in different areas.

The key questions are wide-ranging but include:

- What type of death is it: natural or unnatural, single or multiple, witnessed or un-witnessed, paediatric?
- What is the main knowledge we want: Medical cause of death, mechanism of death or identification?
- Who wants to know it: The police, the local coroner, the family or the medical team?
- What is the tests place: To add information to traditional tests or replace them?

To answer these questions the evidence so far is nowhere near complete and all the author can do is read and critically evaluate the research.

Even when the question is similar the evidence can be unhelpful. Different study populations will have a different prevalence of different diseases. This pre-test probability will have a dramatic effect on the assessment of accuracy using the test. Many studies have different recruitment. For example, it is difficult to compare the results of excellent studies of hospital ITU deaths [21] compared with those from the community [22]. Likewise, large studies and systematic reviews may have a very heterogeneous population, including both natural and unnatural deaths [18, 23].

Another problem can be technical bias. The quality of CT scans available for Post-mortem imaging has improved over the last 20 years and this has almost certainly improved fracture detection and the development of angiography in the dead has changed the diagnosis of coronary artery and other vascular diseases [24, 25]. Old information may therefore not be good information and current research could easily become outmoded by technical advances.

Further research is therefore required to answer all these questions as technical performance/efficacy data needs to be more extensive and in different contexts. Only then can the more complex questions of effectiveness really be answered. Clearly at that point we can start to answer probably the most important question, efficiency or cost-effectiveness; is somebody prepared to pay for the test? Without the latter is is very unlikely that anybody is going to fund research at all.

There are also other potential research avenues. Instead of just looking at post-mortem imaging just to establish the "who, where, when and by what means", perhaps it is time to give something back. Medical research has all the same problems outlined above, but is compounded by the difficulty of research in living subjects due to the risk of harm or inconvenience to them. This is often resolved by clinical trials that are limited in how much investigative data is obtained per subject, or by moving into animal models. However, animal models are expensive and not universally accepted. They also often do not particularly resemble man, particularly the humble mouse. The post-mortem model therefore offers an opportunity to investigate clinical disease and investigate the tests we use in clinical disease in a proper human model, who has given their consent, either personally or via their next of kin. We have been pursuing this line of work in cardiology where there are many questions about grading the degree of coronary artery disease, not only in

investigating cause of death but also in the living in order to evaluate the significance of coronary artery stenosis using new techniques such as optical coherence tomography and measuring pressure difference across stenosis. The cadaver potentially provides a good research model to investigate these techniques in the presence of real disease [26, 27].

38.4 Education

In 2004 Rutty and Swift, recognising the need for specialist training within an emerging field of practice, introduced a new practitioner to the autopsy world; the "necroradiologist" i.e. a specialist in the interpretation of radiological images of the dead [28]. But who is this person? Are they a radiologist with expertise in cadaveric imaging, trained in the external examination of the dead or a pathologist with focused training in post-mortem cross sectional imaging sufficient to report under the guidance and governance of a radiologist? In fact both exist depending upon where one practices in the world and one can argue that the most efficient system is to bring both skill mixes together and for both to work together.

What is clear is that for all branches of medicine, post-mortem imaging is not part of core medical training and in practice takes the practitioner outside what is considered conventional practice. For each profession to work within the criminal justice world training and accreditation will be required to allow a court to consider that the person undertaking the role is suitably medico-legally qualified. It is thus not unreasonable to predict that at some point in the not so distant future optional sub-speciality training in PMSCI will be introduced into radiology and medico-legal autopsy speciality training.

In the mean time we have to do with what is available. Although continuous professional development courses are run in several countries of the world, with the exception of the postgraduate certificate course of Zurich, Switzerland [29] and the postgraduate certificate, diploma and MSC courses of Leicester, United Kingdom [30] no others, to the authors knowledge, have attempted to develop postgraduate University accredited courses in PMSCI for medico-legal practitioners. Ideally a minimal global standard should be developed, possibly through an organisation such as the International Society for Forensic Radiology and Imaging (ISFRI) based upon the experiences of Zurich and Leicester. This will be a complicated task due to the differences both in medical practice and judicial regulations for all the different countries in the world. However, core curriculum activities should be able to be developed to inform and assist those developing similar courses within their respective countries. From experience in developing the Leicester courses, there is a considerable amount of work yet to be done within this key area for PMSCI to develop further.

38.5 Standards

It is all well and good gaining access to a CT scanner and scanning your next homicide victim, but do your scanning protocols, personnel, reports, audit, management, continuity of evidence, image database etc. all come up to the criminal justice standards related to your country of practice? Are your staff security cleared to work with restricted or higher level of material? Do you require your scanner to be licensed by a national body for sampling tissue from the dead? In terms of your management systems do they meet ISO 17025. The point is that practitioners new to this area of practice may not be used to the strict requirements of criminal justice systems.

To date this is an area of practice that has been completely overlooked mainly because the emphasis has been on research rather than service provision. As PMSCI becomes more globally accepted as an adjunct or replacement to the invasive autopsy practitioners within their respective country *must* address the issues of quality of standards and audit of practice. It only takes one very public error within the criminal justice system for the courts to lose confidence in the science and practitioners involved in any branch of forensic work. Currently PMSCI is extremely vulnerable to errors of practice which could have catastrophic repercussions on its development and future use.

38.6 Future Autopsy Practice

Rutty J et al. predicted that in the near future PMCT will become the 'norm' for death investigation, not the invasive autopsy and advised that pathologists amongst others must be prepared for the change that is already upon us [3]. However, to achieve this we, as a global imaging community, must embrace collaborative research undertaken in a similar manner to clinical medical trials, accept the need for postgraduate sub-speciality training and embrace the concept of quality assurance and audit of practice. The emergence of ISFRI and the dedicated Journal of Forensic Radiology and Imaging will hopefully draw the post-mortem imaging community closer together and drive forward the last stages of change to take us into a new era of global post-mortem imaging of the dead.

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