**Introduction**

When someone dies, their body may be subject to a coronial inquest depending on the cause and circumstances of death. Such an inquest will commonly require a coronial autopsy, often including the use of medical imaging. Alternatively, a medical autopsy may be requested by pathologists or other professionals for research purposes.

Virtopsy is a medical-imaging based technique of post-mortem examination emerging in recent times as an adjunct to the conventional autopsy, but now beginning to take on a significance of its own. It comprises a variety of modern medical imaging techniques (foremost multi-slice CT) with a number of applications particularly in forensics. Post-mortem medical imaging is now performed at many sites throughout the developed world and at several Australian mortuary centres including the Victorian Institute of Forensic Medicine and Brisbane's John Tonge Centre. Virtopsy radically contrasts with conventional autopsy, such that in cases where virtopic techniques are employed, the most comprehensive examination is almost entirely non-invasive. During a virtopic examination, CT-guided biopsies (Fig 2.), artificial ventilation and contrast injection are the only times the deceased body needs be touched in the course of data collection. In addition to this, digital image storage and review enables virtopsies to be collaborated on by many different professionals in distant locations. This is in contrast with conventional autopsy wherein a limited number of professionals make important decisions within the bounds of a single, unrepeatable, open-body examination. With these differences in mind, the question is raised as to whether virtopsy may grow and supersede autopsy as the gold standard in post-mortem examination.

Besides the legal importance of accurate and accessible data from post-mortem examinations, other significant advantages may be gained from virtopsy's widespread use. Epidemiological studies rely heavily on post-mortem examination, and Scholing, et al. state that "All these (post-mortem based epidemiological) studies contain valuable information for prevention purposes but also serve as a feedback tool for possible improvements in trauma assessment." Unfortunately, the National Confidential Enquiry into Patient Outcomes and Death (NCEPOD) observed in a 2006 UK-based study that the rate of patient-consenting (medical) autopsy is sharply decreasing and this finding has been reinforced in recent times by Scholing, et al., Ayoub, et al., and Thayil, et al. This lack of patient consent is indicative of autopsy's waning popularity. This is, not conducive to ongoing research into improving medical treatment. There are two possible courses of action in remedying the downward slide in autopsy consent, and they can be summarised thus:

- Somehow make autopsy more acceptable to the public.
- Find a viable alternative method of post-mortem examination.

It has been postulated that virtopsy is an acceptable alternative in certain cases when autopsy is refused, such as when parents refuse following perinatal death, or when the deceased’s relatives do so for cultural/religious reasons Flach, et al. even go so far as to say...
that post-mortem radiological examination could hypothetically replace autopsy in future.

**Methods**

Pubmed searches were performed under the Medical Subject Heading (MeSH) “autopsy” with subsets of ethics, history, instrumentation, methods, statistics, supply and distribution and utilisation. This search was also performed with the truncation “virtop*”, finishing finally with a simple keyword search for “virtopsy”. Articles were limited to case-studies, meta-analyses and reviews within the last five years containing human (i.e. not animal) information.

**Findings**

From these sources were drawn the following key observations:

- Autopsy is considered the gold standard as it has been shown thus far to exceed virtopsy overall in sensitivity and specificity. It should be noted, however, that the studies performed are few with somewhat varying results insofar as virtopsy has shown up some of autopsies deficiencies, of which some examples are listed below.\(^1,2,5\)
- Virtopsy has significant ethical and practical advantages over autopsy. These are also stated below.
- The performance of virtopsy may be enhanced by improved radiological knowledge in the area, hence the term “necroradiology”\(^10,11,12\)

In reference to the second observation, the advantages may be summarised as follows:

- The task of hoisting an occupied body bag onto a scanning table and inserting biopsy needles is far less complicated than eviscerating individual organs for assessment, particularly in the case of a diseased or decaying cadaver.\(^9\)
- Modern medical imaging technology affords the forensic pathologist far more accurate and detailed data than the human eye, if interpreted accurately with expertise.
- Basic medical imaging is able to identify important details concerning the cadaver that a physical autopsy cannot without extreme difficulty, such as the location and number of foreign bodies,\(^6,12\) fine bony fractures\(^6,13\) and volumetric measurements of gas or fluid.\(^1,6,12\)
- The minimally invasive nature of virtopsy makes it more acceptable in cases where religious or ethical concerns arise.\(^6,7,9\)

**Table 1. Non-specific post-mortem radiological signs mimicking ante-mortem pathology**

<table>
<thead>
<tr>
<th>Radiographic appearance</th>
<th>Natural cause</th>
<th>Ante-mortem pathology/pathologies mimicked</th>
<th>Source(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss of differentiation between brain cortex and medulla; brain swelling</td>
<td>Post-mortem hypoxia causing brain oedema</td>
<td>Brain-death/severe stroke</td>
<td>(3)</td>
</tr>
<tr>
<td>Hyperdensity of posterior portion of sagittal sinus and cerebral veins</td>
<td>Lividity (blood sedimentation)</td>
<td>Cerebral venous sinus thrombosis</td>
<td>(3,10)</td>
</tr>
<tr>
<td>Gas bubbles in blood vessels, biliary system, and along organ borders. May be diffuse due to decay, also cf. Table 2</td>
<td>Bacterial putrefaction. Quick onset means there may be no external evidence of putrefaction</td>
<td>Air embolism, penetrating injury, infection</td>
<td>(3,10)</td>
</tr>
<tr>
<td>Localised ground-glass opacity in lungs</td>
<td>Internal livor mortis of lung</td>
<td>Aspiration, lung contusion (more diffuse appearance in true cases), pneumonia</td>
<td>(3,9)</td>
</tr>
<tr>
<td>Hyperdense aortic wall</td>
<td>Contraction of aortic wall with lividity</td>
<td>Atherosclerosis</td>
<td>(3)</td>
</tr>
<tr>
<td>Reduced aortic calibre, or “Vanishing aorta”</td>
<td>Relaxation of blood pressure. Note: may also indicate exsanguination if suspected (Christe et al., 2010, 219)</td>
<td>Exsanguination</td>
<td>(10)</td>
</tr>
<tr>
<td>Hyperdense intravascular clotting in pulmonary arteries</td>
<td>Lividity</td>
<td>Pulmonary thromboembolism</td>
<td>(10)</td>
</tr>
<tr>
<td>Distortion of soft-tissue in external structures e.g. eyes, nose, and genitalia, with areas of mixed radiopacity</td>
<td>Maggot infestation</td>
<td>Tumor, abscess, foreign body</td>
<td>(10)</td>
</tr>
</tbody>
</table>
Finally, virtopic findings can be reviewed and audited in an objective manner at any time by any professional via the use of a Picture Archiving and Communications System (PACS) and teleradiology. Traditional autopsy is an inherently subjective and one-off examination,5,6,9 and faces auditing difficulties.5

With this in mind, Bolliger, et al. acknowledge that the role of post-mortem imaging in forensic medicine is constantly growing12 an observation further supported by O’Donnell,1 et al.10

The advantages are heavily counterbalanced, however, by the final key finding above; if the demonstrated sensitivity and specificity of virtopsy continues to be seen as inferior to that of autopsy, it faces an uncertain future. This shortcoming is attributed to the interpreters of virtopic images by some authors.5,7,10

In the words of O’Donnell, et al.10 “…Post-mortem imaging is simply not the same as clinical imaging… Clinical radiologists with only occasional exposure to post-mortem cross-sectional imaging, even those with a background in forensic interpretation of plain radiographs, are at risk of misinterpreting findings if they rigorously apply the rules of clinical radiological analysis.”

It is postulated in response to this conjecture that radiological specialisation may be required.5,7,10 This is to be found in what is known as necroradiology or post-mortem radiology (Fig 3).

Discussion
The principal stumbling-block to a clinical radiologist faced with virtopic imaging is the myriad of post-mortem physiological processes occurring which may or may not be related to the cause of death. These necroradiological signs are broadly grouped into two categories: non-specific signs, caused by processes common to every deceased body; and specific signs which are indicative of a particular cause of death. A few examples from both categories are shown in Tables 1 and 2.

To make matters more confusing to the inexperienced radiologist, most necroradiological signs can mimic signs of unrelated pathology found in living patients (cf Tables 1 and 2).

These findings indicate the necessity of radiological specialisation when using virtopic techniques in post-mortem examination.

Conclusion
Virtopsy is a potentially desirable alternative to autopsy as it has a number of significant advantages. In addition, it is desirable that the incidence of post-mortem examinations should increase, as is not the case with autopsy in recent times. Professional development in the form of a new radiological sub-speciality, necroradiology, is needed if virtopsy is become viable, in that it may enable virtopsy’s sensitivity and specificity to rival or exceed that of autopsy. If this is shown to be the case in future, virtopsy may become the preferred method of post-mortem examination.7

References
2 National Confidential Enquiry into Patient Outcome and Death (NCEPOD, Great Britain.) The Coroner’s Autopsy: Do we deserve better? 2006.

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