Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Review article

Analysis of the role of PMCT during the COVID-19 pandemic: A systematic review

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ABSTRACT

Objectives: During COVID-19 pandemic PMCT has been proposed as a forensic investigation method. This systematic review is aimed to systematize evidence and peer-reviewed opinions reported during the first two years of pandemic, to evaluate the role of PMCT during the COVID-19 pandemic.
Materials and methods: An online literature search was performed to identify publications on PMCT during the COVID-19 pandemic between December 2019 and March 2022. For each publication included, the following data were collected: title and abstract, year of publication, type of article, number and type of individuals examined. The selected publications were also categorized based on PMCT findings, histopathological results, the comparison between PMCT and histopathological findings, cause of death and proposed role of PMCT during the pandemic.
Results: A total of 20 publications were included, mostly case reports (9/20). All cases examined included adults. The most frequent PMCT pattern in positive cases was diffuse mixed densities with prevalence of consolidations (pattern 1) (54%). In 97% of the cases where a comparison between PMCT and histological results was performed, a correspondence was found. In 82% of the cases the principal cause of death was COVID-19 pneumonia. PMCT has been proposed as a pre-autopsy screening tool in 62%, and as a method for augmenting post-mortem data in 50% of the papers reporting this issue.
Conclusion: This systematic review suggests that PMCT should be regarded as a highly valuable investigative technique for the forensic evaluation of deaths with ascertained or suspected COVID-19 pneumonia.

1. Introduction

Virtual autopsy is a term first used by Thali to describe the radiological techniques applied to post-mortem investigations [1,2]. Even though this term may refer to many different techniques, whole-body post-mortem CT (PMCT) scan remains the most used tool in forensic practice [3,4]. According to current evidence [5,6], the main indications of PMCT regard traumatic cases with skeletal injuries and/or hyperdense foreign objects (e.g., bullets) [7–10]. Nevertheless, PMCT is known to have several limitations, especially, in natural death cases. For instance, it can easily fail to show minor vascular injuries [11]. However, it has been reported that it can help the pathologist in evaluating sudden deaths [12] due to conditions like hemopericardium [13–15] and in cases of suspected cardiomyopathies [16–18].

More recently, many authors underlined the importance of PMCT in COVID-19 cases. PMCT has been reported to be of great help in exploring signs of this disease at both the pulmonary and extra-pulmonary (e.g., brain hypodensities and hemorrhagic lesions, intestinal wall thickening) level [19–22]. In particular, PMCT has been proposed both as a "screening tool" to assess the biological risk before the autopsy (and thus – for instance – chose the facility where the autopsy should be performed and the personal protective equipment that should

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be given to the executors). Moreover, PMCT in combination with percutaneous biopsies to avoid autopsies when the autopsy facility is not adequate for the COVID-19 biological risk [23]. The pre-autopsy application of PMCT is of great medico-legal and public health value [24–27]. Furthermore, it has been proved that COVID-19 cases, especially in untreated patients, can expose the autopsy room operators to a significant biological risk [24–27]. It should be also considered that, as a screening tool, PMCT has been reported to have a high sensitivity, even higher than that of a microbiological testing [28]. Moreover, in 2022, Filograna et al. described a correlation between lung PMCT and histopathological findings, finding that PMCT can even suggest the degree of severity of COVID-19 in forensic cases [29].

In this paper, we performed a systematic review focused on the use PMCT imaging during COVID-19 pandemic. Our aim was to systematize evidence and peer-reviewed opinions reported during the first two years of the pandemic, to evaluate whether PMCT should be implemented as a standard best practice of forensic investigations during COVID-19 pandemic.

2. Materials and methods

A systematic review of scientific articles (in English or other languages) published from December 2019 to March 2022, was performed by searching the online Medline (PubMed) database. Four prefix search terms (postmortem, post-mortem, post mortem, forensic) were individually combined with the suffix CT, computed tomography, radiology, imaging with the search terms 'SARS-CoV-2' and 'COVID-19'. The search terms ''virtual autopsy'' or ''Virtopsy'' were additionally combined with the search terms 'SARS-CoV-2' and 'COVID-19'. A total of 36 search queries were applied.

The methods of the systematic review and exclusion criteria were defined in advance according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [30].

Titles and abstracts were independently screened by the investigators to exclude non-post-mortem CT imaging papers. The inclusion criteria were all types of articles and related only to humans. The exclusion criteria were articles for which full text was not available or were not in English. Duplicates were discarded. From the articles retrieved in the first round of search, additional references were examined by a manual search among the cited references. When a publication was considered potentially relevant, its full text was independently read by two authors (LF and SG). For each publication selected (Table 1), the following information was collected: title and abstract, year of publication, the type of article (original article, case report/brief report/short communication (if 5 or less cases were reported)), narrative review or letter to the editor), number and type of the subjects examined (adults, infants/children). From the papers data were extracted exclusively pertaining cases with ante-mortem or post-mortem SARS-CoV-2 RTPCR positive cases examined with PMCT. The results of PMCT analysis with particular focus on the lungs were recorded, when available. Among the cases with PMCT imaging analysis, some of the stored data were whether an autopsy was performed or not, the results of PMCT imaging analysis, the results of eventually performed (also with percutaneous biopsies) histopathological analysis. Moreover, the eventual comparison between PMCT and histological results and between the cause of death and PMCT pattern were recorded. Finally, the potential use of PMCT in COVID-19 suspected or ascertained cases as proposed by the papers included in the review was recorded.

3. Results

3.1. Selection of the studies

Fig. 1 represents the flow chart developed according to the PRISMA statement [30] (total: 1523).

The search retrieved a total of 1523. A total of 215 peer-reviewed articles were recognized as potentially suitable for inclusion by titles and abstract scanning. After exclusion of duplicates, a total of 17 articles were included in the systematic review. Manual search among the cited references from the articles retrieved in the first round of search provided additional 3 references [31–33]. The full text of the total of 20 articles was examined in detail.

3.2. Description of the selected studies

According to the search terms and manual search through references, 20 publications were retrieved

[23, 29, 31–48]. The results of our systematic review are reported in Table 1 in chronological sequence. As expected, all the papers were published between 2020, the beginning of pandemic, and March 2022.

Most papers were case reports (9/20), followed by original articles (6/20), narrative reviews (3/20) and letters to the Editor (2/20).

From the 20 papers, information about 515 cases with SARS-CoV-2 Real-time PCR (RTPCR) positivity and examined through PMCT were available. Seventeen papers [29, 31–35, 37–44, 46–48] provided detailed information about cases. All cases regarded adults.

Of the 515 cases examined, 289 cases underwent autopsy from 14 articles [29, 31–35, 37, 39–41, 44, 46–48], 234/289 of the study of Fitzek et al. [39]. In one paper of Silva et al. [43], although the 5 cases presented were not autopsied, they underwent ultrasonography (US) guided biopsies of major organs including the lungs, and histopathological data were available. Thus, histopathological analysis of lungs was performed in a total 294 cases positive for SARS-CoV-2 infection examined with PMCT.

3.3. PMCT imaging analysis

Of the 20 papers included in the study, 14 reported detailed description of PMCT lung findings for each case [29, 31–35, 37, 38, 40, 41, 43, 44, 47, 48], with a total amount of 82 cases among the 515 included in the review. In fact, for the 411 cases reported by Fitzek et al. [39] a detailed description of PMCT pulmonary findings was not provided.

Table 1 reports PMCT imaging analysis results for each paper. By screening descriptors of PMCT imaging of the lungs reported in the papers included in the review, we summarized 6 PMCT patterns. The pulmonary PMCT findings were categorized as follows: pattern 1 diffuse mixed densities (i.e. coexistence of ground glass opacities (GGO) and consolidations) with prevalence of consolidations; pattern 2 diffuse mixed densities with prevalence of GGO with or without crazy paving, with or without hypostasis; pattern 3 some upper areas of GGO with or without hypostasis; pattern 4 airless lungs (almost completely or completely consolidated lungs with very few or absent aerated areas); pattern 5 other findings with or without hypostasis; pattern 6 hypostasis alone.

In detail (Table 1), of the 82 cases, pattern 1 (i.e. mixed densities with prevalence of consolidations) was found in 44 cases (54%) [29, 31–33, 35, 37, 40, 41, 43, 47, 48], pattern 2 in 15 cases (18%) [29, 34, 38, 40, 41, 43, 48] pattern 3 in 4 cases (5%) [29,41], pattern 4 in 4 cases (5%) [31, 41, 44], pattern 5 in 11 (13%) [31, 41] and pattern 6 in 4 (5%) [41].

3.4. Histopathological analysis

As reported in Table 1, from the 15 articles [29, 31–35, 37, 39–41, 43, 44, 46–48] histopathological analysis of lungs was performed in a total 297 cases positive for SARS-CoV-2 infection examined with PMCT.

However, detailed data about histopathological analysis was reported in 288 cases, as in the papers of Kniep et al. [40] (3 cases), Silva et al. [43] (5 cases), and De Giorgio et al. [44] (1 case), histopathological results were not specified.

As reported in the Table 1, 282/288 (98%) of these cases showed

Tabe 1
Characteristics of the included studies.

Author, year	Type of article	Nr. of cases and type	Autopsy	PMCT imaging pattern*: Cases	Histopathological results	PMCT vs histopathological results	Ascertained cause of death	Proposed role of PMCT
Ducloyer et al. 2020 [34]	Case report	1 adult	1/1	pattern 2: 1	1/1 diffuse alveolar damage	1/1	1/1 COVID-19 pneumonia	Screening tool
Fitzek et al. 2020 [35]	Case report	1 adult	1/1	pattern 1: 1	1/1 diffuse alveolar damage	n.r.	1/1 COVID-19 pneumonia	n.r.
Malizia et al. 2020 [36]	Narrative review	-	-	-	-	-	-	Screening tool; Increase of post-mortem data
Heinrich et al. 2020 [37]	Case report	1 adult	1/1	pattern 1: 1	1/1 diffuse alveolar damage	n.r	1/1 COVID-19 pneumonia	n.r.
Helmrich et al. 2020 [31]	Original article	14 adults	11/14	pattern 1: 11 pattern 4: 1 pattern 5: 2	14/14 diffuse alveolar damage and/or interstitial pneumonia	n.r.	n.r.	Screening tool
Schweitzer et al. 2020 [32]	Case report	1 adult	1/1	pattern 1: 1	1/1 diffuse alveolar damage	n.r.	1/1 COVID-19 pneumonia	Screening tool
Cittadini et al. 2020 [38]	Letter to the editor	1 adult	0/1	pattern 2: 1	-	-	1/1 COVID-19 pneumonia	Increase of post-mortem data
Fitzek et al. 2021 [39]	Original article	411 adults	234/411	n.r.	234/411 interstitial pneumonia and/or diffuse alveolar damage	234/234 Concordant	353/411 COVID-19 pneumonia 58/411 no COVID-19 pneumonia/ unclear cause of death	n.r.
Kniep et al. 2021 [40]	Case report	3 adults	3/3	pattern 1: 2 pattern 2: 1	n.r.	n.r.	1/3 superinfected COVID-19 2/3 COVID-19 pneumonia	Increase of post-mortem data
O'Donnell et al. 2021 [41]	Original article	39 adults	12/39	pattern 1: 16 pattern 2: 6 pattern 3: 2 pattern 4: 2 pattern 5: 9 pattern 6: 4	9/12 Diffuse alveolar damage 1/12 bacterial pneumonia or bronchopneumonia 2 another pathology	5/12 concordant 7/12 discordant	17/39 COVID-19 pneumonia 22/39 other cause of death	Screening tool
Filograna et al. 2021 [33]	Case report	1 adult	1/1	pattern 1: 1	1/1 Diffuse alveolar Damage	1/1 Concordant	1/1 COVID-19 pneumonia	Screening tool; Increase of post-mortem data
De Giorgio et al. 2021 [42]	Original article	13 adults	n.r.	n.r.	n.r.	n.r.	9/13 COVID-19 pneumonia	Screening tool; Increase of post-mortem data
Silva et al. 2021 [43]	Case report	5 adults	0/5	pattern 1: 2 pattern 2: 2 pattern 5: 1	n.r.	5/5 concordant	4/5 COVID-19 pneumonia 1/5 acute liver failure	Screeningtool
De Giorgio et al. 2021 [44]	Letter to the editor	1 adult	1/1	pattern 4: 1	n.r.	n.r.	1/1 COVID-19 pneumonia	n.r.
Roberts et al. 2021 [45]	Narrative review	-	-	-	-	-	-	Screening tool; Cause of death
De Giorgio et al. 2021 [46]	Original article	9 adults	9/9	n.r.	4/9 interstitial pneumonia 5/9 CO poisoning	n.r.	1/9 COVID-19 multiorgan (cardiac) 3/9 COVID-19 pneumonia 5/9 CO poisoning in COVID-19 infection	Screening tool; increase post-mortem data
Xie et al. 2021 [47]	Case report	1 adult	1/1	pattern 1: 1	1/1 Diffuse alveolar damage	1/1 Concordant		Screening tool

(*continued on next page*)

Tabe 1 (*continued*)

Author, year	Type of article	Nr. of cases and type	Autopsy	PMCT imaging pattern*: Cases	Histopathological results	PMCT vs histopathological results	Ascertained cause of death	Proposed role of PMCT
							1/1 COVID-19 pneumonia and drug intoxication	
Williams et al. 2021 [48]	Case report	5 adults	5/5	pattern 1: 3 pattern 2: 2	5/5 diffuse alveolar damage	5/5 concordant	5/5 COVID-19 pneumonia	Screening tool
Filograna et al. 2022 [29]	Original article	8 adults	8/8	pattern 1: 4 pattern 2: 2 pattern 3: 2	6/8 diffuse alveolar damage (more severe in 4/8) 2/8 scant signs of interstitial pneumonia	8/8 concordant	6/8 COVID-19 pneumonia 2/8 ischemic heart failure in COVID-19 infection	Screening tool; Increase of post-mortem data
Filograna et al. 2022 [23]	Narrative review	-	-	-	-	-	-	Screening tool; Increase of post-mortem data

* PMCT imaging patterns of the lungs: pattern 1 diffuse mixed densities with prevalence of consolidations; pattern 2 diffuse mixed densities with prevalence of GGO with or without crazy paving, with or without hypostasis; pattern 3 some upper areas of GGO with or without hypostasis; pattern 4 airless lungs; pattern 5 other findings with or without hypostasis; pattern 6 hypostasis alone.

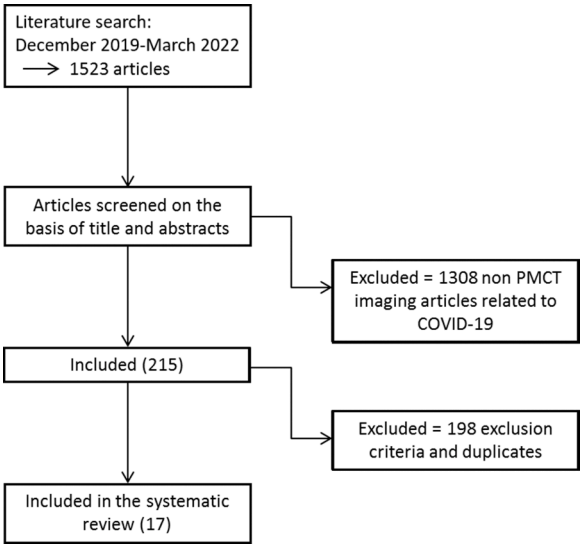

Fig. 1. The PRISMA flow diagram for the systematic review detailing the database searches, the number of abstracts screened, and the full texts retrieved.

histopathological signs of diffuse alveolar damage (DAD) and/or clear COVID-19 interstitial pneumonia. In fact, in the paper of O'Donnell et al. [41] 2 cases showed bacterial pneumonia or bronchopneumonia and 2 demonstrated another pathology, and in the paper of Filograna et al. [29] 2 cases showed scant signs of COVID-19 pneumonia.

3.5. PMCT vs histopathological results

As reported in the Table 1, a proper comparison of PMCT imaging and histopathological analysis results was performed in 8/20 papers [29, 33, 34, 39, 41, 43, 47, 48] and, thus, in 267 cases this issue was assessed at various level of consistency.

In 260/267 cases (97%) a concordance between PMCT and histopathological findings was reported. In the remaining 7 belonging to the study of O'Donnell et al [41], on the contrary, a discrepancy was found.

A grading of both PMCT and histological findings related to pulmonary SARS-CoV-2 involvement was analyzed only in the 8 cases of the study of Filograna et al. and a complete correspondence was demonstrated.

3.6. Ascertained cause of death

The cause of death was reported in 501 of the total 515 cases examined [29, 32–35, 37–44, 46–48]. The ascertained cause of death was COVID-19 pneumonia with or without other concurrent causes, mainly related to comorbidities in 412/501 cases (82%), because of the exception of 58/411 of the study of Fitzek et al. [39], 22/39 cases of the study of O'Donnell et al. [41], 1/5 cases of the study of Silva et al. [43], 6/9 case of the study of De Giorgio et al. [46], and 2/8 cases of the study of Filograna et al. [29] (Table 1).

3.7. Cause of death vs PMCT pattern

In all 16 cases where a comparison between PMCT imaging and histopathological results could be performed [29, 33, 34, 47, 48] and a precise cause of death was attributed, the recognized PMCT pattern was the pattern 1 (10/16 cases) (62%) and 2 (6/16 cases) (38%). In the 2 cases with pattern 3 reported by Filograna et al. [29], the death was attributed to a cause different by COVID-19 pneumonia.

3.8. Proposed role of PMCT in COVID-19 pandemic

Regarding the role of PMCT during COVID-19 pandemic, it was explicitly mentioned in 16/20 papers included in the review [23,29, 31–34, 36, 38, 40–43, 45–48]. Particularly, PMCT imaging was proposed as a pre-autopsy screening tool for COVID-19 in 14/16 papers (87%) [23, 29, 31–34, 36, 41–43, 45–48]. Furthermore, PMCT imaging was proposed as a method to increase of quantity of post-mortem data, especially when performing a classical autopsy was not possible in 8/16 articles (50%) [23, 29, 33, 36, 38, 40, 42, 46].

In 1/16 studies (6%) [45], in presence of SARS-CoV-2 positivity confirmed with viral swabs, typical findings of COVID-19 on PMCT were sufficient to attribute the cause of death to COVID-19 pneumonia, without performing autopsy.

4. Discussion

This systematic review provided 20 articles focused on PMCT imaging during COVID-19 pandemic [23, 29, 31–48]. Thus, a relatively high number of studies has been published since the beginning of COVID-19 pandemic [34]. Case reports represented most of the eligible papers (45%), followed by original articles (30%).

Moreover, of the 20 papers included in the study, 14 reported detailed description of lung PMCT findings with a total amount of only 82 cases among the total of 515 included in the review [29, 31–35, 37,

38, 40, 41, 43, 44, 47, 48].

These results could be explained in our opinion by two main factors. First, the scant diffusion of dedicated CT scans for post-mortem analysis may have contributed together with the need of containment of contagion. Moreover, particularly at the beginning of pandemic, the urgence to share information about this new viral pathogen, may have contributed to the preponderance of case reports in the literature. In fact, 4/9 case reports were published in 2020 [32, 34, 35, 37], but only 1/6 original papers were published in 2020 [31].

Concerning PMCT findings, our analysis of the literature evidenced that the most frequent PMCT was the pattern 1, represented by diffuse mixed densities with prevalence of consolidations (54%) [29, 31–33, 35, 37, 40, 41, 43, 47, 48], followed by the pattern 2, represented by diffuse mixed densities with prevalence of GGO with or without crazy paving (18%) [29, 34, 38, 40, 41, 43, 48]. The pattern 3 constituted by some not dependent areas of GGO with or without hypostasis in 4 cases (5%) [29, 41]. The same percentage (5%) was retrieved for pattern 4 (airless lungs) [31, 41, 44].

According to these results, it could be proposed that, in accordance with the clinical and post-mortem literature, the patterns 1, 2, 3 and even 4, reflect different stages of COVID-19 affecting the lungs [33, 41, 42, 49]. Following this interpretation, the diffuse mixed densities with prevalence of consolidations (pattern 1) and the completely airless lungs (pattern 4), might be the expression of more advanced stages of lung pathology due to SARS-CoV-2 infection till the complete consolidations of both lungs as occurs in ARDS [33, 41, 42, 49]. In line with this interpretation, the diffuse mixed densities with prevalence of GGO with or without crazy paving of the pattern 2 [29, 34, 38, 40, 41, 43, 48] resembles the most typical imaging alteration of patients who died by the second week after symptom onset [50]. Finally, the scant not dependent areas of GGO (typical of COVID-19 early stages in clinical setting) with or without hypostasis of the pattern 3 [29, 41] might be interpreted as typical of early stages of COVID-19 [50]. Thus, it might be hypothesized that PMCT imaging might be a valid tool not only for the diagnosis of COVID-19 pneumonia, but also for staging the lung involvement.

Regarding histopathological analysis, of the 288 cases studied with PMCT, where histopathological data were available, [29, 31–35, 37, 39, 41, 46–48], the majority (282 cases) showed histopathological signs of DAD and/or clear COVID-19 interstitial pneumonia, as it occurs in advanced stages of pulmonary infections by SARS-CoV-2.

This data is in accordance with the pertinent literature reporting histopathologic findings of lung pathology related to COVID-19 [51–59].

Three progressive phases of pulmonary involvement by COVID-19 have been identified by Buja et al. [56]: acute/exudative, organizing/proliferative, proliferative/fibrotic. In general, according to current literature, the main COVID-19-related histopathological is DAD. The extent of DAD varies depending on the stage and severity of the disease. DAD may be associated with intra-alveolar exudates, pneumocyte hyperplasia/atypia, hyaline membrane, proteinaceous exudates and alveolar edema, with major inflammatory infiltration [51, 52, 55]. Moreover, DAD may be associated with possible consolidation with fibroblastic proliferation [48, 52], and/or pulmonary thromboemboli [54, 58].

Furthermore, in a recent study Romanova et al. [59] reported that for the 91% of cadavers positive for SARS-CoV-2 infection, where autopsy ascertained cause of death was other than COVID-19, histopathological analysis of the lungs did not show DAD.

Based on this evidence, DAD can be considered the predominant histopathological findings in deaths with ascertained SARS-CoV-2 infection, and it seems to be the expression of severe lung involvement by COVID-19.

On the other hand, in the 260/267 cases [29, 33, 34, 39, 41, 43, 47, 48] where a proper comparison between PMCT imaging and pulmonary histopathological analysis results was performed a concordance between PMCT and histopathological findings was ascertained.

Through analysis of Table 1, 5 papers with 16 cases can be identified [29, 33, 34, 47, 48], where a proper comparison between the revealed PMCT pattern and the histopathological analysis can be conducted for each case and a precise cause of death was attributed for each case. It can be noted that patterns 1 and 2, considered here as the typical pattern of diffuse COVID-19 involvement of the lungs, were found in 10 cases and 4 cases respectively [29, 33, 34, 47, 48]. In these 14/16 cases signs of DAD/advanced interstitial pneumonia were detected on histopathological analysis and the cause of death was attribute to COVID-19 pneumonia. Moreover, pattern 3, interpreted as typical for early stages of pulmonary SARS-CoV-2 infection was found in 2 cases of Filograna et al, where histological examination confirmed the PMCT pattern and the cause of death was not attributed to COVID-19 pneumonia. Moreover, a match between PMCT and histopathology in the grading of pulmonary SARS-CoV-2 involvement was demonstrated in the study of Filograna et al. [29].

Following these data, a general correspondence between PMCT and histopathology can be recognized also in the determination of the severity of lung involvement by COVID-19. Thus, the ability of PMCT imaging in staging the severity of COVID-19 pneumonia is further confirmed by the comparison between PMCT and histopathological analysis, opening new possibilities for the determination of the cause of death through PMCT imaging.

Regarding the possible or applied role of PMCT during COVID-19 pandemic, the majority of the papers that explicitly mentioned this issue (16/20 papers) [23, 29, 31–34, 36, 38, 40–43, 45–48] proposed PMCT imaging as a pre-autopsy screening tool for COVID-19 (14/16 papers) [23, 29, 31–34, 36, 41–43, 45–48]. A possible bias of PMCT is the presence of post-mortem changes [14] that might obscure PMCT findings of early stages of COVID-19 pneumonia [23, 29, 33, 34, 36, 41, 48]. Moreover, PMCT was suggested as a method to increase of quantity of post-mortem data, especially when performing a classical autopsy is not possible in 8/16 articles [23, 29, 33, 36, 38, 40, 42, 46].

About the possibility to attribute the cause of death with PMCT imaging, without histopathological confirmation, the 10 papers that mention this issue [23, 29, 33, 41–46, 48] (except for the article by Roberts and Traill [45]) suggest that caution must be undertaken when attributing the cause of death if a histopathological analysis is not performed. This is because there is currently insufficient published literature about this issue, the findings reported for assessment of SARS-CoV-2 infection of the lungs using PMCT are not sufficiently specific, and there are pathways of death in SARS-CoV-2 infection other than pneumonia.

Moreover, it has been demonstrated that clinical radiologists are able to differentiate COVID-19 pneumonia from other viral pneumonia on CT imaging with moderate to high accuracy [60]. Indeed, the major weakness of PMCT in being equally accurate in detecting COVID-19 pneumonia depends on the specific characteristics of PMCT imaging and its interpretation.

On the other hand, as suggested by O'Donnell [41], agonal (e.g., aspiration of gastric contents, reduced ventilation, and effects of resuscitation), previous lung disease, or superadded complications of COVID-19 pneumonia, peri-mortem changes, for example a superimposed ARDS due to concomitant pathology may obscure the SARS-CoV-2 pneumonia. In general post-mortem changes [61, 62], may obscure underlying COVID-19 changes.

Moreover, other pathologies related to COVID-19 other than pneumonia can cause the death in an individual affected by SARS-CoV-2 infection, such as thromboembolism and multiorgan failure [54].

However, in the context of the pandemic peak, Roberts et al. [45], suggests that if COVID-19 pneumonia is suspected based on PMCT, and SARS-CoV-2 positivity is confirmed with viral swabs, it is possible to avoid autopsy and to attribute the cause of death to COVID-19 pneumonia.

5. Conclusions

This systematic review suggests that virtual autopsy with PMCT imaging should be regarded as a highly valuable post-mortem investigative technique during COVID-19 pandemic.

PMCT was demonstrated as being a valuable tool for diagnosing and staging COVID-19 pneumonia. Although the good concordance with histopathological data, PMCT imaging might not be considered a consistent method for diagnosing COVID-19 pneumonia as the cause of death.

However, this review demonstrated that PMCT imaging can be considered a useful method able to increase information, with a reduced risk of infection, about COVID-19 pneumonia, with promising perspectives about the determination of the cause of death. Nonetheless, this systematic review suggests that virtual autopsy with PMCT imaging should be regarded as a highly valuable post-mortem investigative technique during COVID-19 pandemic in the forensic evaluation of deaths with ascertained or suspected COVID-19 pneumonia.

Declaration of Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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