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Virtopsy approach: Structured reporting versus free reporting for PMCT findings

Wolf Schweitzer*, Christine Bartsch, Thomas D. Ruder, Michael J. Thali

Institute of Legal Medicine, Universität Zürich, Zürich, Switzerland

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ABSTRACT

Introduction: While post mortem CT (PMCT) serves as increasingly wide-spread tool for pre-autopsy examination in forensic medicine, the scope and role of reporting should follow legal requirements as set out by law and landmark court decisions. We initially used free form reporting, but after a hyoid fracture was missed and not reported in a case of manual strangulation, and after a range of other less serious incidents, we switched to a structured reporting system. Methods and material: Twenty randomly chosen PMCT reports of each of the two types (free form, structured reporting containing 108 items) were checked for explicit reporting of absent or present findings of an arbitrary list of findings of forensic relevance. Results: Free form reports contained 13% to 75% of forensically relevant findings, depending on the specific finding that was checked. Structured reports did contain 100% of the items that were tested even though the system that we used would yield a "not checked" entry if left untouched by the user. Discussion: Unchecked or unreported data has the capacity to act as a liability rather than an asset given that no jurisdiction specifically requires court appointed experts to partially ignore data for possible later analysis and interpretation. Wasting time on irrelevant findings while missing crucial data is a real risk particularly when radiologists enter the field of forensic medicine. Structured reports then can remedy the problem through acting as a guideline. Even though this study has limitations as only two very different techniques were compared, considering structured reporting in a comprehensive fashion is strongly recommended both on study results and legal considerations.

1. Introduction

The core task of post-mortem examination of bodies is to provide a comprehensive account of all relevant findings. The resulting documentation serves as basis for expert opinions regarding manner and cause of death, as well as various reconstructive aspects. Also, forensic observations should be integrated into investigations at an optimal point in time [1]. This translates down to all examinations done as part of a forensic pathology examination of a dead body.

The role of post mortem computed tomography (PMCT) imaging is to document the body before autopsy [2] as that is a relatively destructive process that affects anatomical integrity or increases contamination across bodily compartments. So proper timing of dissection steps that are performed can be of essence. Ignoring PMCT findings may cause problems later in any given case.

When there are significant PMCT findings that have the capacity to alter the subsequent sequence or extent of the examination, then their verbal and written reporting is relevant even outside their consideration under the aspect of forensic relevance as to the hypotheses at hand. Also, initial examinations often cannot rely on authorities to forward reliable information at all. Much rather, case history, witness statements and circumstances may be absent, wrong or insufficient during the first hours and days of any given judiciary death examination. Analysis of PMCT data has to account for that – and just as the procedure for a medico-legal autopsy [3] has to cover all forensically relevant aspects, there is considerable burden of responsibility also for the expert that writes the PMCT report.

Laws concerning expert evidence take these responsibilities into account. Since medico-legal autopsies are performed under the auspices of the investigative authorities, all data are subject to laws pertaining to evidence.[1] With that, the presence of all of data gathered, as well as case relevant significant content of any data (including PMCT data with presence as well as absence of relevant findings) have to be explicitly reported. Just capturing and storing data is not legally sufficient in the medico-legal context.

* Corresponding author.
E-mail addresses: wolf.schweitzer@irm.uzh.ch (W. Schweitzer), christine.bartsch@irm.uzh.ch (C. Bartsch), thomas.ruder@irm.uzh.ch (T.D. Ruder), michael.thali@irm.uzh.ch (M.J. Thali).

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[1] SR 312.0 Swiss Criminal Procedure Code Art 6 "The criminal justice authorities shall investigate ex officio *all* the circumstances relevant to the assessment of the criminal act and the accused. They shall investigate the incriminating and exculpating circumstances *with equal care*." [Text highlighting by authors of this paper.]

Generally, protocols and reports are written by experts after they examined the evidence. As expert opinions are based on these, reports and protocols must be detailed and explicit and they must contain enough detail of both absence or presence of forensically relevant appearances to justify the opinions to be derived – otherwise, building a sound expert opinion on basis of these reports is not possible. As hypotheses and thus the requirement for further opinions may change in due course of a court trial, protocols and reports must be comprehensive.

In the USA, two court decisions had sustaining significant impact on expert evidence: *Daubert v. Merrell Dow Pharmaceuticals* [4], and *Kumho Tire Co. v. Carmichael* [5].

The *Daubert* decision requires scientific experts to explain why a particular scientific test that is applied in a specific case is scientific, and why it is applicable in any given particular case, regardless of the question whether that test had gained general acceptance throughout a particular scientific community. At the time, that was new as the prior *Frye* [6] decision had found it sufficient for admissibility of scientific evidence to show that a particular scientific test was generally accepted; conversely, if a test had not gained recognition within the scientific community, expert testimony regarding the results had been judged to be inadmissible under the *Frye* standards.

The *Kumho Tire* case adds another angle to expert testimony as the decision more specifically details how Rule 702[2] is to be interpreted: courts are explicitly granted the discretionary authority to determine the reliability of a particular method in a particular case by establishing whether the expert could reliably demonstrate a cause or effect or such based on the specifics of application of that method in that particular case [7]. So it is not enough to have judges appreciate the power of PMCT generally and as such, but a ruling of a minimally reliably applied PMCT method must rely on specific case based facts at hand – explicitly and in each and every case, based on the documents and findings provided then and there.

To leverage the technology of Virtopsy's most often used PMCT from a mere data gathering method to a serious tool in forensic investigation, PMCT analysis and subsequent written report must comprehensively reflect content of the data in as much as case specific and general forensic questions are concerned. And as the autopsy as assumed gold standard in forensic pathology has to also cover forensically relevant [8] features, so does the PMCT analysis and report. Furthermore, there must be accountability on behalf of the author of the report [9].

This is best achieved by having the expert sign off a complete and verbally explicit list of all details one is supposed to look at. Also, that is good practice in radiology [10].

PMCT reporting thus has to achieve three goals. Firstly, the report must cover specific case-relevant forensic questions at hand (e.g., the distance between the foot soles and a particular leg injury in a car pedestrian collision case). Secondly, all of the typical, usually ever-present forensic questions that stand second in line have to be covered (e.g., were there bullet fragments, or were there signs of strangulation). Thirdly, the pathologists need to be made aware of whether they should conduct a regular medico-legal autopsy of the body as it is, or do whether they may have to be careful about something specific. One of the particular strengths of pre-autopsy CT analysis is to be early in suspecting and identifying possible surprising or course-altering findings while not foregoing the specificity that autopsy validation has.

1.1. Current problem

Initially, all Virtopsy cases' routine PMCTs were reported using free form reporting [11]. The readers of PMCT were free in what they wanted to report, and how they wanted to formulate their written reports. There were a few incidents that had sparked our interest though; these included (but were not restricted to) the following two:

- In one instance, a hyoid fracture was overlooked on PMCT scan that was performed and read on a Friday afternoon. We were dealing with a possible homicide which only became apparent on the following Monday when autopsy disclosed neck injuries.
- In another instance, PMCT was only appreciated on small 3D reconstructions and some skeletal fractures were missed at first; after the first cut, the pathologist asked whether indeed the PMCT report was correct in stating absence of fractures, and the problems were addressed.

We introduced a comprehensive structured reporting system in 2012. Now, we compare the quality of structured and free form PMCT reports by checking whether they contain explicit information regarding a number of relevant forensic questions.

2. Method and material

Data analysis was performed retrospectively. Data was collected in accordance with our institute's policies, local ethical committee's opinion and laws pertaining to bio-medical research.

2.1. Selection of analyzed reports – free and structured

We randomly picked 20 cases from the time when we used free reporting for our PMCT data (group F), and 20 reports from the time period that had us use a structured reporting system (group S).

2.2. Key features evaluated for this study

We scored selected reports as to their quality. In order to do that, the presence of a range of explicit wordings (detailed below) was noted. Key feature choice was based on three assumptions: firstly, frequent signs of trauma should not be missed (tagged F, below). Secondly, rare occurrences of harder to detect but particularly relevant trauma should be reported (tagged R, see below). And thirdly, findings that have the capacity to alter the autopsy strategy should be reported (S). Reporting of absence or presence of pathology was considered equally important.

We noted, whether the reports explicitly mentioned the absence or presence of signs signaling the following:

- Hemorrhage into the abdominal and pleural cavity (F): Thoracal and, particularly, abdominal organs are particularly vulnerable to blunt force trauma because of the lax and compressible abdominal wall [12] and thus, they are frequently encountered in forensic pathology [].
- Subarachnoid hemorrhage (F): Head trauma with subarachnoid hemorrhage may cause serious pathophysiological disturbances [13] or death [14], and in instances of PMCT being used

[2] Federal Rules of Evidence – ARTICLE VII. OPINIONS AND EXPERT TESTIMONY – RULE 702. TESTIMONY BY EXPERT WITNESSES – A witness who is qualified as an expert by knowledge, skill, experience, training, or education may testify in the form of an opinion or otherwise if: (a) The expert's scientific, technical, or other specialized knowledge will help the trier of fact to understand the evidence or to determine a fact in issue; (b) the testimony is based on sufficient facts or data; (c) the testimony is the product of reliable principles and methods; and (d) the expert has reliably applied the principles and methods to the facts of the case. (As amended April 17, 2000, eff. December 1, 2000; April 26, 2011, eff. December 1, 2011.)

Table 1
Criteria included.

Diagnosis	Free reports, score	Structured reports, score
Skeletal fractures[a]	0.75 ± 0.44	1.00 ± 0.00
Body cavities[b]	0.13 ± 0.33	1.00 ± 0.00
Subarachnoid hemorrhage[c]	0.40 ± 0.50	1.00 ± 0.00
Neck structures[d]	0.37 ± 0.49	1.00 ± 0.00
Intravascular gas[e]	0.41 ± 0.43	1.00 ± 0.00
Overall score[f]	0.38 ± 0.24	1.00 ± 0.00
Case properties		
Path/Rad[g]	17/3	12/8
Board passed[h]	19/20	14/20
PMCT years experience[i]	4.0 ± 1.3	2.9 ± 1.5
Trauma/Non-trauma[j]	8/12	8/12

Wilcoxon $p < 0.02$.

[a] Explicit mention of head, spine, shoulder girdle, pelvis, extremities and skeletal structures and presence/absence of fractures.

[b] Explicit mention of pleural and abdominal cavities being with or without hemorrhage.

[c] Explicit mention of absence or presence of subarachnoid hemorrhage.

[d] Explicit mention of hyoid bone and thyroid cartilage.

[e] Explicit mention of intravascular gas being present or not in large vessels. Statistical differences.

[f] Wilcoxon $p < 0.001$.

[g] Fisher's Exact Test: ns.

[h] Fisher's Exact Test: $p < 0.05$.

[i] Wilcoxon $p < 0.04$.

[j] Chi-Square likelihood ratio: ns.

to decided for or against medicolegal autopsy, its mention in documentation is therefore important.

- Hyoid or thyroid cartilage fracture (R): Despite being relatively rare, injuries in the context of asphyxia particularly due to strangulation must not be missed [12].
- Skeletal fracture to bones of head, spine, shoulder girdle, pelvis, or extremities (F): Fractures are particularly common consequences of trauma in forensic pathology (see also discussion).
- Intravascular gas combined with short time of death estimate to suggest sepsis [15–18], possibly necessitating rapid microbiological blood sampling (S).

The criteria for scoring were as follows: each instance was awarded a score of 0 for absent and a score of 1 for present explicit mention of each item listed above (see Table 1). Overall quality of each report was obtained by averaging these. Thus, a report that covered all angles yielded a score of 1, whereas a less optimal report might yield 0.8. So a completely uninformative report with regard to the items listed above would, theoretically, achieve a 0 score.

2.3. Technical description of free reports

Free reports ranged from 1 to 3 pages in length, usually containing a disclaimer: "This is a preliminary CT report. The data has not been analyzed to cover every possible question that might arise later. If further or more detailed analysis becomes necessary, let us know and submit your questions. Determination as to cause and manner of death will be given in the final report of the pathologist."

2.4. Technical description of structured report

Structured reports contained 4 pages in length. An overview over the structured report system that we introduced is given in Fig. 1 (see also figure caption for description). The user is presented with both a structured list (with typed out findings) and an empty text field (for free documentation). By default, all report items will yield a "not checked" text when left untouched. So the user will first have to actively alter the default by entering their findings for all items they do not wish to remain "not checked", even for an "inconspicuous" or "normal" description. The web-page based form is then submitted by the user, and a structured report is generated by the system.

The data entry system contains a number of 108 single items to be checked. Of these 108 items, 56 (51%) pertain to the musculoskeletal system, 34 (31%) pertain to the chest, 13 (12%) cover head and brain, foreign material and air accumulations occur in 5 items (5%) and superficial structures are to be described under 2 items (2%).

Each item contains both a drop down list and a free text entry field. As they are filled in by the user using a web browser, relatively fast navigation across the entry fields is possible using keyboard commands (such as using the tabulator, space or arrow keys). The generated structured report contains a text that contains highlighted parts (by adding red color, underline typesetting and a few stars at the end); these highlighted parts refer to text entries or drop down list selections that represent deviations from the normal, from the intact, from the not injured. So-called positive findings thus are easy to find throughout the comprehensive final report.

The report that is generated also contains delimiters; these are usually diacritical text elements (such as the colon character ":") used to separate text strings so they can be separated for semi-automatic or automatic database import.

In a current version of our experimental reporting tool, we simultaneously export structured report data to a delimiter-separated data file upon generation of the report.

2.5. Software

Statistical evaluation was performed using JMP (SAS Institute, Cary, NC, USA). The technical basis for data entry and report generation was hand coded using PHP (Hypertext Preprocessor, The PHP Group, http://www.php.net) running on Apache 2 (The Apache Software Foundation, http://www.apache.org/).

3. Results

Along all five criteria that were checked, free reports scored significantly lower on forensically relevant content quality than structured reports (details in Table 1).

The examiners that issued the reports contained forensic pathologists with experience in PMCT reading, as well as radiologists and radiology trainees. Pathology and radiology training, board certification and PMCT years experience were listed for both report types (see Table 1). Both groups – free reports and structured reports – contained eight cases of mechanical trauma and twelve cases that did not exhibit mechanical trauma findings (but covered natural death or disease and poisoning cases).

4. Discussion

Forensically relevant items were missed in critical subject areas in 25%–79% free form PMCT reports, as we found out. Conversely and for the specific purposes of forensic pathology, structured reporting contained all key features that we checked for. The difference was statistically significant. With PMCT gaining increasing acceptance worldwide [19–26], this seems to be a relevant subject. The poor performance of the free form reports is not easily explained by the examiners' backgrounds (see Table 1).

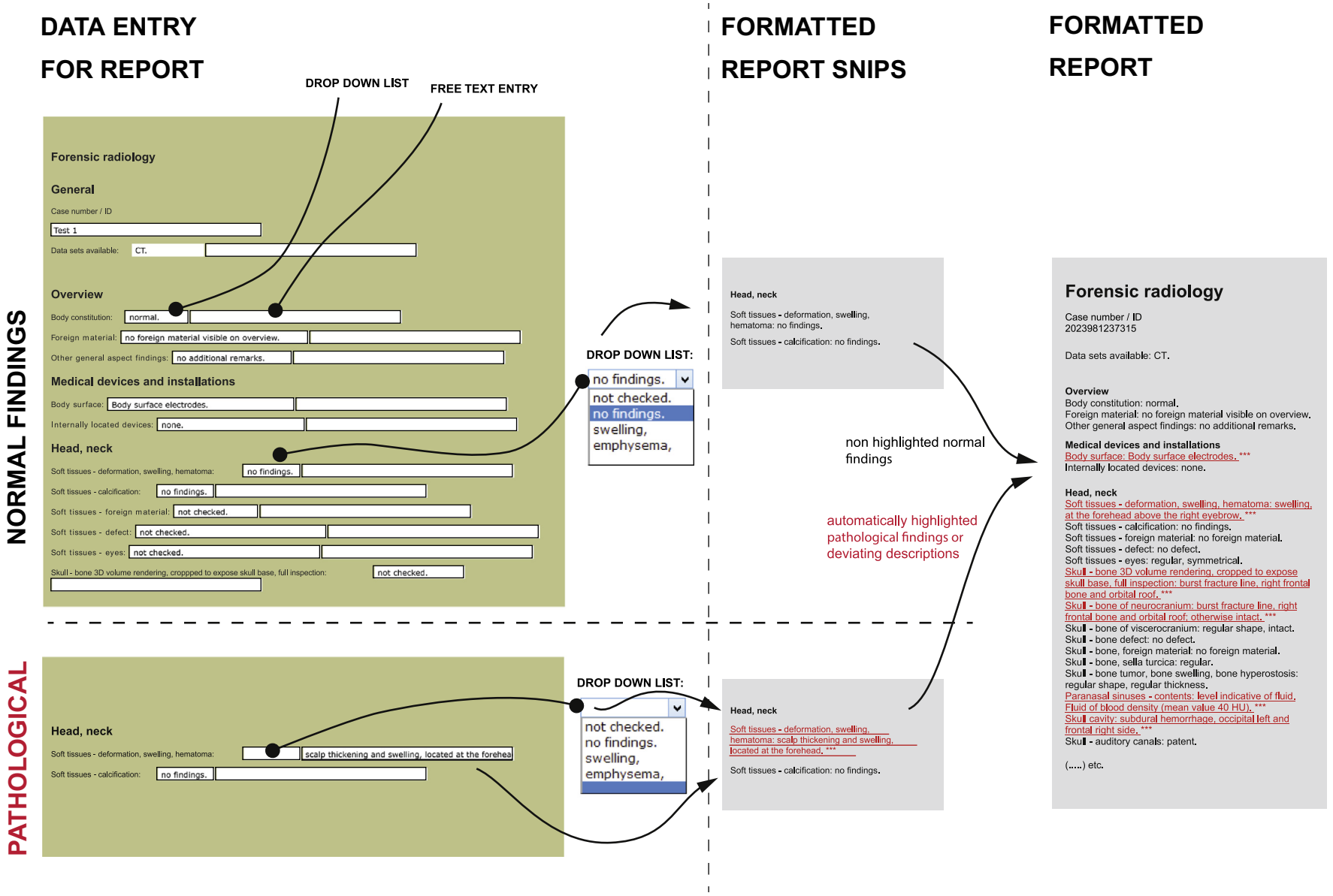

Fig. 1. Structured report system introduced in our facility: data entry (left column) is performed using a web browser based form. For each subject or entry, the form contains a drop down list and a free text entry field. By default, all drop down lists exhibit a "not checked" option and free text entry fields are empty. After submitting the whole form to generate the report, the content of all drop down lists and free text fields is evaluated: if the selection is either "not checked" or otherwise not normal, or if the free text entry field contains added text, then presence of pathology or otherwise abnormal findings are assumed and the report text will highlight that particular item as red, underline it and add stars at the end. Default normal entry is not highlighted. With that, the structured report ends up containing diagnoses type set in highlighted text that can then be printed, saved or transferred to a word processor or database linked text system. (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this article.)

4.1. Definition of a structured report

Theoretical considerations alone can tell us that a systematic approach to comprehensively reporting observations in forensic cases is absolutely mandatory [7]. However when defining the content for a structured reporting system in forensic pathology, be it for autopsies or for PMCT reporting, there are three types of findings to look for: frequent findings, and infrequent but important findings. The third category of findings pertains to those that may impact the dissection strategy or sequence normally used. According to a number of studies, injuries in violent deaths pertain to the musculosketal system (25–93%), head and brain (36–55%), superficial structures (57%), solid organs (12–27%), the chest (4–43%) and there are fluid collections (10%) and abnormal air collections (28%) [27–29]. At the same time one has to also plan a strategy that minimizes the occurrence of Black Swans [30] at all cost.

Defining a good dissection strategy can be critical. Gas contained within veins or arteries may be indicative of a forensically relevant bacterial infection [31,32]. Particularly if the autopsy is planned for later rather than immediately after PMCT, microbiological blood sampling then might have to be performed right away (rather than in due course of the autopsy). Findings may affect the brain or spinal cord removal technique that matter could include hemorrhages, cysts or tumors [33]. Furthermore, medical implants such as orthopedic implants can be difficult to assess properly at autopsy. So a PMCT might provide clues as to where best to place the saw or knife in order to identify relevant findings.

With that, the choice of items to be covered in our PMCT reports and the precise wording that we use in our system is still subject of further development.

4.2. Liability aspect

Giving our experts enjoy the freedom to report whatever they saw fit and the added disclaimer note did not prevent critical incidents such as the two problems described in the introductory section of this paper (see above). Unchecked or unreported data, from view of a court or judge, has the capacity to act as liability rather than asset [34]. Nowhere in Swiss or American criminal or procedural law is there a legally binding statement that says that experts should routinely perform limited analyses or that they should produce reports that provide preliminary results and add a disclaimer at the end. Ultimately, it becomes apparent that the core responsibility of the expert cannot be shifted to the overseeing authority by way of a disclaimer note.

4.3. Dual method aspect

With PMCT (and even more so with post-mortem MRI) and a subsequent medico-legal autopsy, we are technically introducing a dual method approach (to add to the so-called “four eye principle” [35]) into forensic pathology. And yet, quality perception depends largely on checked, interpreted and documented results – not on untapped findings looming inside PMCT data sets. So comprehensive reporting should be enforced by authorities as other approaches are not producing a reliable authenticated and responsible basis for expert opinions. Even without these legal aspects, structured radiology reporting is well known as preferred form by the clients by the people to whom the reports are addressed [36,37].

4.4. Guidance aspect

As radiologists are new to forensic pathology, their role is not so much to fast forward to the interesting bits, as it is to explicitly provide a full scope of any case they are presented with. As we had also seen, clinical radiologists may cover PMCT findings of no or little forensic relevance [38]. Covering irrelevant findings costs too much time and wastes efforts, however, while missing forensically relevant findings is unacceptable for above-mentioned reasons. So both are problematic strategically. Structured reporting is an effective remedy as it also acts as a guide, as a directing tool [39] and an important step in implementing quality assurance tools [40].

4.5. Limitations

In an ideal test setup, one would test both free form and structured reports against a gold standard reporting method. To be a gold standard method, that then would have to have a performance in excess of 10:1 [41] over both reporting methods in question. In absence of such an ideal testing procedure, errors found are only relative values and specific to the comparisons that were performed. Another limitation of this study is that time is of essence: checking a PMCT scan very thoroughly, and taking note of an exhaustive list of findings, can require considerably more time than typing a free form report related to case specific findings. Weighing cost against risk is not possible with our data.

This study only covers a limited number of reports (20 reports) for extreme differences in reporting technique (free reporting versus structured reporting of 108 items). Evaluating more subtle differences, such as structured reports with less items, or covering case specific facets of the reporting, could be expected to yield less extreme differences in terms of case-specific forensic quality.

Furthermore, what is forensically relevant is highly dependent on case specifics. As the forensic case load may vary greatly among countries, among different situations, or also across time, the content of a reporting system may have to reflect that. In particular, mass fatalities carry a particular risk of missing details and may benefit from a particularly well structured approach; the details of a suitable reporting system for such an application will have to be adapted to comply with specific needs as to details and time requirements.

4.6. Conclusions

Structured reporting in PMCT has the capacity to provide a technically reliable basis for good PMCT reporting. Free form reports yielded an unsatisfactory quality in terms of forensic relevance. It is therefore recommended to follow a strategy that forces the expert that reports and evaluates the PMCT findings to be exhaustive and verbose in their reporting in as much as all angles covered by a comprehensive medico-legal death investigation are concerned. This can remedy the content-wise shortcomings of free form reports and thus provide legally sufficient written documents to supplement medico-legal PMCT data.

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