Overview and summary of relevant publications on COVID-19

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The literature search strategy is based on a systematic approach which involved looking for common terms and keywords in the field of Radiology for COVID-19.

Databases: Searches were conducted in PubMed, Google Scholar, and internet searches with search terms which included Radiology, image findings, CT, 2019-nCoV and COVID. Radiology societies and major radiological journal websites were searched to ensure completeness.

Societies: RSNA, ACR, ESR, STR, CSR, SIR and ARRS websites were searched for relevant articles.

Journals in scope: Radiology, AJR, Lancet, European Radiology, and JAMA

Literature review results

Selection criteria: All relevant articles to COVID-19 were found though the above database searches and society positions were reviewed by the MCA team to summarized based on relevance. A few review papers are summarized, which take into considerations some of the early findings, case reports and several publications from China and hence a majority of the initial case reports, commentaries and letter to editors are deliberately not included.
Table 1 represents relevant studies. Note that only most important studies are summarized.

Timeframe: All articles published before 26 March 2020 were reviewed and hence this summary represents a snapshot in time. Preference was given to scientific articles compared to case reports and commentaries. The evidence and information related to COVID-19 is very dynamic and rapidly evolving with the disease. Future revisions of this document will include advances in the knowledge.

Please note that this literature overview is not meant to be a complete list of all the radiological publications on COVID-19, instead represents a living document of the relevant publications as of 20 April 2020.

Abbreviations

ACU	Area under the receiver operating characteristic curve
CAP	Community acquired pneumonia
COVID-19	Coronavirus disease 19
CSF	Cerebrospinal fluid
CT	Computed tomography
CXR	Chest x-rays
GGO	Ground-glass opacification
ICU	Intensive care unit
MERS	Middle East respiratory syndrome
RT-PCR	Reverse-transcription polymerase chain reaction
SARS	Severe acute respiratory syndrome
UC	Urgent care

Table 1 summarizing relevant publications on COVID-19

	Title of the publication	Purpose	Pts	Outcome
1	Pan, Y., Guan, H., Zhou, S. *et al.* **Initial CT findings and temporal changes in patients with the novel coronavirus pneumonia (2019-nCoV): a study of 63 patients in Wuhan, China.** *Eur Radiol* (2020). https://rdcu.be/b3aZx	The purpose of this study was to observe the imaging characteristics of the novel coronavirus pneumonia.	63	Imaging changes in novel viral pneumonia are rapid. The manifestations of the novel coronavirus pneumonia are diverse. Imaging changes of typical viral pneumonia and some specific imaging features were observed. Therefore, we need to strengthen the recognition of image changes to help clinicians to diagnose quickly and accurately.
2	Ye, Z., Zhang, Y., Wang, Y. *et al.* **Chest CT manifestations of new coronavirus disease 2019 (COVID-19): a pictorial review.** *Eur Radiol* (2020). https://doi.org/10.1007/s00330-020-06801-0	To review the typical and relatively atypical CT manifestations with representative COVID-19 and hope to strengthen the recognition of these features with radiologists and help them make a quick and accurate diagnosis.		Ground glass opacities, consolidation, reticular pattern, and crazy paving pattern are typical CT manifestations of COVID-19. • Emerging atypical CT manifestations, including airway changes, pleural changes, fibrosis, nodules, etc., were demonstrated in COVID-19 patients. • CT manifestations may associate with the progression and prognosis of COVID-19.
3	Fang Y, Zhang H,Xie J et al. **Sensitivity of Chest CT for COVID-19: Comparison to RT-PCR**, *Radiology* February 2020. https://doi.org/10.1148/radiol.2020200432	The purpose of this study was to compare the sensitivity of chest CT and viral nucleic acid assay at initial patient presentation	51	In a series of 51 patients with chest CT and RT-PCR performed in 3 days, the sensitivity of CT for COVID-19 was 98% compared to RT-PCR sensitivity of 71%.
4	Bernheim A,Mei X, Huang M et al. **Chest CT Findings in Coronavirus Disease-19 (COVID-19): Relationship to Duration of Infection,** *Radiology* February 2020. https://doi.org/10.1148/radiol.202020046	The hypothesis that certain CT findings may be more common depending on the time course of infection.	121	The hallmarks of COVID-19 infection on imaging were bilateral and peripheral ground-glass and consolidative pulmonary opacities. Notably, 20/36 (56%) of early patients had a normal CT. With a longer time after the onset of symptoms, CT findings were more frequent, including consolidation, bilateral and peripheral disease, greater total lung involvement, linear opacities, “crazy-paving” pattern and the “reverse halo” sign. Bilateral lung involvement was observed in 10/36 early patients (28%), 25/33 intermediate patients (76%), and 22/25 late patients (88%).
5	Li Y ,Xia L et al.Coronavirus Disease 2019 (COVID-19): **Role of Chest CT in Diagnosis and Management.** *AJR* March 2020. https://doi.org/10.2214/AJR.20.22954	To determine the misdiagnosis rate of radiologists for coronavirus disease 2019 (COVID-19) and evaluate the performance of chest CT in the diagnosis and management of COVID-19.	51	Chest CT had a low rate of missed diagnosis of COVID-19 (3.9%, 2/51) and may be useful as a standard method for the rapid diagnosis of COVID-19 to optimize the management of patients. However, CT is still limited for identifying specific viruses and distinguishing between viruses
6	Shi H, Han X et al. **Radiological findings from 81 patients with COVID-19 pneumonia in Wuhan,**	Aim to describe the CT findings across different time points	81	COVID-19 pneumonia manifests with chest CT imaging abnormalities, even in asymptomatic patients, with rapid evolution from focal unilateral to diffuse bilateral ground-

	China: a descriptive study. *Lancet* February 2020 https://doi.org/10.1016/S1473-3099(20)30086-4	throughout the disease course.		glass opacities that progressed to or co-existed with consolidations within 1–3 weeks.
7	Han R, Huang L et al. **Early Clinical and CT Manifestations of Coronavirus Disease 2019 (COVID-19) Pneumonia.** https://www.arrs.org/downloads/ajr/Early-Clinical-CT-Manifestations-COVID-19-Pneumonia.pdf	To investigate early clinical and CT manifestations of coronavirus disease (COVID-19) pneumonia.	180	The early CT findings are patchy GGO with or without consolidation involving multiple lobes, mainly in the peripheral zone, accompanied by halo sign, vascular thickening, crazy paving pattern, or air bronchogram sign.
8	Wang Y, Dong C et al. **Temporal Changes of CT Findings in 90 Patients with COVID-19 Pneumonia: A Longitudinal Study**. *Radiology* March 2020 https://doi.org/10.1148/radiol.2020200843	To perform a longitudinal study to analyze the serial CT findings over time in patients with COVID-19 pneumonia	90	The extent of lung abnormalities on CT peaked during illness days 6-11. The temporal changes of the diverse CT manifestations followed a specific pattern, which might indicate the progression and recovery of the illness.
9	Ai T, Yang Z et al. **Correlation of Chest CT and RT-PCR Testing in Coronavirus Disease 2019 (COVID-19) in China:** A Report of 1014 Cases. Radiology February 2020. https://doi.org/10.1148/radiol.2020200642	To investigate the diagnostic value and consistency of chest CT as compared with comparison to RT-PCR assay in COVID-19.	1014	Chest CT has a high sensitivity for diagnosis of COVID-19. Chest CT may be considered as a primary tool for the current COVID-19 detection in epidemic areas.
10	Chen N, Zhou M, Dong X et al. **Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study,** *Lancet*, February 2020. https://doi.org/10.1016/S0140-6736(20)30211-7	To clarify the epidemiological and clinical characteristics of 2019-nCoV pneumonia	99	The 2019-nCoV infection was of clustering onset, is more likely to affect older males with comorbidities, and can result in severe and even fatal respiratory diseases such as acute respiratory distress syndrome. In general, characteristics of patients who died were in line with the MuLBSTA score, an early warning model for predicting mortality in viral pneumonia.
11	Xie, X, Zhong, Z, Zhao, W, Zheng, C, Wang, F, Liu, J. **Chest CT for typical 2019-nCoV pneumonia: relationship to negative RT-PCR testing.** *Radiology* February 2020. https://doi.org/10.1148/radiol.2020200343	To describe CT imaging features of five patients with initial negative or weakly positive RT-PCR results but high suspicion of 2019-nCoV infection.	5	In patients at high risk for 2019-nCoV infection, chest CT evidence of viral pneumonia may precede positive negative RT-PCR test results.
12	Song F, Shi N, Shan F et al. **Emerging Coronavirus 2019-nCoV Pneumonia.** *Radiology* 2020.	To investigate the clinical, laboratory, and imaging findings of emerging 2019-	51	Patients with fever and/or cough and with conspicuous ground-glass opacity lesions in the peripheral and posterior lungs on CT images, combined with normal or decreased white blood cells and a history of epidemic

	https://doi.org/10.1148/radiol.2020200274	nCoV pneumonia in humans		exposure, are highly suspected of having 2019 Novel Coronavirus (2019-nCoV) pneumonia.
13	Pan F, Ye T et al. **Time course of lung changes on chest CT during recovery from 2019 novel coronavirus (COVID-19) pneumonia.** *Radiology* 2020. https://doi.org/10.1148/radiol.2020200370	To determine the change in chest CT findings associated with COVID-19 pneumonia from initial diagnosis until patient recovery.	21	In patients recovering from COVID-19 pneumonia (without severe respiratory distress during the disease course), lung abnormalities on chest CT showed greatest severity approximately 10 days after initial onset of symptoms.
14	Ng MY,Lee EYP et al. **Imaging Profile of the COVID-19 Infection: Radiologic Findings and Literature Review**. *Radiology* February 2020. https://doi.org/10.1148/ryct.2020200034	21 COVID-19 cases from two Chinese centers with CT and chest radiograph (CXR) findings, as well as follow-up imaging in 5 cases	21	The COVID-19 infection pulmonary manifestation is predominantly characterized by ground-glass opacification with occasional consolidation on CT.
15	Chung M, Bernheim A et al. CT **Imaging Features of 2019 Novel Coronavirus (2019-nCoV).** *Radiology* February 2020. https://doi.org/10.1148/radiol.2020200230	Describe and characterize the key CT findings in a group of 21 patients infected with 2019-nCoV in China, with the goal of familiarizing radiologists and clinical teams with the imaging manifestations of this new outbreak	21	Of 21 patients with the 2019 novel coronavirus, 15 (71%) had involvement of more than two lobes at chest CT, 12 (57%) had ground-glass opacities, seven (33%) had opacities with a rounded morphology, seven (33%) had a peripheral distribution of disease, six (29%) had consolidation with ground-glass opacities, and four (19%) had crazy-paving pattern. Lung cavitation, discrete pulmonary nodules, pleural effusions, and lymphadenopathy were absent. Fourteen percent of patients (three of 21) presented with a normal CT scan.
16	Moosa-Basha M, Meltzer C et al. et al. **Radiology Department Preparedness for COVID-19:** Radiology Scientific Expert Panel. *Radiology* March 2020. https://pubs.rsna.org/doi/10.1148/radiol.2020200988	Radiology preparedness is a set of policies and procedures directly applicable to imaging departments designed *(b)* to support the care of patients with COVID-19, and *(c)* to maintain radiologic diagnostic and interventional support for the entirety of the hospital and health system		Sensitivity and specificity of chest CT for COVID-19 are reported to range from 80%-90% and 60%-70%, respectively. CT Imaging is reserved for those cases where it will impact patient management and is clinically indicated or to evaluate for unrelated urgent/emergent indications.
17	Hosseiny M, Kooraki S et al. **Radiology Perspective of Coronavirus Disease 2019 (COVID-19): Lessons from Severe Acute Respiratory Syndrome and Middle East Respiratory Syndrome** *AJR* February 2020. https://doi.org/10.2214/AJR.20.22969	to review the lessons from imaging studies obtained during severe acute respiratory syndrome (SARS) and Middle East respiratory syndrome (MERS) outbreaks		Early evidence suggests that initial chest imaging will show abnormality in at least 85% of patients, with 75% of patients having bilateral lung involvement initially that most often manifests as subpleural and peripheral areas of ground-glass opacity and consolidation.

18	Salehi S, Abedi A et al. **Coronavirus Disease 2019 (COVID-19): A Systematic Review of Imaging Findings in 919 Patients.** *AJR* February 2020. https://www.ajronline.org/doi/abs/10.2214/AJR.20.23034	The search records were screened, 30 studies consisting of 19 case series and 11 case reports with a total of 919 patients were included in the final review.	919	The characteristic patterns and distribution of CT manifestations: ground glass opacification (GGO) (88.0%), bilateral involvement (87.5%), peripheral distribution (76.0%), and multi-lobar (more than one lobe) involvement (78.8%)
19	**Li L, Qin L et al. Artificial Intelligence Distinguishes COVID-19 from Community Acquired Pneumonia on Chest CT**. *Radiology* March 2020. https://doi.org/10.1148/radiol.2020200905	To develop a fully automatic framework to detect COVID-19 using chest CT and evaluate its performances.	3322	deep learning model can accurately detect COVID-19 and differentiate it from community acquired pneumonia and other lung diseases.
20	**Yang W, Yan F. Patients with RT-PCR Confirmed COVID-19 and Normal Chest CT**. *Radiology* March 2020. https://doi.org/10.1148/radiol.2020200702	Patient with (RT-PCR) confirmed COVID-19 infection may have normal chest CT findings at admission		At present, RT-PCR test remains the reference standard to make a definitive diagnose of COVID-19 infection despite the false-negative rate.
21	ZU Z, Jiang M et al , **Coronavirus Disease 2019 (COVID-19): A Perspective from China.** *Radiology* February 2020. https://doi.org/10.1148/radiol.2020200490	A review focusing on the etiology, epidemiology, and clinical symptoms of COVID-19, while highlighting the role of chest CT in prevention and disease control.		Radiologists understanding of clinical and chest CT imaging features of coronavirus disease 2019 (COVID-19) will help to detect the infection early and assess the disease course.
22	Wu Z, McGoogan JM. **Characteristics of and Important Lessons From the Coronavirus Disease 2019 (COVID-19) Outbreak in China: Summary of a Report of 72,314 Cases From the Chinese Center for Disease Control and Prevention**. *JAMA*. February 2020.http://jamanetwork.com/article.aspx?doi=10.1001/jama.2020.2648	Chinese Center for Disease Control and Prevention recently published the largest case series to date of coronavirus disease 2019 (COVID-19) in mainland China (72 314 cases, updated through February 11, 2020).		This Viewpoint summarizes key findings from this report and discusses emerging understanding of and lessons from the COVID-19 epidemic.
23	Lei et al., 2020 CT **Imaging of the 2019 Novel Coronavirus (2019-nCoV) Pneumonia.** *Radiology* https://pubs.rsna.org/doi/10.1148/radiol.2020200236	Case report		First case report demonstrating ground-glass opacities in both lungs the published in Radiology.
24	Yoon SH, Lee KH et al. **Chest Radiographic and CT findings of the 2019 Novel Coronavirus Disease**	This study presents a preliminary report on the chest radiographic and computed	9	Chest CT images showed bilateral involvement in eight of the nine patients, and a unilobar reversed halo sign in the other patient. COVID-19 pneumonia in Korea primarily manifested as pure to mixed ground-glass

	(COVID-19): Analysis of Nine Patients treated in Korea. *Korean J Radiol* 2020;21(4):494-500 https://doi.org/10.3348/kjr.2020.0132	tomography (CT) findings of the 2019 novel coronavirus disease (COVID-19) pneumonia in Korea.		opacities with a patchy to confluent or nodular shape in the bilateral peripheral posterior lungs. A considerable proportion of patients with COVID-19 pneumonia had normal chest radiographs.
25	Hurt B, Kligerman S, et al. Deep Learning **Localization of Pneumonia 2019 Coronavirus (COVID-19) Outbreak**. *J Thorac Imaging*. April 2020 https://journals.lww.com/thoracicimaging/Citation/9000/Deep_Learning_Localization_of_Pneumonia__2019.99441.aspx	Study describes a deep learning approach to augment radiographs with a color probability overlay to improve the diagnosis of pneumonia.		Algorithm predicted and consistently localized areas of pneumonia with increasing likelihood, as the subtle airspace opacities increased over time. It is worth noting that each radiograph was analyzed by the algorithm independently without awareness of the time course or relationship of previous films. In each case, the predicted probability map correctly localizes the findings and assigns likelihoods that mirror the severity of the imaging findings
26	Raptis C, Hammer M et al. **Chest CT and Coronavirus Disease (COVID-19): A Critical Review of the Literature to Date**. *AJR* April 2020 https://www.ajronline.org/doi/full/10.2214/AJR.20.23202	The purpose of this article is to critically review some of the most frequently cited studies on the use of CT for detecting COVID-19.		To date, the radiology literature on COVID-19 has consisted of limited retrospective studies that do not substantiate the use of CT as a diagnostic test for COVID-19. Research describing CT features of COVID-19 has consisted mostly of retrospective reviews and case studies, and it should be "considered low quality" according to the authors.
27	Weinstock et al. **Chest X-Ray Findings in 636 Ambulatory Patients with COVID-19 Presenting to an Urgent Care Center: A Normal Chest X-Ray Is no Guarantee**. *JUCM* April 2020 https://www.jucm.com/documents/jucm-covid-19-studyepub-april-2020.pdf/?utm_campaign-news	To determine what percentage of urgent care (UC) patients with confirmed COVID-19 had normal vs abnormal chest x-rays (CXR) and to describe specific imaging characteristics and the frequency of each abnormal findings on plain film radiography	636	Most patients (566/636) had either normal or only mildly abnormal CXRs (89%), despite being symptomatic enough to warrant imaging as determined by the treating UC provider. Chest x-rays obtained from confirmed and symptomatic COVID-19 patients presenting to the UC were normal in 58.3% of cases, and normal or only mildly abnormal in 89% of patients. When abnormal, the most common findings were present in the lower lobes and the pattern was interstitial and/or multifocal. Pleural effusions and lymphadenopathy were uncommon.
28	Murphy et al., **COVID-19 on the Chest Radiograph: A Multi-Reader Evaluation of an AI System** *Radiology* May 2020 https://pubs.rsna.org/doi/10.1148/radiol.2020201874	To evaluate the performance of an artificial intelligence (AI) system for detection of COVID-19 pneumonia on chest radiographs.		Using RT-PCR test results as the reference standard, the AI system correctly classified CXR images as COVID-19 pneumonia with an AUC of 0.81. The system significantly outperforms each reader at their highest possible sensitivities. At their lowest sensitivities, only one reader can significantly outperform the AI system (p=0.04). In conclusions, an AI system for detection of COVID-19 on chest radiographs was comparable to six independent readers.
29	Prokop et al. **CO-RADS – A categorical CT assessment scheme for patients with suspected COVID-19: definition and evaluation** *Radiology* April 2020 https://pubs.rsna.org/doi/10.1148/radiol.2020201473	To introduce the COVID-19 Reporting and Data System (CO-RADS) for standardized assessment of pulmonary involvement of COVID-19 on non-enhanced chest CT and report its initial		CO-RADS is a categorical assessment scheme for pulmonary involvement of COVID-19 on non-enhanced chest CT providing very good performance for predicting COVID-19 in patients with moderate to severe symptoms and has a substantial interobserver agreement, especially for categories 1 and 5.

		interobserver agreement and performance.		
30	Kandemirli et al., **Brain MRI Findings in Patients in the Intensive Care Unit with COVID-19 Infection** *Radiology* May 2020 https://pubs.rsna.org/doi/10.1148/radiol.2020201697	To describe MRI findings of patients in the ICU with COVID-19 pneumonia	27	50 of 235 ICU patients developed neurological symptoms. Brain MRI was performed in 27 ICU patients, of which 44% (12/27) of the patients had abnormal MRI findings. In 10/27 (37%) patients, cortical FLAIR signal abnormality was present. Accompanying subcortical and deep white matter signal abnormality on FLAIR images were each present in 3 patients. Abnormalities involved the frontal lobe in 4, parietal lobe in 3, occipital lobe in 1, insular cortex in 3 and cingulate gyrus in 3 patients
31	Grillet et al., **Acute Pulmonary Embolism Associated with COVID-19 Pneumonia Detected by Pulmonary CT Angiography** *Radiology* April 2020 https://pubs.rsna.org/doi/10.1148/radiol.2020201544	The main objective of our study was to evaluate pulmonary embolus in association with COVID-19 infection using pulmonary CT angiography.	100	Finally, 100 patients with COVID-19 infection and severe clinical features were included were examined with contrast enhanced CT. Of 100 patients meeting inclusion criteria, 23 (23%, [95%CI, 15-33%]) patients had acute pulmonary embolism.
32	Qu et al., **Infection Control for CT Equipment and Radiographers' Personal Protection During the Coronavirus Disease (COVID-19) Outbreak in China.** *AJR* June 2020 https://www.ajronline.org/doi/full/10.2214/AJR.20.23112	Describe the modifications to the CT examination process to effectively evaluate infection prevention and control management in COVID-19 at one institution.		Strict disinfection of examination rooms, arrangement of waiting areas, and efforts to increase radiographers' awareness of personal protection made at our institution during the COVID-19 outbreak. In addition, they discuss the potential of using artificial intelligence in imaging patients with contagious diseases.
33	Merkler et al. **Risk of Ischemic Stroke in Patients with Covid-19 versus Patients with Influenza** *JAMA* July 2020 https://jamanetwork.com/journals/jamaneurology/fullarticle/2768098	To compare the rate of ischemic stroke between patients with Covid-19 and patients with influenza, a respiratory viral illness previously linked to stroke	1,916	Among 2,132 patients with emergency department visits or hospitalizations with Covid-19, 31 patients had an acute ischemic stroke. The median age of patients with stroke was 69 years and 58% were men. Stroke was the reason for hospital presentation in 8 (26%) cases. For our comparison cohort, we identified 1,516 patients with influenza, of whom 0.2% had an acute ischemic stroke. After adjustment for age, sex, and race, the likelihood of stroke was significantly higher with Covid-19 than with influenza infection. Patients with COVID-19 appear to have a heightened risk of acute ischemic stroke compared with patients with influenza. In this retrospective cohort study from 2 New York City academic hospitals, approximately 1.6% of adults with COVID-19 who visited the emergency department or were hospitalized experienced ischemic stroke, a higher rate of stroke compared with a cohort of patients with influenza. Additional studies are needed to confirm these findings and to investigate possible thrombotic mechanisms associated with COVID-19.
34	Abdel-Mannan et al., **Neurologic and Radiographic Findings Associated With COVID-19 Infection in Children**	To report the neurological manifestations of children with COVID-19.	50	Of the 27 children with COVID-19 pediatric multisystem inflammatory syndrome, 4 patients (14.8%) who were previously healthy had new-onset neurological symptoms. Symptoms included encephalopathy, headaches, brainstem and cerebellar signs, muscle

	JAMA Neurology July 2020 https://jamanetwork.com/journals/jamaneurology/fullarticle/2767979?resultClick=1			weakness, and reduced reflexes. All 4 patients required intensive care unit admission for the treatment of COVID-19 pediatric multisystem inflammatory syndrome. In this case-series study, children with COVID-19 presented with new neurological symptoms involving both the central and peripheral nervous systems and splenial changes on imaging, in the absence of respiratory symptoms. Additional research is needed to assess the association of neurological symptoms with immune-mediated changes among children with COVID-19.
35	Mahammedi et al., **Imaging in Neurological Disease of Hospitalized COVID-19 Patients: An Italian Multicenter Retrospective Observational Study** *Radiology* May 2020 https://pubs.rsna.org/doi/10.1148/radiol.2020201933	The purpose of the study was to systematically characterize neurological symptoms and neuroimaging features in hospitalized COVID-19 patients from multiple institutions in Italy.		Of 725 consecutive hospitalized patients with COVID-19, 108 (15%) had acute neurological symptoms requiring neuroimaging. The most common neurological symptoms were altered mental status in 64 (59%) patients and ischemic stroke in 34 (31%) patients. The neuroimaging features of hospitalized COVID-19 patients were variable, without specific pattern but dominated by acute ischemic infarcts and intracranial hemorrhages. MR neuroimaging spectrum may include posterior reversible encephalopathy syndrome, hypoxic-ischemic encephalopathy, exacerbation of demyelinating disease and nonspecific cortical pattern of T2 FLAIR hyperintense signal with associated restriction diffusion that may be caused by systemic toxemia, viremia and/or hypoxic effects. Currently, there is a poor mechanistic understanding of the neurological symptoms in COVID-19 patients, whether these are arising from critical illness or from direct CNS invasion of SARS-CoV-2.
36	Jin Y-H, Cai L et al. **A rapid advice guideline for the diagnosis and treatment of 2019 novel coronavirus (2019-nCoV) infected pneumonia (standard version).** *Mil Med Res* 2020;7:4. https://mmrjournal.biomedcentral.com/articles/10.1186/s40779-020-0233-6	Based on the request from frontline clinicians and public health professionals of 2019-nCoV infected pneumonia management, an evidence-based guideline urgently needs to be developed.		This guideline includes the guideline methodology, epidemiological characteristics, disease screening and population prevention, diagnosis, treatment and control (including traditional Chinese Medicine), nosocomial infection prevention and control, and disease nursing of the 2019-nCoV. This rapid advice guideline is suitable for the first frontline doctors and nurses, managers of hospitals and healthcare sections, community residents, public health persons, relevant researchers, and all person who are interested in the 2019-nCoV.
37	Ting DSW, Carin L et al. **Digital technology and COVID-19.** *Nature Medicine* March 2020 https://www.nature.com/articles/s41591-020-0824-5	To explore the potential application of four inter-related digital technologies (the IoT, big-data analytics, AI and blockchain) to augmenting two traditional public-health strategies for tackling COVID-19: (1) monitoring, surveillance, detection and prevention of COVID-19; and (2) mitigation of the impact to healthcare indirectly related to COVID-19		There is a wide range of digital technology that can be used to augment and enhance these public-health strategies. The immediate use and successful application of digital technology to tackle a major, global public-health challenge in 2020 will probably increase the public and governmental acceptance of such technologies for other areas of healthcare, including chronic disease in the future.

38	Zheng Y-Y, Ma Y-T et al. **COVID-19 and the cardiovascular system.** *Nature Reviews Cardiology.* https://www.nature.com/articles/s41569-020-0360-5	Understanding the damage caused by SARS- CoV-2 to the cardiovascular system and the underlying mechanisms is of the greatest importance, so that treatment of these patients can be timely and effective, and mortality reduced.		Severe acute respiratory syndrome coronavirus 2 (SARS- CoV-2) infects host cells through ACE2 receptors, leading to coronavirus disease (COVID-19)-related pneumonia, while also causing acute myocardial injury and chronic damage to the cardiovascular system. Particular attention should be given to cardiovascular protection during treatment for COVID-19.
39	Bai H, Ben H, Xiong Z et al **Performance of radiologists in differentiating COVID-19 from viral pneumonia on chest CT.** *Radiology* March 2020. https://doi.org/10.1148/radiol.2020200823	To assess the performance of United States (U.S.) and Chinese radiologists in differentiating COVID-19 from viral pneumonia on chest CT.	424	Radiologists in China and the United States distinguished COVID-19 from viral pneumonia on chest CT with high specificity but moderate sensitivity. Three Chinese radiologists had sensitivities of 72%, 72% and 94% and specificities of 94%, 88% and 24% in differentiating 219 COVID-19 from 205 non-COVID-19 pneumonia. Four United States radiologists had sensitivities of 93%, 83%, 73% and 73% and specificities of 100%, 93%, 93% and 100%. The most discriminating features for COVID-19 pneumonia included a peripheral distribution (80% vs. 57%, $p<0.001$), ground-glass opacity (91% vs. 68%, $p<0.001$) and vascular thickening (58% vs. 22%, $p<0.001$).
40	Zhao W, Zhong Z, Xie X et al **Relation Between Chest CT Findings and Clinical Conditions of Coronavirus Disease (COVID-19) Pneumonia: A Multicenter Study** *AJR* March 2020. https://www.ajronline.org/doi/abs/10.2214/AJR.20.22976	to investigate the relation between chest CT findings and the clinical conditions of COVID-19 pneumonia.	101	Patients with confirmed COVID-19 pneumonia have typical imaging features that can be helpful in early screening of highly suspected cases and in evaluation of the severity and extent of disease. Most patients with COVID-19 pneumonia have GGO or mixed GGO and consolidation and vascular enlargement in the lesion. Lesions are more likely to have peripheral distribution and bilateral involvement and be lower lung predominant and multifocal. CT involvement score can help in evaluation of the severity and extent of the disease.
41	Leung et al., **Respiratory virus shedding in exhaled breath and efficacy of face masks** *Nature Medicine* March 2020 https://doi.org/10.1038/s41591-020-0843-2	To identify human coronaviruses, influenza viruses and rhinoviruses in exhaled breath and coughs of children and adults with acute respiratory illness.	123	Viral RNA was identified from respiratory droplets and aerosols for all three viruses. Surgical face masks significantly reduced detection of influenza virus RNA in respiratory droplets and coronavirus RNA in aerosols, with a trend toward reduced detection of coronavirus RNA in respiratory droplets.
42	Van Doremalen et al., **Aerosol and Surface Stability of SARS-CoV-2 as Compared with SARS-CoV-1** *NEJM* March 2020 https://www.nejm.org/doi/10.1056/NEJMc2004973	To evaluate the stability of SARS-CoV-2 and SARS-CoV-1 in aerosols and on various surfaces and estimated their decay rates using a Bayesian regression model		Results indicate that aerosol and fomite transmission of SARS-CoV-2 is plausible, since the virus can remain viable and infectious in aerosols for hours and on surfaces up to days (depending on the inoculum shed). These findings echo those with SARS-CoV-1, in which these forms of transmission were associated with nosocomial spread and super-spreading events, and they provide information for pandemic mitigation efforts
43	Pan et al., **Association of Public Health Interventions With the Epidemiology of the COVID-19 Outbreak in Wuhan, China** *JAMA* March 2020 https://jamanetwork.com/journals/jama/fullarticle/2764658	To evaluate the association of public health interventions with the epidemiological features of the COVID-19 outbreak in Wuhan by 5 periods according to key		A series of multifaceted public health interventions was temporally associated with improved control of the COVID-19 outbreak in Wuhan, China. Findings may inform public health policy in other countries and regions

		events and interventions.		
44	Foust et al., **International Expert Consensus Statement on Chest Imaging in Pediatric COVID-19 Patient Management: Imaging Findings, Imaging Study Reporting and Imaging Study Recommendations** *Radiology* April 2020 https://pubs.rsna.org/doi/10.1148/ryct.2020200214	To specifically address concerns around pediatric patients, a group of international experts in pediatric thoracic imaging from 5 continents convened to create a consensus statement describing the imaging manifestations, reporting and recommendations		Results were compiled into two structured reporting algorithms (one for CXR and one for chest CT) and 8 consensus recommendations for utilization of chest imaging in pediatric COVID-19 infection
45	Zhou et al., **Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study** *Lancet* March 2020 https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(20)30566-3/fulltext	To report risk factors for mortality and a detailed clinical course of illness, including viral shedding		Potential risk factors of older age, high SOFA score, and d-dimer greater than 1 µg/mL could help clinicians to identify patients with poor prognosis at an early stage. Prolonged viral shedding provides the rationale for a strategy of isolation of infected patients and optimal antiviral interventions in the future.
46	Oudkerk et al., **Diagnosis, Prevention, and Treatment of Thromboembolic Complications in COVID-19: Report of the National Institute for Public Health of the Netherlands.** *Radiology* April 2020 https://pubs.rsna.org/doi/10.1148/radiol.2020201629	A potential link between mortality, D-dimer values and a prothrombotic syndrome has been reported in patients with COVID-19 infection.		This report summarizes evidence for thromboembolic disease, potential diagnostic and preventive actions as well as recommendations for patients with COVID-19 infection.
47	Nair et al., **A British Society of Thoracic Imaging statement: considerations in designing local imaging diagnostic algorithms for the COVID-19 pandemic** *Clinical Radiology* March 2020 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7128118/	They considered how a CXR would also fit into diagnostic algorithms, and in particular, how the use of CT would alter management in settings where a CXR was or was not available.		A high pre-test probability is assumed for symptomatic cases, based on one or more of: clinical presentation (Pyrexia of 37.8); acute onset persistent cough, hoarseness, nasal discharge or congestion, shortness of breath, sore throat, wheezing, sneezing; and compatible laboratory abnormalities (relative lymphopenia, elevated C-reactive protein [CRP]
48	Borghesi et al., **Radiographic severity index in COVID-19 pneumonia: relationship to age and sex in 783 Italian patients** *La radiologia medica* May 2020	To improve the risk stratification of patients infected with SARS-CoV-2, an experimental chest X-ray (CXR) scoring system for quantifying lung abnormalities was introduced in our	783	The CXR score was significantly higher in males than in females only in groups aged 50 to 79 years. A significant correlation was observed between the CXR score and age in both males and females. Males aged 50 years or older and females aged 80 years or older with coronavirus disease 2019 showed the highest CXR score (median ≥ 8). In conclusion, males aged 50 years or older and females aged 80 years or older showed the highest risk of

	https://link.springer.com/content/pdf/10.1007/s11547-020-01202-1.pdf	Diagnostic Imaging Department.		developing severe lung disease. Our results may help to identify the highest-risk patients and those who require specific treatment strategies.
49	Jones et al., **COVID-19 and Kawasaki Disease: Novel Virus and Novel Case** *Hospital Pediatrics* April 2020 https://hosppeds.aappublications.org/content/early/2020/04/06/hpeds.2020-0123	This study looked at a total of 2143 patients, 1412 of whom had suspected but unconfirmed COVID-19 infection, but there was little description of co-incidence of other clinical conditions, and no cases reported of concurrent Kawasaki disease (KD). Authors describe the case of a pediatric patient diagnosed and treated for classic KD in the setting of confirmed COVID-19 infection, published with parental permission.	2143	This is the first described case of KD with concurrent COVID-19 infection. KD is an acute vasculitis of childhood and the leading cause of acquired heart disease in children in developed countries, with 50% of cases occurring in those <2 years of age, and 80% in those <5 years of age.4 The diagnosis of "classic" KD is considered in patients presenting with fever for 5 days together with at least 4 out of 5 clinical criteria in the absence of an alternate diagnosis. Although the clinical significance of our patient's positive COVID-19 testing in the setting of her KD is not clear, her testing for COVID-19 appears accurate. This case report may serve as a useful reference to other clinicians caring for pediatric patients affected by COVID-19 as understanding of the clinical presentation patterns continue to evolve. Further description of the clinical course of pediatric patients diagnosed with COVID-19 remains necessary, particularly regarding the potential association with KD.
50	Daly et al., **Neuropilin-1 is a host factor for SARS-CoV-2 infection** *bioRxiv* June 2020 https://www.biorxiv.org/content/10.1101/2020.06.05.134114v1	The study investigated the biological importance of the SARS-CoV-2 S1 interaction with Neuropilin-1 (NRP1).		It was demonstrated that, in addition to engaging the known receptor ACE2, SARS-CoV-2 can bind to Neuropilin-1 (NRP1). This interaction enhances infection by SARS-CoV-2 in cell culture. NRP1 thus serves as a host factor for SARS-CoV-2 infection and provides a therapeutic target for COVID-19.
51	Cantuti-Castelvetri et al., **Neuropilin-1 facilitates SARS-CoV-2 cell entry and provides a possible pathway into the central nervous system** *bioRixv* June 2020 https://www.biorxiv.org/content/10.1101/2020.06.07.137802v2	Understanding how SARS-CoV-2 enters and spreads within human organs is crucial for developing strategies to prevent viral dissemination. For many viruses, tissue tropism is determined by the availability of virus receptors on the surface of host cells2. Both SARS-CoV and SARS-CoV-2 use angiotensin-converting enzyme 2 (ACE2) as a host receptor, yet, their tropisms differ.		It was shown that cellular receptor neuropilin-1 (NRP1), known to bind furin-cleaved substrates, significantly potentiates SARS-CoV-2 infectivity, which was inhibited by a monoclonal blocking antibody against the extracellular b1b2 domain of NRP1. NRP1 is abundantly expressed in the respiratory and olfactory epithelium, with highest expression in endothelial cells and in the epithelial cells facing the nasal cavity. Neuropathological analysis of human COVID-19 autopsies revealed SARS-CoV-2 infected NRP1-positive cells in the olfactory epithelium and bulb. In the olfactory bulb infection was detected particularly within NRP1-positive endothelial cells of small capillaries and medium-sized vessels. Studies in mice demonstrated, after intranasal application, NRP1-mediated transport of virus-sized particles into the central nervous system. Thus, NRP1 could explain the enhanced tropism and spreading of SARS-CoV-2.
52	Ellinghaus et al., **Genomewide Association Study of Severe Covid-19 with Respiratory Failure** *NEJM* June 2020	Respiratory failure is a key feature of severe Covid-19 and a critical driver of mortality, but for reasons poorly defined affects less than 10% of SARS-		We herein report the first robust genetic susceptibility loci for the development of respiratory failure in Covid-19. 835 Covid-19 patients and 1,255 controls from Italy, and 775 Covid-19 patients and 950 controls from Spain were included in the final analysis. In Total, 8,582,968 single-nucleotide polymorphisms (SNPs) were analyzed using a metaanalysis

	https://www.nejm.org/doi/full/10.1056/NEJMoa2020283	CoV-2 infected patients.		of both case-control panels. The signal was located at the ABO blood group locus and a blood-group-specific analysis showed higher risk for A-positive individuals and a protective effect for blood group O. Identified variants may help guide targeted exploration of severe Covid-19 pathophysiology.
53	Kaminetzky et al., **Pulmonary Embolism on CTPA in COVID-19 Patients** *Radiology* July 2020 https://pubs.rsna.org/doi/10.1148/ryct.2020200308	To evaluate PE prevalence on computed tomography pulmonary angiogram (CTPA) in COVID+ patients and factors associated with PE severity	62	62 patients underwent CTPA prior to the first reported local COVID-19 case were retrogradely selected. The relative rate of CTPA-positivity was recorded.37.1% of COVID+ CTPA exams diagnosed PE. PE can be a cause of decompensation in COVID+, and D-dimer can be used to stratify patients regarding PE risk and severity. Patients with confirmed COVID-19 had pulmonary embolism diagnosed in 37% of CTPA examinations with D-dimer levels associated with the presence of pulmonary embolism and the degree of pulmonary artery obstruction.

1. Pan et al., 2020 CT findings in 63 patients in Wuhan, China. Eur Radiology (Feb 2020)[1]

Aim: The purpose of this study was to observe the imaging characteristics of the novel coronavirus pneumonia.

Materials and Methods: Sixty-three confirmed patients were enrolled. High-resolution CT (HRCT) of the chest was performed. The number of affected lobes, ground glass nodules (GGO), patchy/punctate ground glass opacities, patchy consolidation, fibrous stripes and irregular solid nodules in each patient's chest CT image were recorded.

Results: Mean number of affected lobes was 3.3 ± 1.8. Nineteen (30.2%) patients had one affected lobe, five (7.9%) patients had two affected lobes, four (6.3%) patients had three affected lobes, seven (11.1%) patients had four affected lobes while 28 (44.4%) patients had 5 affected lobes. Fifty-four (85.7%) patients had patchy/punctate ground glass opacities, 14 (22.2%) patients had GGO, 12 (19.0%) patients had patchy consolidation, 11 (17.5%) patients had fibrous stripes and 8 (12.7%) patients had irregular solid nodules. Fifty-four (85.7%) patients progressed, including single GGO increased, enlarged and consolidated; fibrous stripe enlarged, while solid nodules increased and enlarged.

Fig. 1. Images showing GGO (ground-glass opacity (arrow)

Conclusion: Imaging changes in novel viral pneumonia are rapid. The manifestations of the novel coronavirus pneumonia are diverse. Imaging changes of typical viral pneumonia and some specific imaging features were observed. Therefore, we need to strengthen the recognition of image changes to help clinicians to diagnose quickly and accurately.

Bayer´s comment: *Initial CT findings for COVID patients show different patterns in the lungs.*

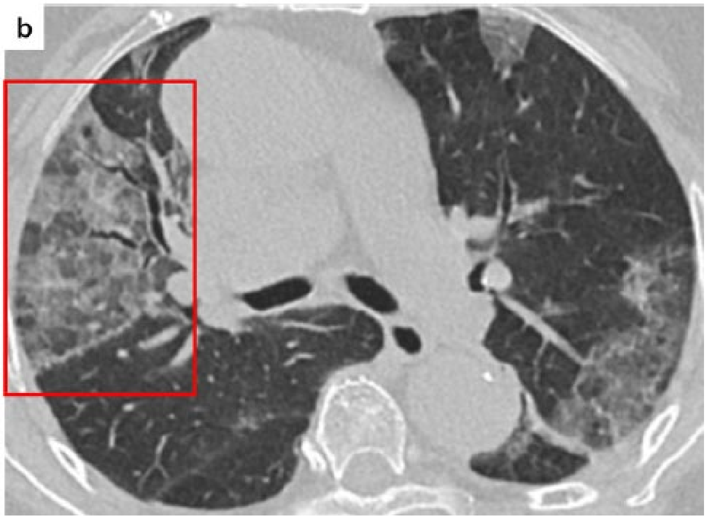
2. Ye et al., Chest CT manifestations- Pictorial review. Eur Radiology (Feb 2020)[2]

Aim: To review the typical and relatively atypical CT manifestations with representative COVID-19.

Materials and Methods: We will respectively describe each imaging feature of COVID-19 with RT-PCR confirmed cases at our hospital.

Results: GGO were defined as hazy areas with slightly increased density in lungs without obscuration of bronchial and vascular margins, which may be caused by partial displacement of air due to partial filling of airspaces or interstitial thickening. Reticular pattern was defined as thickened pulmonary interstitial structures such as interlobular septa and intralobular lines, manifested as a collection of innumerable small linear opacities on CT images. Crazy paving pattern demonstrates as thickened interlobular septa and intralobular lines with superimposition on a GGO background, resembling irregular paving stones.

Fig. 2



CT scan shows reticular pattern superimposed on the background of GGO, resembling the sign of crazy paving stones in the right middle lobe (red frame)

Conclusion: The various imaging features for COVID-19 are described in a pictorial fashion.

Bayer´s comment: *Good pictorial review of the various imaging aspects and good educational article.*

3. Fang et al., Sensitivity of Chest CT – Comparison with RT-PCR. Radiology (Feb 2020)[3]

Aim: The purpose of this study was to compare the sensitivity of chest CT and viral nucleic acid assay at initial patient presentation.

Materials and Methods: In this retrospective analysis 51 patients were included who had chest CT and RT-PCR performed. Patients who presented with a history of travel to Wuhan within 14 days and those with fever or acute respiratory symptoms were included. If initial negative RT-PCR testing, repeat testing was performed at 1-day intervals.

Results: 50/51 (98%) patients had evidence of abnormal CT compatible with viral pneumonia at baseline while one patient had a normal CT. Of 50 patients with abnormal CT, 36 (72%) had typical CT manifestations (e.g. peripheral, subpleural ground glass opacities, often in the lower lobes. In this patient sample, difference in detection rate for initial CT (50/51) patients was greater than first RT-PCR (36/51) patients.

Fig. 3. 74-year male with CT showing bilateral subpleural ground glass opacities (GGO)

Conclusion: The sensitivity of chest CT was greater than that of RT-PCR (98% vs 71%, respectively. The study results support the use of chest CT for screening of COVID-19 patients with clinical and epidemiologic features particularly when RT-PCR testing is negative

Bayer´s comment: *Other studies have reported much higher sensitivity for RT-PCR. The authors acknowledge the reasons for low efficacy of viral nucleic acid detection. RT-PCR is highly sensitive, however, at late stage a throat swab might be not reliable anymore as the virus replicates in the lungs. Therefore, suction catheter or sputum is needed for PCR test.*

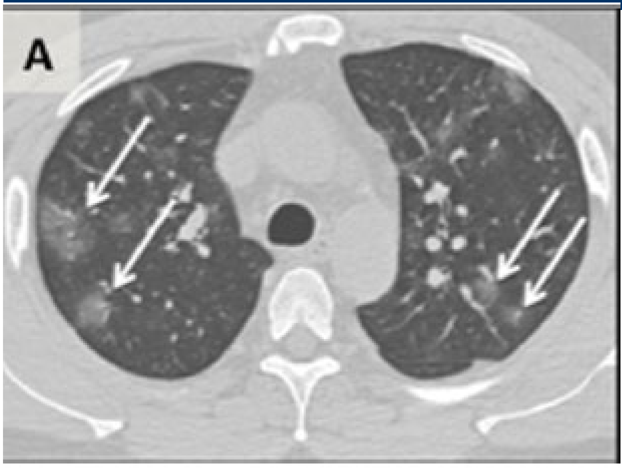
4. Bernheim et al., Chest CT findings in COVID-19- Infection Duration. Eur Radiology (Feb 2020)[4]

Aim: Chest CT were reviewed for common CT findings in relationship to the time between symptom onset and initial CT scan.

Materials and Methods: 121 adult patients admitted to four hospitals who underwent chest CT were enrolled.

Results: Of the 121 patients 27 (22%) had no ground-glass opacities and no consolidation on chest CT. Of the 94 patients with ground-glass opacities, consolidation, or both, 41 (34%) had only ground-glass opacities (with no consolidation), and 2 patients (2%) had consolidation in the absence of ground-glass opacities. 18 (15%) had opacities in one lobe, 14 patients (12%) had two affected lobes, 11 patients (9%) had three affected lobes, 18 patients (15%) had four affected lobes, and 33 patients (27%) had disease affecting all five lobes. 73 of 121 patients (60%) had bilateral lung disease. Thoracic lymphadenopathy, lung cavitation and pulmonary nodules were absent in all 121 patients and only 1 patient had a pleural effusion.

Fig. 4



An axial CT image without intravenous contrast in a 36-year-old male shows bilateral ground-glass opacities in the upper lobes with a rounded morphology (arrows).

Conclusion: Pattern of ground glass and consolidative pulmonary opacities often with bilateral and peripheral lung distribution is emerging as the chest CT hallmark of COVID-19 infection.

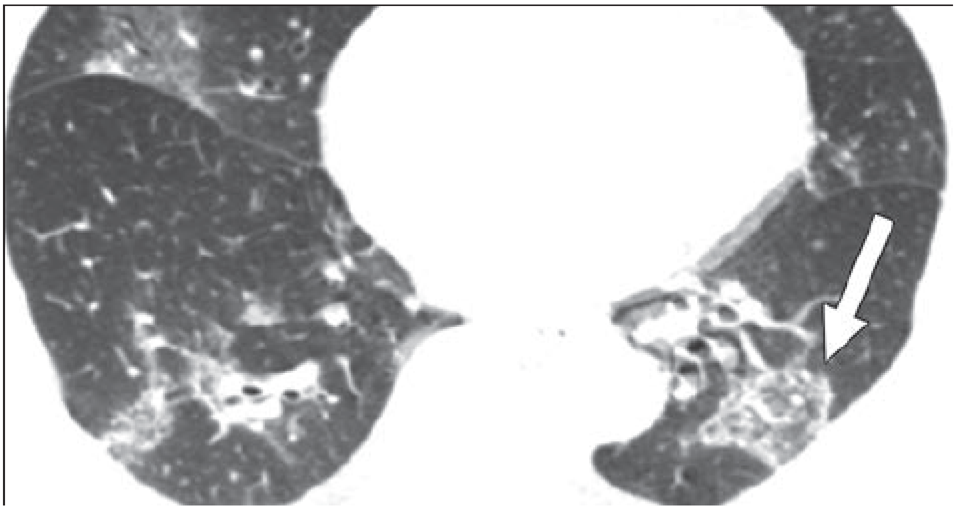
5. Li et al., Role of Chest CT in Diagnosis and management. AJR (March 2020)[5]

Aim: To determine the misdiagnosis rate of radiologists for coronavirus disease 2019 (COVID-19) and evaluate the performance of chest CT in the diagnosis and management of COVID-19.

Materials and Methods: This study included the first 51 patients with a diagnosis of COVID-19 infection confirmed by nucleic acid testing (23 women and 28 men; age range, 26–83 years) and two patients with adenovirus (one woman and one man; ages, 58 and 66 years). We reviewed the clinical information, CT images, and corresponding image reports of these 53 patients. The CT images included images from 99 chest CT examinations, including initial and follow-up CT studies. We compared the image reports of the initial CT study with the laboratory test results and identified CT patterns suggestive of viral infection

Results: COVID-19 was misdiagnosed as a common infection at the initial CT study in two inpatients with underlying disease and COVID-19. Viral pneumonia was correctly diagnosed at the initial CT study in the remaining 49 patients with COVID-19 and two patients with adenovirus. our study group of patients with COVID-19, CT showed a reversed halo sign in two (3.9%) patients and pulmonary nodules with a halo sign in nine (17.6%) patients.

Fig. 5. Transverse CT scan shows “reversed halo” sign in left lower lobe (arrow)



Conclusion: Chest CT had a low rate of missed diagnosis of COVID-19 (3.9%, 2/51) and may be useful as a standard method for the rapid diagnosis of COVID-19 to optimize the management of patients.

6. Shi et al., Radiological findings from 81 patients. Eur Radiology (Feb 2020)[6]

Aim: Aim to describe the CT findings across different time points throughout the disease course.

Materials and Methods: 81 patients with COVID-19 pneumonia (confirmed by next-generation sequencing or RT-PCR) who underwent serial chest CT scans were retrospectively enrolled. Patients were grouped based on the interval between symptom onset and the first CT scan: group 1 (subclinical patients; scans done before symptom onset), group 2 (scans done ≤1 week after symptom onset), group 3 (>1-week to 2 weeks), and group 4 (>2 weeks to 3 weeks). Imaging features and their distribution were analyzed and compared across the four groups.

Results: They found predominantly bilateral abnormality (79%), peripheral (54%), ill-defined (81%) and ground-glass opacification (65%) mainly in right lower lobes. In group 1 (n=15), the predominant pattern was unilateral (nine [60%]) and multifocal (eight [53%]) ground-glass opacities (14 [93%]). Lesions quickly evolved to bilateral (19 [90%]), diffuse (11 [52%]) ground-glass opacity predominance (17 [81%]) in group 2 (n=21). Thereafter, the prevalence of ground-glass opacities continued to decrease (17 [57%] of 30 patients in group 3, and five [33%] of 15 in group 4), and consolidation and mixed patterns became more frequent (12 [40%] in group 3, eight [53%] in group 4).

Conclusion: COVID-19 pneumonia manifests with chest CT imaging abnormalities, even in asymptomatic patients, with rapid evolution from focal unilateral to diffuse bilateral ground-glass opacities that progressed to or co-existed with consolidations within 1–3 weeks

Bayer´s comment: *Describes the time course among the various groups in terms of image findings and the time course of disease evolution. Limitations include use of WHO criteria in 33 patients, inability to account for individual variations and having follow-up CT in only 57 patients of the 81*

7. Han et al., Early Clinical and CT manifestations. AJR (March 2020)[7]

Aim: To investigate early clinical and CT manifestations of COVID-19 pneumonia.

Materials and Methods: Patients with COVID-19 pneumonia confirmed by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) nucleic acid test (reverse transcription–polymerase chain reaction) were enrolled in this retrospective study. The clinical manifestations, laboratory results, and CT findings were evaluated.

Results: One hundred eight patients included with 94/108 having fever as clinical manifestation. The distribution of involved lobes was one lobe in 38 (35%) patients, two or three lobes in 24 (22%), and four or five lobes in 46 (43%). The major involvement was peripheral (97 patients [90%]), and the common lesion shape was patchy (93 patients [86%]). Sixty-five (60%) patients had ground-glass opacity (GGO), and 44 (41%) had GGO with consolidation. The size of lesions varied from smaller than 1 cm (10 patients [9%]) to larger than 3 cm (56 patients [52%]). Vascular thickening (86 patients [80%]), crazy paving pattern (43 patients [40%]), air bronchogram sign (52 patients [48%]), and halo sign (69 [64%]) were also observed in this study.

Conclusion: The early CT findings are patchy GGO with or without consolidation involving multiple lobes, mainly in the peripheral zone, accompanied by halo sign, vascular thickening, crazy paving pattern, or air bronchogram sign.

Bayer´s comment: *No CT follow-up to evaluate treatment efficacy and no histopathologic correlation of CT findings available.*

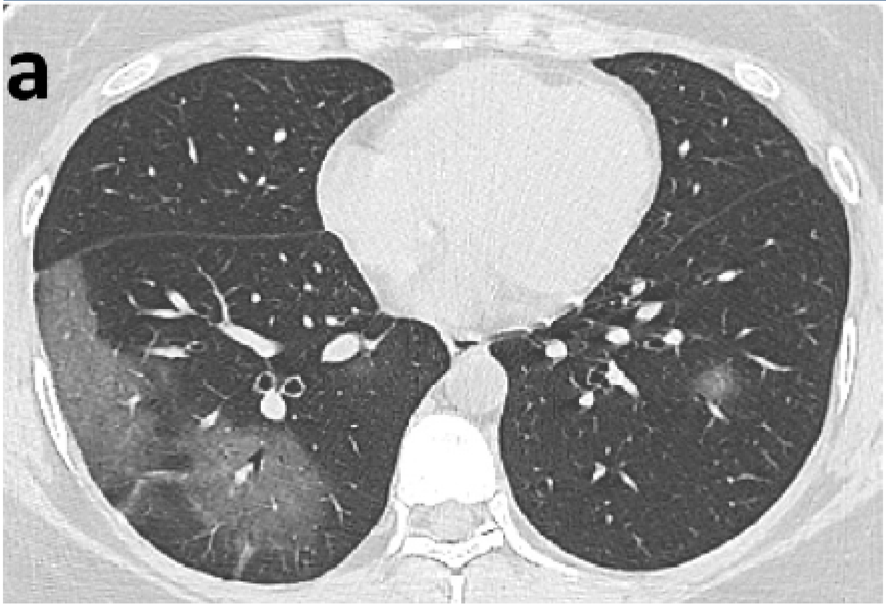
8. Wang et al., Temporal changes in 90 patients. Eur Radiology (March 2020)[8]

Aim: To perform a longitudinal study to analyze the serial CT findings over time in patients with COVID-19 pneumonia.

Materials and Methods: 90 patients (mean age, 45 years) with COVID-19 pneumonia were prospectively enrolled and followed up. A total of 366 CT scans were acquired and reviewed by 2 groups of radiologists for the patterns and distribution of lung abnormalities.

Results: CT scores and number of zones involved progressed rapidly and peaked during days 6-11. The main pattern of abnormalities after symptom onset was ground-glass opacity (35/78 [45] to 49/79 [62%]. Pure ground-glass opacity was the most prevalent of the GGO after symptom onset. Ground-glass opacity with superimposed irregular lines and interfaces was more commonly seen since illness days 6-11. Lesions distribution was bilateral and subpleural. Consolidation was the second most prevalent finding during illness days 0-5 and 6-11, with the percentage of 18/79 (23%) and 20/85 (24%).

Fig. 6. Scan obtained on day 1 showed multiple pure ground-glass opacity mainly in right lower lobe of 35-year woman.



Conclusion: The extent of lung abnormalities on CT peaked during illness days 6-11. The temporal changes of the diverse CT manifestations followed a specific pattern, which might indicate the
progression and recovery of the illness.

9. Ai et al., Correlation of Chest CT and RT-PCR Testing COVID-19 in China: A Report of 1014 Cases. Radiology (Feb 2020)[9]

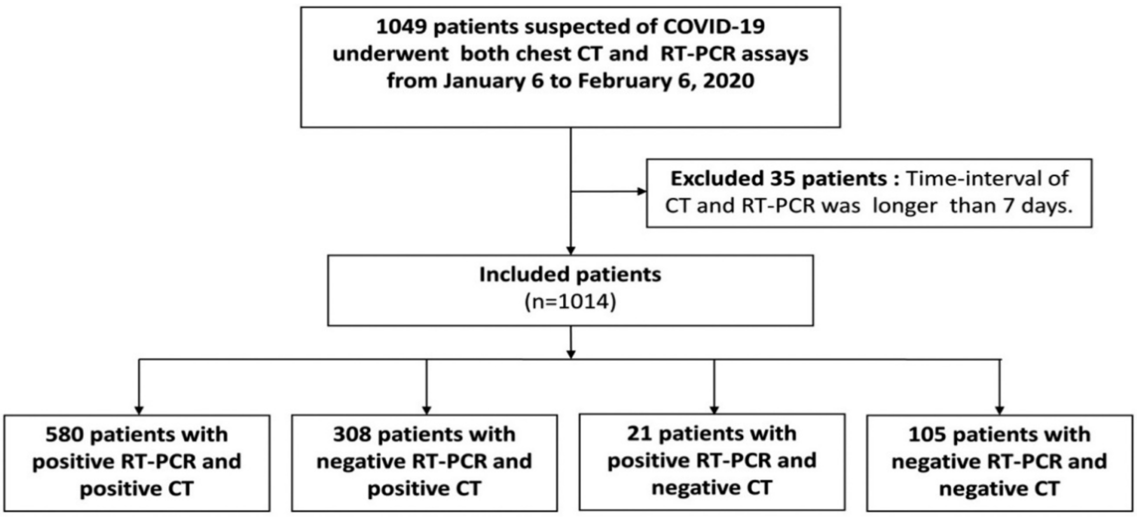
Aim: To investigate the diagnostic value and consistency of chest CT as compared with comparison to RT-PCR assay in COVID-19.

Materials and Methods: From Jan 6 - Feb 6, 2020, 1,014 patients in Wuhan, China who underwent both chest CT and RT-PCR tests were included. With RT-PCR as reference standard, the performance of chest CT in diagnosing COVID-19 was assessed.

Besides, for patients with multiple RT-PCR assays, the dynamic conversion of RT-PCR results (negative to positive, positive to negative, respectively) was analyzed as compared with serial chest CT scans for those with time-interval of 4 days or more.

Results:

- Of 1014 patients, 59% (601/1014) had positive RT-PCR results, and 88% (888/1014) had positive chest CT scans. The sensitivity of chest CT in suggesting COVID-19 was 97% (95%CI, 95-98%, 580/601 patients) based on positive RT-PCR results.
- In patients with negative RT-PCR results, 75% (308/413) had positive chest CT findings; of 308, 48% were considered as highly likely cases, with 33% as probable cases.
- By analysis of serial RT-PCR assays and CT scans, the mean interval time between the initial negative to positive RT-PCR results was 5.1 ± 1.5 days; the initial positive to subsequent negative RT-PCR result was 6.9 ± 2.3 days).
- 60% to 93% of cases had initial positive CT consistent with COVID-19 prior (or parallel) to the initial positive RT-PCR results. 42% (24/57) cases showed improvement in follow-up chest CT scans before the RT-PCR results turning negative.



Conclusion:

- Chest CT has a high sensitivity for diagnosis of COVID-19. Chest CT may be considered as a primary tool for the current COVID-19 detection in epidemic areas.
- Chest CT imaging has high sensitivity for diagnosis of COVID-19. This study and analysis suggest that chest CT should be considered for the COVID-19 screening, comprehensive evaluation, and following-up, especially in epidemic areas with high pre-test probability for disease.

Author's opinion:

- In the current emergency, the low sensitivity of RT-PCR implies that many COVID-19 patients may not be identified and may not receive appropriate treatment in time; such patients constitute a risk for infecting a larger population given the highly contagious nature of the virus. Chest CT, as a routine imaging tool for pneumonia diagnosis, is relatively easy to perform and can produce fast diagnosis.
- In this context, chest CT may provide benefit for diagnosis of COVID-19. As recently reported, chest CT demonstrates typical radiographic features in almost all COVID-19 patients, including ground-glass 4 opacities, multifocal patchy consolidation, and/or interstitial changes with a peripheral distribution **(1).**
- Those typical features were also observed in patients with negative RT-PCR results but clinical symptoms. It has been noted in small-scale studies that the current RT-PCR testing has limited sensitivity, while chest CT may reveal pulmonary abnormalities consistent with COVID-19 in patients with initial negative RT-PCR results **(2,3)**

References

(1) *Chung M, Bernheim A, Mei X et al. CT imaging features of 2019 novel coronavirus (2019-nCoV).* ***Radiology*** *2020. DOI: 10.1148/radiol.2020200230.*
(2) *Huang P, Liu T, Huang L et al. Use of chest CT in combination with negative RT-PCR assay for the 2019 novel coronavirus but high clinical suspicion.* ***Radiology*** *2020. DOI: 10.1148/radiol.2020200330.*
(3) *Xie X, Zhong Z, Zhao W et al. Chest CT for typical 2019-nCoV pneumonia: relationship to negative RT-PCR testing.* ***Radiology*** *2020. DOI: 10.1148/radiol.2020200343.*

Bayer´s comment:

- *The typical findings in Chest CT with negative RT-PCR testing in highly endemic areas or highly suspected patients could be an indicative to the early treatment for these patients till the confirmation with PCR.*
- *CT can't be a screening tool as recommended by most of the societies however CT is very important in adding the diagnosis and follow up of the patients.*

10. Chen N, Zhou M, Dong X et al. Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study, The Lancet (Feb 2020)[10]

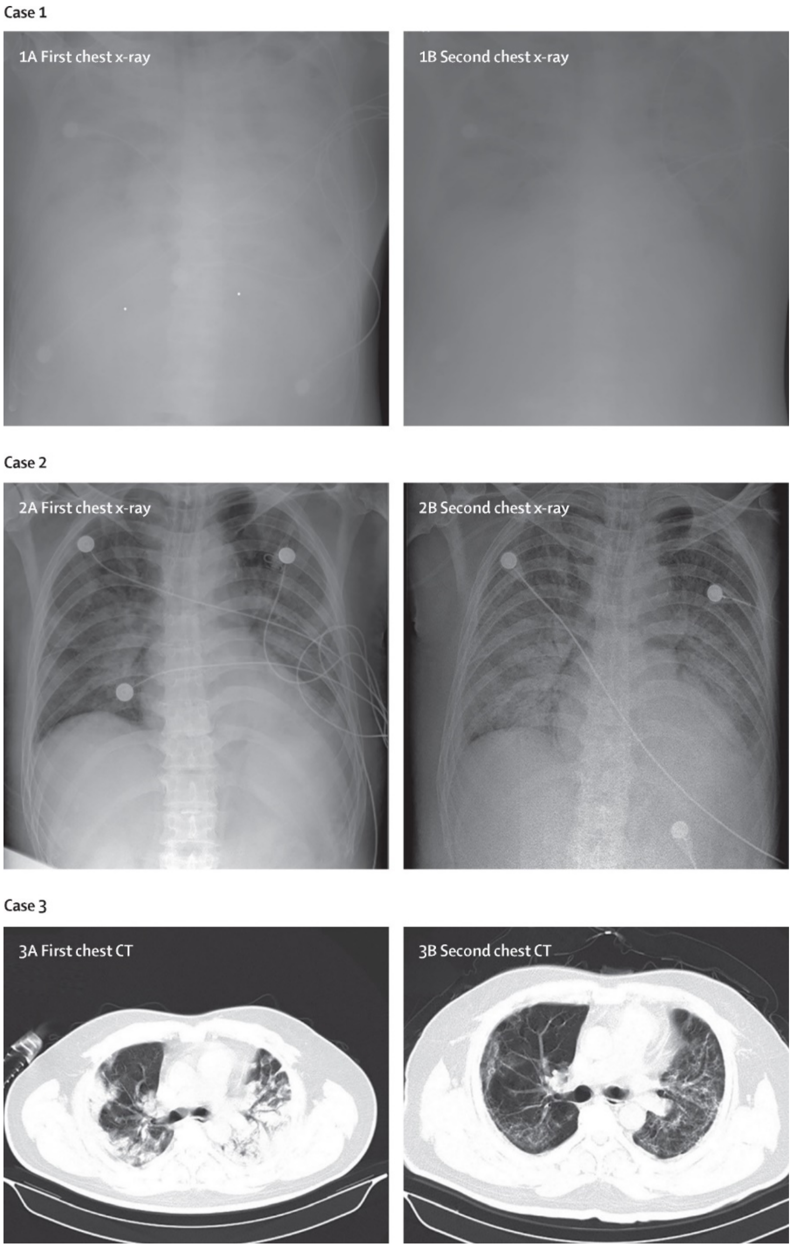
Aim: To clarify the epidemiological and clinical characteristics of 2019-nCoV pneumonia.

Materials and Methods: Retrospective, single-center study included all confirmed cases of 2019-nCoV in Wuhan Jinyintan Hospital from Jan 1 to Jan 20, 2020. Cases were confirmed by real-time RT-PCR and were analyzed for epidemiological, demographic, clinical, and radiological features and laboratory data. Outcomes were followed up until Jan 25, 2020.The study included 99 patients.

Results:

- Of the 99 patients with 2019-nCoV pneumonia, 49 (49%) had a history of exposure to the Huanan seafood market.
- 2019-nCoV was detected in all patients by real-time RT-PCR.
- The average age of the patients was 55·5 years (SD 13·1), including 67 men and 32 women.
- 50 (51%) patients had chronic diseases.
- Patients had clinical manifestations of fever (82 [83%] patients), cough (81 [82%] patients), shortness of breath (31 [31%] patients), muscle ache (11 [11%] patients), confusion (nine [9%] patients), headache (eight [8%] patients), sore throat (five [5%] patients), rhinorrhoea (four [4%] patients), chest pain (two [2%] patients), diarrhea (two [2%] patients), and nausea and vomiting (one [1%] patient).
- 17 (17%) patients developed acute respiratory distress syndrome and, among them, 11 (11%) patients worsened in a short period of time and died of multiple organ failure.
- **According to chest x-ray and CT**, 74 (75%) patients showed bilateral pneumonia (75%) with just 25 (25%) patients showing unilateral pneumonia. 14 (14%) patients showed multiple mottling and ground-glass opacity. Additionally, pneumothorax occurred in one (1%) patient.

Fig. 7



Case 1: chest x-ray was obtained on Jan 1 (1A). The brightness of both lungs was diffusely decreased, showing a large area of patchy shadow with uneven density. Tracheal intubation was seen in the trachea and the heart shadow outline was not clear. The catheter shadow was seen from the right axilla to the mediastinum. Bilateral diaphragmatic surface and costal diaphragmatic angle were not clear, and chest x-ray on Jan 2 showed worse status (1B).

Case 2: chest x-ray obtained on Jan 6 (2A). The brightness of both lungs was decreased and multiple patchy shadows were observed; edges were blurred, and large ground-glass opacity and condensation shadows were mainly on the lower right lobe. Tracheal intubation could be seen in the trachea. Heart shadow roughly presents in the normal range. On the left side, the diaphragmatic surface is not clearly displayed. The right side of the diaphragmatic surface was light and smooth, and rib phrenic angle was less sharp. Chest x-ray on Jan 10 showed worse status (2B).

Case 3: chest CT obtained on Jan 1 (3A) showed mass shadows of high density in both lungs. Bright bronchogram is seen in the lung tissue area of the lesion, which is also called broncho-inflation sign. Chest CT on Jan 15 showed improved status (3B).

Conclusion:

- The 2019-nCoV infection was of clustering onset, is more likely to affect older males with comorbidities, and can result in severe and even fatal respiratory diseases such as acute respiratory distress syndrome.
- In general, characteristics of patients who died were in line with the MuLBSTA score, an early warning model for predicting mortality in viral pneumonia. Further investigation is needed to explore the applicability of the MuLBSTA score in predicting the risk of mortality in 2019-nCoV infection.
- Early identification and timely treatment of critical cases of 2019-nCoV are important. Effective life support and active treatment of complications should be provided to effectively reduce the severity of patients' conditions and prevent the spread of this new coronavirus in China and worldwide.

- Study has several limitations:
    - First, only 99 patients with confirmed 2019-nCoV were included; suspected but undiagnosed cases were ruled out in the analyses. It would be better to include as many patients as possible in Wuhan, in other cities in China, and even in other countries to get a more comprehensive understanding of 2019-nCoV.
    - Second, more detailed patient information, particularly regarding clinical outcomes, was unavailable at the time of analysis; however, the data in this study permit an early assessment of the epidemiological and clinical characteristics of 2019-nCoV pneumonia in Wuhan, China.

Bayer´s comment: *Studying the epidemiological, clinical, lab and imaging characteristic of the COVID-19 patients is very important to aid in the better diagnosis and early treatment. The MuLBSTA score system and identifying other scores could aid in the predicting the risk of mortality and helping to identify the patients who are at sever risk. However, as per the study further investigation is needed to explore the applicability of the MuLBSTA score in predicting the risk of mortality in 2019-nCoV infection.*

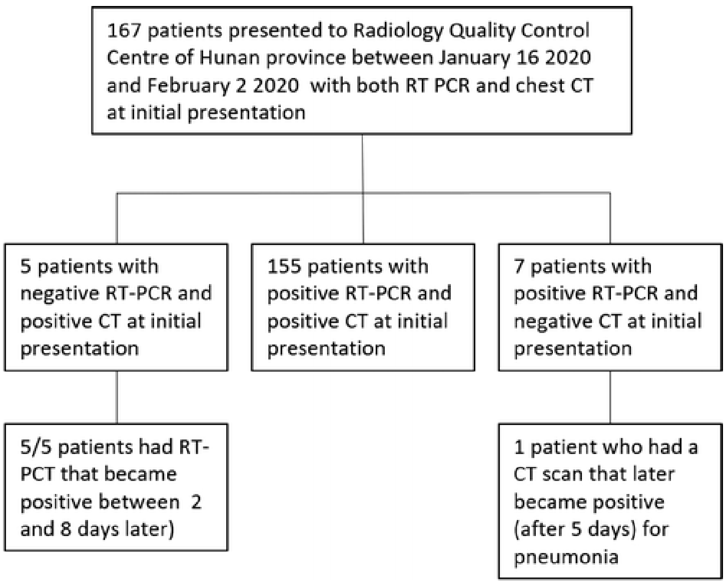
11. Xie, X, Zhong, Z, Zhao, W, Zheng, C, Wang, F, Liu, J. Chest CT for typical 2019-nCoV pneumonia: relationship to negative RT-PCR testing. Radiology (Feb 2020)[11]

Aim: The purpose of the study was to describe CT imaging features of five patients with initial negative or weakly positive RT-PCR results but high suspicion of 2019-nCoV infection.

Materials and Methods: Available clinical history, laboratory, and epidemic characteristics were collected. According to the guideline of 2019-nCoV, the patients were typed into four group, mild, common, severe and fatal types. All patients underwent CT scanning on the same day when initial mouth swab test was performed.

Results:

- 167 patients were evaluated; of these 5 (3%) patients initially had negative RT-PCR but positive chest CT with pattern consistent with viral pneumonia.
- After positive CT findings, all patients were isolated for presumed 2019-nCoV pneumonia. Repeat swab testing and RT-PCR tests 2019-nCoV infection in all patients.
- In 7 patients (4%), CT was initially negative while RT-PCR was positive. In 155 patients (93%), both RT-PCR and CT were concordant for 2019-nCoV infection. Of the 5 patients with negative RT-PCR and positive CT at initial presentation.



Conclusion: In the context of typical clinical presentation and exposure to other individuals with 2019-nCoV, CT features of viral pneumonia may be strongly suspicious for 2019-nCoV infection despite negative RT-PCR results. In these cases, repeat swab testing and patient isolation should be considered.

Bayer´s comment: *CT findings in highly suspected patents of COVID-19 infection with negative RT-PCR is very important to consider.*

12. Song F, Shi N, Shan F et al. Emerging Coronavirus 2019-nCoV Pneumonia. Radiology (Feb 2020)[12]

Aim: To investigate the clinical, laboratory, and imaging findings of emerging 2019-nCoV pneumonia in humans

Materials and Methods: 51 patients with laboratory-confirmed 2019-nCoV infection by using real-time reverse transcription polymerase chain reaction underwent thin-section CT. The imaging findings, clinical data, and laboratory data were evaluated. All CT examinations were performed with a 64-section scanner without the use of contrast material. The CT protocol was as follows: tube voltage, 120 kV; automatic tube current (180 mA–400 mA); iterative reconstruction technique; detector, 64 mm; rotation time, 0.35 second; section thickness, 5 mm; collimation, 0.625 mm; pitch, 1.5; matrix, 512 × 512; and breath hold at full inspiration. Reconstruction kernel used was lung smooth with a thickness of 1 mm and an interval of 0.8 mm. The following windows were used: a mediastinal window with a window width of 350 HU and a window level of 40 HU, and a lung window with a width of 1200 HU and a level of −600 HU.

Results:

- 51 patients included 25 (49%) men and 26 (51%) women, with ages ranging from 16 to 76 years (mean age, 49 years ± 16 [standard deviation).
- 50 patients (98%) had some contact with individuals from Wuhan, China.
- Most common symptoms were fever (49 of 51, 96%) and cough (24 of 51, 47%).
- Most of the patients had a normal white blood cell count (37 of 51, 73%) and neutrophil count (44 of 51, 86%). The lymphocyte count was low (33 of 51, 65%) or normal (17 of 51, 35%). C-reactive protein level was elevated in 41 of 51 patients (80%). Thirty-one of 51 (61%) patients had a low CD4+ cell count, with a range of 72–408 cells/µL.
- 44 of 51 (86%) patients with a total of 1284 of 1324 (97%) lesions involving both lungs and 32 of 51 (63%) patients with 1194 of 1324 (90%) lesions involving four to five lobes.
- 46 of 51 (90%) patients with 703 of 1324 (53%) lesions distributed in the lower lobes, 41 of 51 (80%) patients with 1179 of 1324 (89%) lesions distributed in the posterior part of the lung, and 44 of 51 (86%) patients with 1198 of 1324 (91%) lesions distributed in the lung periphery.

Conclusion: The most common patterns of 2019 Novel Coronavirus (2019-nCoV) pneumonia on thin-section CT images are pure ground-glass opacity (GGO), GGO with reticular and/or interlobular septal thickening, GGO with consolidation, and consolidation, with prominent distribution in the posterior and peripheral part of the lungs. Consolidation lesions could serve as a marker of disease progression or more severe disease. Although the positive nucleic acid testing is the diagnostic reference standard, patients with fever and/or cough and with GGO-prominent lesions in the peripheral and posterior part of lungs on CT images, combined with normal or decreased white blood cells and a history of epidemic exposure, should be highly suspected of having 2019-nCoV pneumonia.

Bayer´s comment: *CT findings in highly suspected patents of COVID-19 infection with negative RT-PCR is very important to consider.*

13. Pan F, Ye T et al. Time course of lung changes on chest CT during recovery from 2019 novel coronavirus (COVID-19) pneumonia. Radiology (March 2020)[13]

Aim: To determine the change in chest CT findings associated with COVID-19 pneumonia from initial diagnosis until patient recovery.

Materials and Methods: This retrospective review included patients with RT-PCR confirmed COVID-19 infection presenting between 12 January 2020 to 6 February 2020. Repeated Chest CT was obtained at approximately 4-day intervals. The total CT score was the sum of lung involvement (5 lobes, score 1-5 for each lobe, range, 0 none, 25 maximum) was determined.

Results:

- 21 patients (6 males and 15 females, age 25-63 years) with confirmed COVID-19 pneumonia were evaluated and underwent a total of 82 pulmonary CT scans with a mean interval of 4±1 days (range: 1-8 days).
- All patients were discharged after a mean hospitalized period of 17±4 days (range: 11-26 days).
- Maximum lung involved peaked at approximately 10 days (with the calculated total CT score of 6) from the onset of initial symptoms ($R2=0.25$), $p<0.001$).
- Based on quartiles of patients from day 0 to day 26 involvement, 4 stages of lung CT were defined

1. Early stage (0-4 days after onset of the initial symptom): In this stage, GGO was the main radiological demonstration distributed subpleurally in the lower lobes unilaterally or bilaterally.
2. Progressive stage (5-8 days after the onset of the initial symptom): In this stage, the infection rapidly aggravated and extended to a bilateral multi-lobe distribution with diffuse GGO, crazy-paving pattern and consolidation.
3. Peak stage (9-13 days after the onset of the initial symptom): In this stage, the involved area of the lungs slowly increased to the peak involvement and dense consolidation became more prevalent. Findings included diffuse GGO, crazy-paving pattern, consolidation, and residual parenchymal bands.
4. Absorption stage (≥14 days after the onset of the initial symptom): In this stage, the infection was controlled, and the consolidation was gradually absorbed. No crazy-paving pattern was present anymore. However, in this process, extensive GGO could be observed as the demonstration of the consolidation absorption. Noticeably, in this study, no crazy-paving was observed in this stage, likely as a result of recovering. Based on the total CT score, the absorption stage extended beyond 26 days (our last days of follow-up) from the onset of initial symptoms.

Conclusion:

- In patients recovering from COVID-19 pneumonia (without severe respiratory distress during the disease course), lung abnormalities on chest CT showed greatest severity approximately 10 days after initial onset of symptoms.
- In patients recovering from COVID-19 infection, four stages of evolution on chest CT were identified: early stage (0-4 days); progressive stage (5-8 days); peak stage (10-13 days); and absorption stage (≥14 days).

- In patients who recovered from COVID-19 pneumonia, initial lung findings on chest CT were small subpleural ground glass opacities (GGO) that grew larger with crazy-paving pattern and consolidation.
- Lung involvement increased to consolidation up to two weeks after disease onset.
- After two weeks, the lesions were gradually absorbed leaving extensive GGO and subpleural parenchymal bands.

Bayer´s comment: *The study showed that the severity in CT appears after 10 days with classification of the evolution of CT features according to stages from mild to severe. A limitation of the study is the lack of a severe COVID-19 comparison group. Most of the patients with severe pneumonia and ARDS are still hospitalized. Therefore, the analysis was limited to patients with mild COVID-19 pneumonia.*

14. Ng MY,Lee EYP et al. Imaging Profile of the COVID-19 Infection: Radiologic Findings and Literature Review. Radiology (Feb 2020)[14]

Aim: To present 21 COVID-19 cases from two Chinese centers with CT and chest radiograph (CXR) findings, as well as follow-up imaging in 5 cases.

Materials and Methods: Retrospective study in Shenzhen and Hong Kong. Patients with COVID-19 infection were included. A systematic review of the published literature on COVID-19 infection's radiological features.

Results:

- The predominant imaging pattern is of ground-glass opacification with occasional consolidation in the peripheries.
- Pleural effusions and lymphadenopathy were absent in all cases.
- Patients demonstrate evolution of the ground-glass opacities into consolidation, and subsequent resolution of the airspace changes.
- Ground-glass and consolidative opacities visible on CT are sometimes undetectable on chest radiographs, suggesting that CT is a more sensitive imaging modality for investigation.
- The systematic review identified 4 other studies confirming the findings of bilateral and peripheral ground glass with or without consolidation as the predominant finding on CT chest examinations.

Conclusion:

- The COVID-19 infection pulmonary manifestation is predominantly characterized by ground-glass opacification with occasional consolidation on CT.
- CT has been used on a massive scale to help identify and investigate suspected or confirmed cases of COVID-19.
- The most common findings on chest CT were bilateral ground-glass opacities with or without consolidation in the lung periphery.
- The e power of this CT in helping to raise suspicion as well as to follow the course of the disease is becoming increasingly apparent. In the Guangdong province, chest CTs are being requested on every patient suspected of having COVID-19.
- In addition to aiding in disease screening and follow-up evaluation, further investigation is also necessary to determine the role of CT in helping guiding therapy.

Bayer´s comment: *Chest CT is playing an important role in patients with suspected infection in the diagnosis and follow up of these patients. Further investigation is necessary to determine the role of CT in guiding therapy.*

15. Chung M, Bernheim A et al. CT Imaging Features of 2019 Novel Coronavirus (2019-nCoV). Radiology (Feb 2020)[15]

Aim: To describe and characterize the key CT findings in a group of 21 patients infected with 2019-nCoV in China, with the goal of familiarizing radiologists and clinical teams with the imaging manifestations of this new outbreak. Early disease recognition can speed up treatment and prompt early patient isolation. This will allow for early implementation of public health surveillance, containment, and response to this communicable disease.

Materials and Methods: From January 18, 2020, until January 27, 2020, 21 patients admitted to three hospitals in three provinces in China with confirmed 2019-nCoV underwent chest CT. All scans were obtained with the patient in the supine position during end-inspiration without intravenous contrast material. All patients were positive for 2019-nCov at laboratory testing of respiratory secretions obtained by means of bronchoalveolar lavage, endotracheal aspirate, nasopharyngeal swab, or oropharyngeal swab.

Results:

- Of 21 patients with the 2019 novel coronavirus, 15 (71%) had involvement of more than two lobes at chest CT, 12 (57%) had ground-glass opacities, seven (33%) had opacities with a rounded morphology, seven (33%) had a peripheral distribution of disease, six (29%) had consolidation with ground-glass opacities, and four (19%) had crazy-paving pattern.
- Lung cavitation, discrete pulmonary nodules, pleural effusions, and lymphadenopathy were absent.
- Fourteen percent of patients (three of 21) presented with a normal CT scan.

Conclusion:

- The radiologist plays a crucial role in the rapid identification and early diagnosis of new cases, which can be of great benefit not only to the patient but to the larger public health surveillance and response systems.
- There is value in recognizing that the CT appearance of 2019-nCoV shares some similarities with that of other diseases that cause viral pneumonia, particularly those within the same viral family (SARS and MERS).
- Presently, worldwide public health measures are updating and evolving daily to manage this current outbreak. As new cases are identified, other unique pulmonary CT imaging manifestations may emerge as potential points for discernment in this patient population.
- Future studies will be instrumental in determining how patients with parenchymal lung disease evolve after treatment.

Bayer´s comment: *With the study limitations presented as small number of patient's chest radiography may have some utility, with the potential to serve as a screening tool on the front lines in medical settings with high disease prevalence but limited resources. However the gold standard in the confirmation of the disease is the RT-PCR testing.*

16. Mossa-Basha M, Meltzer C et al. et al. Radiology Department Preparedness for COVID-19: Radiology Scientific Expert Panel. Radiology (March 2020)[16]

Aim: The *Radiology* Editorial Board has assembled a team of radiologists who are active in coordination, development, and implementation of radiology preparedness policies for COVID-19. Radiology preparedness is a set of policies and procedures directly applicable to imaging departments designed to support the care of patients with COVID-19, and to maintain radiologic diagnostic and interventional support for the entirety of the hospital and health system. The Editorial Board hopes that readers may find one or more the highlighted healthcare systems to be similar to their own, providing impetus for action or confirmation of your current preparedness activities.

Materials and Methods: Review of a highlighted healthcare readiness for the COVID-19 infections.

Results: The recommendations are summarized in the below tables

Table 1: Relationship between the healthcare institution and radiology department in relationship to the COVID-19 pandemic
☐ Central coordination for COVID-19 preparedness for messaging between hospital infection control and the radiology department
☐ Screening (standardized questionnaire) for COVID-19 prior to patient examinations, at the time of scheduling, hospital entrances and at radiology front desks
☐ Rapid isolation of patients with suspicion of COVID-19 at screening
☐ Training of all employees to follow infection control protocols and to use personal protective equipment (PPE)
☐ Centralization of PPE supplies to prevent shortages, distributed based on clinical need
☐ Restricted travel for staff for all domestic and international work –related activities
☐ Use of video-conferencing for hospital/ health system staff meetings.

Table 2: Radiology Preparedness for COVID-19 pandemic
☐ Implementation of standard operating procedures for radiological imaging and procedures for patients with known or suspected COVID-19 exposure
☐ Imaging only for those COVID-19 patients where imaging will impact management
☐ Performance of imaging at locations with less foot traffic and with fewer critically ill patients. When possible, portable imaging is performed
☐ Standardized hospital protocols for decontaminating imaging rooms, especially CT scanners, after caring for a COVID-19 patient
☐ Improving capability for remote interpretations (home, other sites) in the case of staff isolation or patient surge

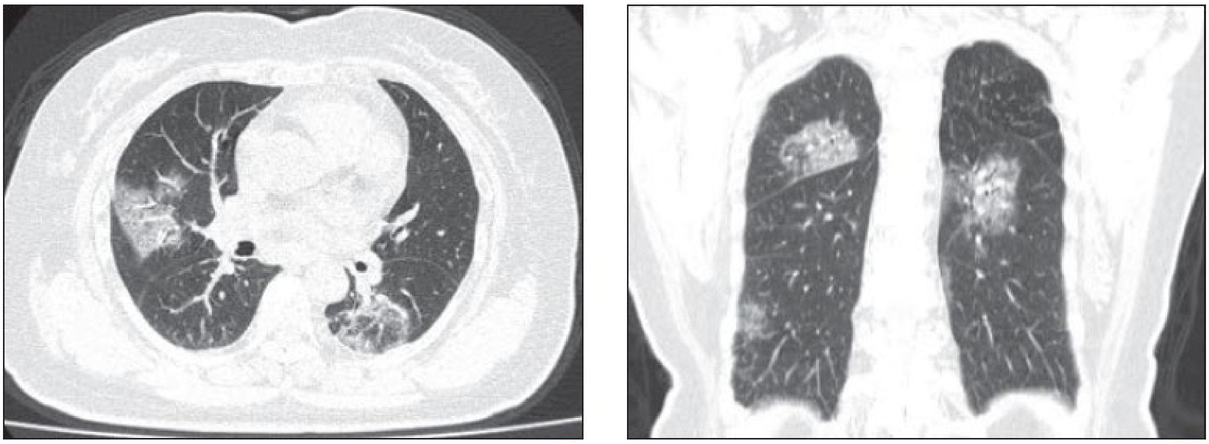
Bayer´s comment: *The radiology department readiness for the endemic is very crucial and should be in line with the hospital and the national healthcare system. Looking to the variations of measures between institutions. That could help the single department or hospital to adapt the suitable measures and to recognize new measures which they can introduce.*

17. Hosseiny et al., Radiology Perspective of COVID-19: Lessons From Severe Acute Respiratory Syndrome and Middle East Respiratory Syndrome. Cardiopulmonary Imaging (Feb 2020)[17]

Aim: The aim of this review is to familiarize radiologists with the imaging spectrum of coronavirus syndromes and to discuss the reported imaging features of COVID-19. Since the etiologic and clinical features of COVID-19 are similar to those of severe acute respiratory syndrome (SARS) and Middle East respiratory syndrome (MERS), the experience from those pulmonary syndromes can be helpful for managing the emerging COVID-19 outbreak.

Conclusion: The reported imaging features in COVID-19 are variable and nonspecific and have significant overlap with those of SARS and MERS. Early evidence suggests that initial chest imaging will show abnormality in at least 85% of patients, with 75% of patients having bilateral lung involvement initially that most often manifests as subpleural and peripheral areas of ground-glass opacity and consolidation. Older age and progressive consolidation might suggest poorer prognosis. Besides the acute phase, CT is recommended for follow-up in individuals who are recovering from COVID-19 to evaluate long-term or permanent lung damage including fibrosis, as is seen with SARS and MERS infections.

Fig. 8



A B

79-year-old woman who presented with fever, dry cough, and chest pain for 3 days. Her husband and daughter-in-law had been recently diagnosed with COVID-19. Patient expired 11 days after admission
A and **B,** Axial (A) and coronal (B) CT images show multiple patchy, peripheral, bilateral areas of groundglass opacity.

Bayer´s comment: *This review of experiences with the MERS and SARS outbreaks shows that some imaging features of SARS and MERS overlap with COVID-19. The experiences with SARS and MERS show that follow-up imaging should be performed in individuals recovering from COVID-19 to look for evidence of chronic involvement of the lungs.*

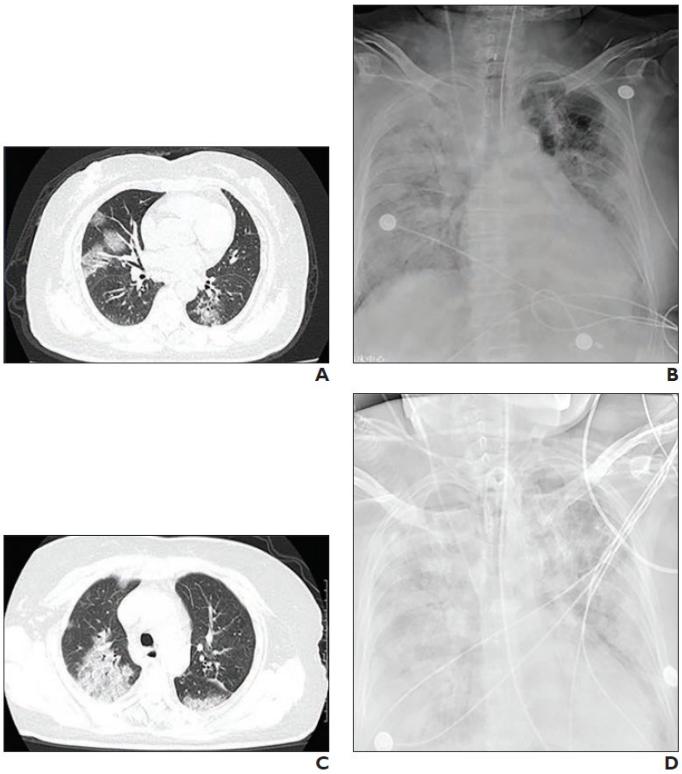
18. Salehi et al., Coronavirus Disease 2019 (COVID-19): A Systematic Review of Imaging Findings in 919 Patients.AJR (Feb 2020)[18]

Aim: Available information on CT features of COVID-19 is scattered in different publications, and a cohesive literature review has yet to be compiled.

Materials and Methods: Systematic literature search of PubMed, Embase (Elsevier), Google Scholar, and the World Health Organization database.

Results: Known features of COVID-19 on initial CT include bilateral multilobar ground-glass opacification (GGO) with a peripheral or posterior distribution, mainly in the lower lobes and less frequently within the right middle lobe. Atypical initial imaging presentation of consolidative opacities superimposed on GGO may be found in a smaller number of cases, mainly in the elderly population. Septal thickening, bronchiectasis, pleural thickening, and subpleural involvement are some of the less common findings, mainly in the later stages of the disease. Pleural effusion, pericardial effusion, lymphadenopathy, cavitation, CT halo sign, and pneumothorax are uncommon but may be seen with disease progression. Follow-up CT in the intermediate stage of disease shows an increase in the number and size of GGOs and progressive transformation of GGO into multifocal consolidative opacities, septal thickening, and development of a crazy paving pattern, with the greatest severity of CT findings visible around day 10 after the symptom onset. Acute respiratory distress syndrome is the most common indication for transferring COVID-19 patients to the intensive care unit (ICU) and the major cause of death in these patients. Imaging patterns corresponding to clinical improvement usually occur after week 2 of the disease and include gradual resolution of consolidative opacities and decrease in the number of lesions and involved lobes.

Fig. 9



79-year-old woman who presented with chest pain, cough, and fever for 3 days. Patient developed acute respiratory distress syndrome within subsequent few days and died 11 days after admission. A and B, CT image (A) and chest radiograph (B) show ground glass opacification (GGO) on day 1. C and D, CT image (C) and chest radiograph (D) obtained on day 4 show GGO has progressed to airspace consolidation.

Conclusion: This review of available English studies of COVID-19 provides insight into the initial and follow-up CT imaging findings for the disease.

Bayer´s comment: *This systematic literature review (Feb 19, 2020) identified the CT characteristics of COVID-19 by summarizing key imaging findings in different stages of the disease. Reported findings should be interpreted with caution since several studies are limited in terms of sample size, data availability, and methodologic quality.*

19. Li et al., AI distinguishes COVID-19 from pneumonia on Chest CT. Radiology (March 2020)[19]

Aim: To develop a fully automatic framework to detect COVID-19 using chest CT and evaluate its performances and robustness.

Materials and Methods: A deep learning model, COVID-19 detection neural network (COVNet), was developed to extract visual features from volumetric chest CT exams for the detection of COVID-19. Community acquired pneumonia (CAP) and other non-pneumonia CT exams were included to test the robustness of the model. Datasets were collected from 6 hospitals. Diagnostic performance was assessed by the area under the receiver operating characteristic curve (AUC), sensitivity and specificity.

Results: The collected dataset consisted of 4356 chest CT exams from 3,322 patients. The per-exam sensitivity and specificity for detecting COVID-19 in the independent test set was 114 of 127 (90%) and 294 of 307 (96%), respectively, with an AUC of 0.96. The per-exam sensitivity and specificity for detecting CAP in the independent test set was 87% (152 of 175) and 92% (239 of 259), respectively, with an AUC of 0.95.

Conclusion: A deep learning model can accurately detect COVID-19 and differentiate it from CAP and other lung disease.

Fig. 10

Table 3. The performance of deep learning framework COVNet on the independent testing set.

	Sensitivity %	Specificity %	AUC	P-value
COVID-19	90 (114 of 127) [83, 94]	96 (294 of 307) [93, 98]	0.96 [0.94, 0.99]	<0.001
CAP	87 (152 of 175) [81, 91]	92 (239 of 259) [88, 95]	0.95 [0.93, 0.97]	<0.001
Non-Pneumonia	94 (124 of 132) [88, 97]	96 (291 of 302) [94, 98]	0.98 [0.97, 0.99]	<0.001

Note: Values in parentheses are the numbers for the percentage calculation. Values in brackets are 95% confidence intervals [95%CI, %]. AUC = area under the receiver operating characteristic curve, COVID-19 = coronavirus disease 2019, CAP = community acquired pneumonia, COVNet = COVID-19 detection neural network.

Bayer´s comment: *Li et al. developed a robust deep learning model to differentiate COVID-19 from CAP in chest CT images. Further robustness test of COVNet to differentiate COVID-19 virus from other viral pneumonias (e.g. influenza) that are confirmed by RT-PCR. Deep learning model lacks transparency and interpretability. Model does not categorize COVID-19 into different severity degrees in order to monitor and treat patients.*

20. Yang W, Yan F. Patients with RT-PCR Confirmed COVID-19 and Normal Chest CT. Radiology (Letter to the Editor, March 2020)[20]

Letter to the Editor

Summary: The letter refers to the recent published studies on COVID-19 published in Radiology.
At present, RT-PCR test remains the reference standard to make a definitive diagnose of COVID-19 infection despite the false-negative rate. On the fifth edition of the Diagnosis and Treatment Program of 2019 New Coronavirus Pneumonia proposed by The National Health Commission of China, chest CT findings were included as evidence of clinical diagnosis of COVID-19 for patients in Hubei province. However, chest CT findings were removed from diagnostic criteria in the most recently published sixth version. The final diagnosis of COVID-19 should be confirmed by positive RT-PCR test or gene sequencing.
Authors point out that the early diagnosis of COVID-19 is critical for prevention and control of this pandemic. Clinicians should always be vigilant to identify patients with COVID-19 infection, who may have few or no clinical symptoms, normal chest CT findings, and/or even initial negative RT-PCR test.

Bayer´s comment: *Yang and Yan empathize that the early detection of COVID-19 is critical. Both CT and RT-PCR are critical. However, a normal chest CT scan cannot exclude the diagnosis of COVID-19, especially for patients with early onset of symptoms.*

21. Zu et al., COVID-19: A Perspective from China. Radiology (Feb 2020)[21]

Aim: This review focuses on the etiology, epidemiology, and clinical symptoms of COVID-19, while highlighting the role of chest CT in prevention and disease control.

Summary: Radiologists understanding of clinical and chest CT imaging features of COVID-19 will help to detect the infection early and assess the disease course.

Key points:

- COVID-19 presents with nonspecific clinical manifestations, so diagnosis depends on epidemiological factors including Wuhan exposure or close contact history.
- Typical CT findings of COVID-19 include peripherally distributed multifocal ground-glass opacities (GGOs) with patchy consolidations and posterior part or lower lobe involvement predilection
- Increasing numbers, extent, and density of GGOs on CT indicate disease progression.
- Thin-slice chest CT plays a vital role in early detection, observation, and disease evaluation

Bayer´s comment: *Zu et al. highlight the role of chest CT and how it may help in diagnosis, guide clinical decision making, and monitor disease progression.*

22. Wu Z, McGoogan JM. COVID-19 Outbreak in China: Summary of a Report of 72,314. JAMA (Feb 2020)[22]

Aim: To summarize key findings from the largest Chinese case series of 72,314 patients and discuss emerging understanding of and lessons from the COVID-19 epidemic.

Materials and Methods: Of 72,314 cases, 44,672 were classified as RT-PCR confirmed cases of COVID-19 (62%), 16,186 as suspected cases (22%; based on symptoms only), 10,567 as clinically diagnosed cases (15%; based on symptoms only and chest CT image), and 889 as asymptomatic cases (1%; RT-PCR confirmed but lack of symptoms)

Box. Key Findings From the Chinese Center for Disease Control and Prevention Report

72 314 Cases (as of February 11, 2020)
- Confirmed cases: 44 672 (62%)
- Suspected cases: 16 186 (22%)
- Diagnosed cases: 10 567 (15%)
- Asymptomatic cases: 889 (1%)

Age distribution (N = 44 672)
- ≥80 years: 3% (1408 cases)
- 30-79 years: 87% (38 680 cases)
- 20-29 years: 8% (3619 cases)
- 10-19 years: 1% (549 cases)
- <10 years: 1% (416 cases)

Spectrum of disease (N = 44 415)
- Mild: 81% (36 160 cases)
- Severe: 14% (6168 cases)
- Critical: 5% (2087 cases)

Case-fatality rate
- 2.3% (1023 of 44 672 confirmed cases)
- 14.8% in patients aged ≥80 years (208 of 1408)
- 8.0% in patients aged 70-79 years (312 of 3918)
- 49.0% in critical cases (1023 of 2087)

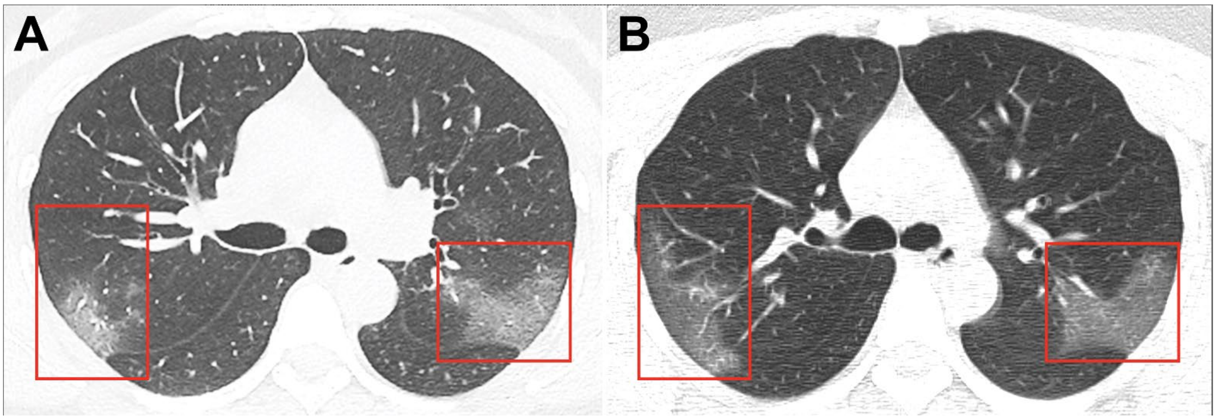
Health care personnel infected
- 3.8% (1716 of 44 672)
- 63% in Wuhan (1080 of 1716)
- 14.8% cases classified as severe or critical (247 of 1668)
- 5 deaths

Conclusion: The major goal of China's current outbreak response activities is to help "buy time" for science to catch up before COVID-19 becomes too widespread. China must now focus on adjusting tactics and strategies as new evidence becomes available.

23. Lei et al., 2020 CT Imaging of the 2019 Novel Coronavirus (2019-nCoV) Pneumonia. Radiology[23]

Case: 33-year-old woman with a 5-day history of fever and cough. Patient worked in Wuhan, China. Body temperature was elevated to 39°C and coarse breath sounds of both lungs were heard at auscultation. Laboratory blood studies showed leucopenia and an increase in C-reactive protein, erythrocyte sedimentation rate and D-dimer. Unenhanced chest CT showed multiple peripheral ground-glass opacities in both lungs (Figure 11A). Patient was COVID-19 positive measured in the sputum by Real-time fluorescence polymerase chain reaction. After 3 days of treatment, combined with interferon inhalation, the patient was clinically worse with progressive pulmonary opacities found at repeat chest CT (Figure 11B).

Fig. 11



Unenhanced CT images in a 33-year-old woman. **A)** Image shows multiple ground-glass opacities in bilateral lungs. Ground-glass opacities are seen in the posterior segment of right upper lobe and apical posterior segment of left superior lobe. **B)** Image obtained 3 days after follow-up shows progressive ground-glass opacities in the posterior segment of right upper lobe and apical posterior segment of left superior lobe. The bilateralism of the peripheral lung opacities, without subpleural sparing, are common CT findings of COVID-19.

***Bayer´s comment:** First case report demonstrating ground-glass opacities in both lungs the published in Radiology.*

24. Yoon SH, Lee KH et al. Chest Radiographic and CT findings of the 2019 Novel Coronavirus Disease (COVID-19): Analysis of Nine Patients treated in Korea. Korean J Radiol (March 2020)[24]

Aim: This study presents a preliminary report on the chest radiographic and computed tomography (CT) findings of the 2019 novel coronavirus disease (COVID-19) pneumonia in Korea.

Materials and Methods: We collected nine patients with COVID-19 infections who had undergone chest radiography and CT scans. We analyzed the radiographic and CT findings of COVID-19 pneumonia at baseline. Fisher's exact test was used to compare CT findings depending on the shape of pulmonary lesions.

Results: Three of the nine patients (33.3%) had parenchymal abnormalities detected by chest radiography, and most of the abnormalities were peripheral consolidations. Chest CT images showed bilateral involvement in eight of the nine patients, and a unilobar reversed halo sign in the other patient. In total, 77 pulmonary lesions were found, including patchy lesions (39%), large confluent lesions (13%), and small nodular lesions (48%). The peripheral and posterior lung fields were involved in 78% and 67% of the lesions, respectively. The lesions were typically ill-defined and were composed of mixed ground-glass opacities and consolidation or pure ground-glass opacities. Patchy to confluent lesions were primarily distributed in the lower lobes ($p = 0.040$) and along the pleura ($p < 0.001$), whereas nodular lesions were primarily distributed along the bronchovascular bundles ($p = 0.006$).

Conclusion: COVID-19 pneumonia in Korea primarily manifested as pure to mixed ground-glass opacities with a patchy to confluent or nodular shape in the bilateral peripheral posterior lungs. A considerable proportion of patients with COVID-19 pneumonia had normal chest radiographs.

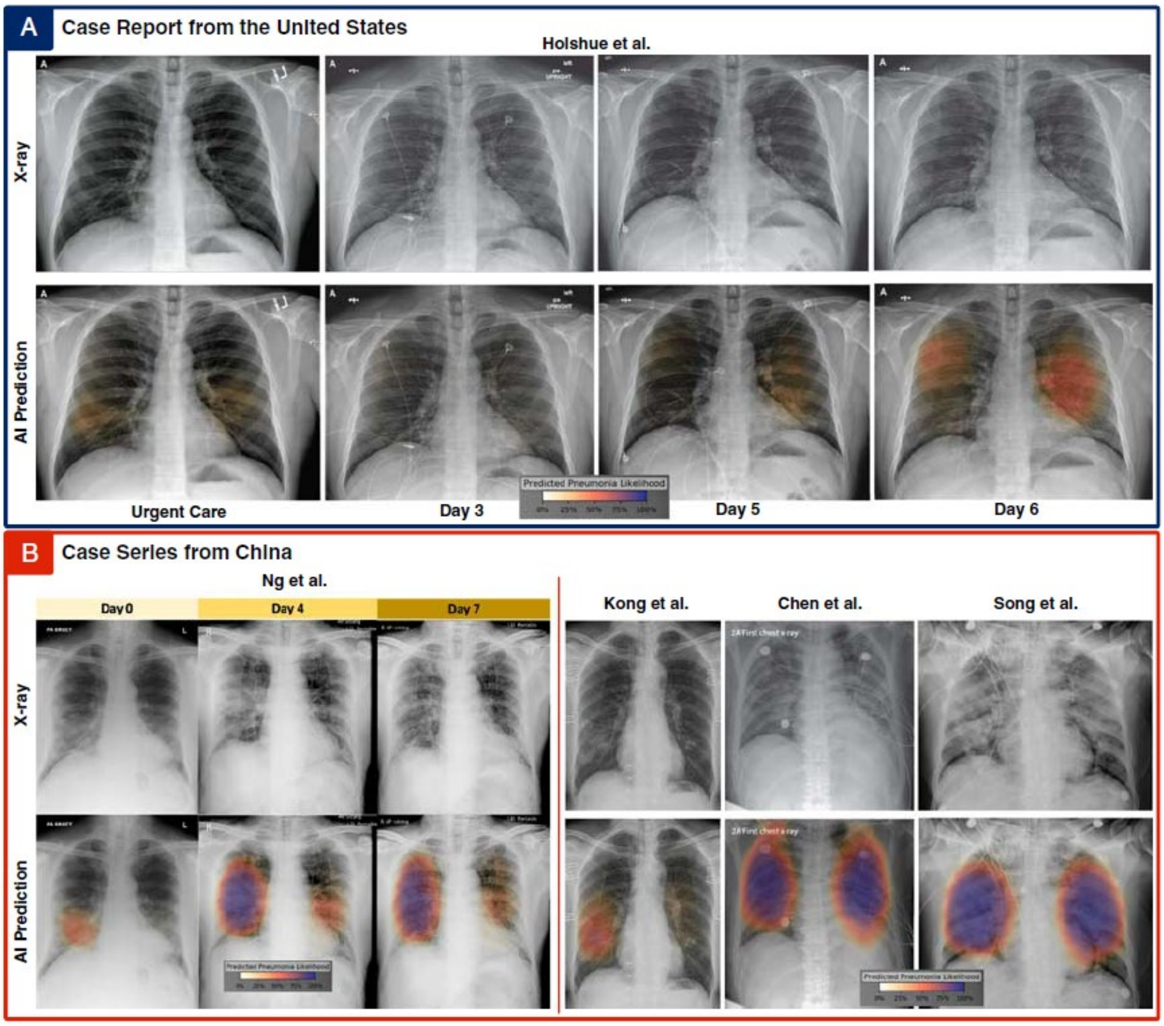
25. Hurt B, Kligerman S, et al. Deep Learning Localization of Pneumonia 2019 Coronavirus (COVID-19) Outbreak. J Thorac Imaging (April 2020)[25]

Aim: This study describes a deep learning approach to augment radiographs with a color probability overlay to improve the diagnosis of pneumonia. In contrast to common whole-image classification approaches, this approach learns pixel-level likelihoods of pneumonia across the lung parenchyma. This provides natural transparency and explainability.

Materials and Methods: 10 frontal chest radiographs from 5 COVID-19 patients treated in China and the US were analyzed. Publication figures with frontal chest radiographs were downloaded as JPEG files and manually cropped to only include the frontal radiograph. These images were used as inputs for our DL algorithm, implemented as a U-Net trained with 22K radiologist-annotated radiographs, which produces pneumonia probability maps overlaid onto an input radiograph.

Results: Radiographs and the corresponding pneumonia probability maps are shown for each x-ray in Figure 12 below. DL algorithm predicted and consistently localized areas of pneumonia with increasing likelihood, as the subtle airspace opacities increased over time. Each radiograph was analyzed by the algorithm independently without awareness of the time course or relationship of previous films.

Fig. 12



Radiographs and the corresponding pneumonia probability maps shown for each x-ray

A) Serial chest radiographs from a US patient with foci of infection that progress over several days. Initially, subtle perihilar airspace opacities are highlighted by the algorithm with low likelihood, which become less apparent on day 3, and continue to progress on days 5 and 6.

B) Additional radiographs from 4 Chinese patients. Increasingly confluent airspace opacities in all 4 patients are each highlighted by the algorithm. The predicted probability map correctly localizes the findings and assigns likelihoods that mirror the severity of the imaging findings.

Conclusion: Results illustrate a degree of generalizability and robustness of the DL approach, suggesting that it may have utility in early diagnosis and longitudinal follow-up of suspected pneumonia, including patients with COVID-19 pneumonia. Results imply that cross-institutional generalizability is feasible.

Bayer´s comment: *A larger study is needed to assess the generalizability of the DL algorithm across multiple institutions. Results from Hurt et al. support the idea that DL algorithms can be a powerful tool for physicians as they become further integrated into the clinical diagnostic workflow. AI may help physicians to augment sensitivity of chest x-ray by highlighting subtle abnormalities that may be missed by less experienced physicians, and triage patients for CT.*

26. Raptis C, Hammer M et al. Chest CT and Coronavirus Disease (COVID-19): A Critical Review of the Literature to Date. AJR (April 2020)[26]

Aim: Studies in the radiology literature have suggested that CT might be sufficiently sensitive and specific in diagnosing COVID-19 when used in lieu of a reverse transcription–polymerase chain reaction test; however, this suggestion runs counter to current society guidelines. The purpose of this article is to critically review some of the most frequently cited studies on the use of CT for detecting COVID-19.

The group outlined the following conclusions:
Sensitivity. Even one false-negative finding on CT could result in outbreaks among patients' contacts, the group noted. "If a study cohort contains patients who are more likely to have a true-positive finding and less likely to have a false-negative finding, sensitivity will be overestimated," it wrote.
Specificity. CT does not describe features that are necessarily unique to COVID-19; those most characteristic of the disease (peripheral, bilateral ground-glass opacities, primarily in the lower lobes) are also associated with other conditions. "We believe that reports of CT having high specificity in diagnosing COVID-19 pneumonia should be viewed with skepticism," the group wrote.
Implications for clinical practice. Overuse of chest CT can deplete hospital resources and bring infected patients into contact with noninfected individuals, thus increasing the risk of disease transmission, the group noted. "Even in situations in which RT-PCR test results are negative, delayed, or not available, no data of which we are aware support CT as an adequate replacement test because its true sensitivity is unknown ... and because CT findings lack specificity," the authors wrote.

Author's Conclusion: To date, the studies reporting CT features of COVID-19 pneumonia have been retrospective reviews and case series. They should be considered low quality, providing a level 3 body of evidence [ACR Appropriateness Criteria: www.acr.org/Clinical-Resources/ACR-Appropriateness-Criteria]. This is not to say these studies are not valuable. Reports of the various CT features of COVID-19 pneumonia are an important first step in helping radiologists identify patients who may have COVID-19 pneumonia in the appropriate clinical environment. However, test performance and management issues arise when inappropriate and potentially overreaching conclusions regarding the diagnostic performance of CT for COVID-19 pneumonia are based on low-quality studies with biased cohorts, confounding variables, and faulty design characteristics. At present, CT should be reserved for evaluation of complications of COVID-19 pneumonia or for assessment if alternative diagnoses are suspected. As the medical community gains experience in treating patients with COVID-19 pneumonia, high- quality data hopefully will emerge and will support a more expanded role for CT. We (and the radiology community at large) will welcome any such data to improve the care of patients with this disease.

Bayer´s comment: *Chest CT screening for diagnosis or exclusion of COVID-19 is currently not recommended by most professional organizations. However, it can evaluate disease extent and support triage of patients. RT-PCR is the gold standard for screening and confirmation of diagnosis. Due to CT's lack of specificity, RSNA has provided recommendations for standardized reporting of COVID-19 imaging features (Simpson S, et al. Radiological Society of North America Expert Consensus Statement on Reporting Chest CT Findings to COVID-19. Endorsed by the Society of Thoracic Radiology, the American College of Radiology, and RSNA. Radiology. 25). Goals are: aid radiologists in recognizing findings, decrease reporting variability, increase confidence reporting findings, facilitate enhanced communication between stakeholders.*

27. Weinstock et al. Chest X-Ray Findings in 636 Ambulatory Patients with COVID-19 Presenting to an Urgent Care Center: A Normal Chest X-Ray Is no Guarantee. JUCM (April 2020)[27]

Aim: To determine what percentage of urgent care (UC) patients with confirmed COVID-19 had normal vs abnormal chest x-rays (CXR) and to describe specific imaging characteristics and the frequency of each abnormal findings on plain film radiography.

Materials and Methods: A electronic medical record database of a large UC company in the greater NYC area was reviewed for patients with positive SARS-CoV-2 PCR tests who also underwent CXR in UC between March 9 and March 24, 2020. Eleven board-certified radiologists, with knowledge that they were only reading imaging studies of COVID-19 patients, were each given a subset of the CXRs with oral and written instructions to re-read the films while disregarding the initial reading. Their readings were classified as normal, mild, moderate, or severe disease. They subsequently characterized specific findings. Lastly, overreads were compared with the initial CXR reading.

Results: Of the 636 CXRs reviewed among patients with confirmed COVID-19, 363 were male (57.1%) and 273 were female (42.9%). Patient ages ranged from 18 to 90 years of age, with most (493 patients, or 77.5%) being 30–70 years old. There were 371 CXRs reread as normal (58.3%). Of the 265 abnormal cases (41.7%), 195 demonstrated mild disease, 65 demonstrated moderate disease, and five demonstrated severe disease. Interstitial changes and GGOs were the predominant descriptive findings in 151 (23.7%) and 120 (18.9%) of the total, respectively. Location of the abnormalities were in the lower lobe in 215 (33.8%), bilateral in 133 (20.9%), and multifocal in 154 (24.2%). Effusions and lymphadenopathy were uncommon.

Author's Conclusion: This is the first study to specifically explore CXR findings of patients with confirmed COVID-19 evaluated in a UC setting. Most patients (566/636) had either normal or only mildly abnormal CXRs (89%), despite being symptomatic enough to warrant imaging as determined by the treating UC provider. CXRs obtained from confirmed and symptomatic COVID-19 patients presenting to the UC were normal in 58.3% of cases, and normal or only mildly abnormal in 89% of patients. When abnormal, the most common findings were present in the lower lobes and the pattern was interstitial and/or multifocal.

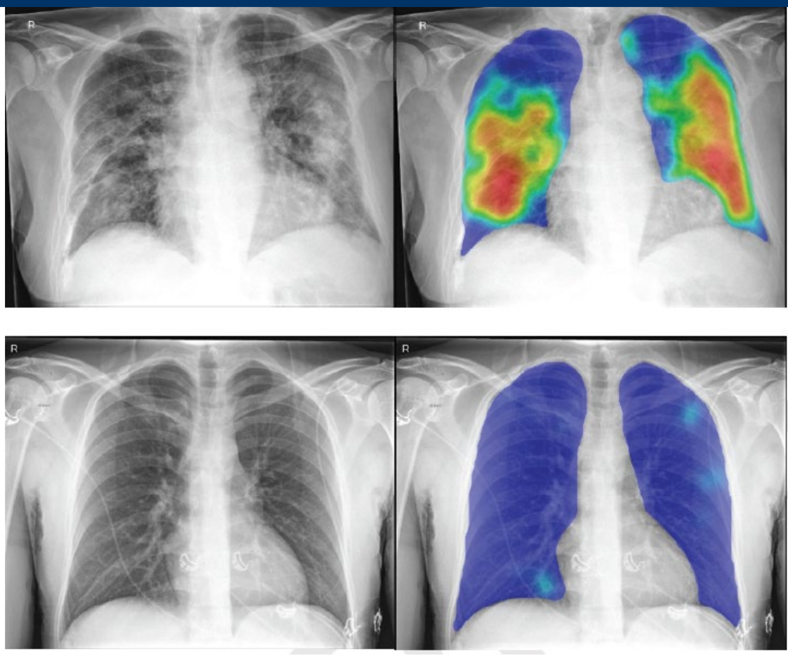
28. Murphy et al. COVID-19 on the Chest Radiograph: A Multi-Reader Evaluation of an AI System. Radiology (May 2020)[28]

Aim: To evaluate the performance of an artificial intelligence (AI) system for detection of COVID-19 pneumonia on chest radiographs.

Materials and Methods: An AI system (CAD4COVID-Xray) was trained on 24,678 CXR images including 1,540 used only for validation while training. The test set consisted of a set of continuously acquired CXR images (n=454) obtained in patients suspected for COVID-19 pneumonia (223 RT-PCR positive subjects, 231 RTPCR negative subjects). The radiographs were independently analyzed by six readers and by the AI system.

Results: The mean age of the patients was 67 years (56% male). Using RT-PCR test results as the reference standard, the AI system correctly classified CXR images as COVID-19 pneumonia with an AUC of 0.81. The system significantly outperformed each reader ($p < 0.001$ using McNemar test) at their highest possible sensitivities.

Fig. 13



Top Row: 74-year-old male with positive RT-PCR test for SARS-COV2 viral infection. (A) Frontal chest x-ray (B) The artificial intelligence (AI) system heat map overlaid on the image showing the pneumonia related features. The AI system score for this subject is 99.8.
Bottom Row: 30-year-old male with negative RT-PCR test for SARS-COV2 viral infection. (C) Frontal chest x-ray (D) The artificial intelligence (AI) system heat map overlaid on the image. The AI system score for this subject is 0.2.

Author's Conclusion: An AI system for detection for COVID-19 on chest radiographs was comparable to six independent readers.

Bayer comment: *The reported algorithm showed even higher sensitivities than the readers. However, there are biases to be assumed introduced by the limited training case numbers and larger more comprehensive clinical validation would have to be performed to prove algorithm effectiveness and level of performance.*

29. Prokop et al. CO-RADS – A categorical CT assessment scheme for patients with suspected COVID-19: definition and evaluation. Radiology (May 2020)[29]

Aim: To introduce the COVID-19 Reporting and Data System (CO-RADS) for standardized assessment of pulmonary involvement of COVID-19 on non-enhanced chest CT and report its initial inter-observer agreement and performance.

Materials and Methods: The Dutch Radiological Society (NVvR) developed CO-RADS based on other efforts for standardization, such as Lung-RADS or BI-RADS. CO-RADS assesses the suspicion for pulmonary involvement of COVID-19 on a scale from 1 (very low) to 5 (very high). The system was evaluated using 105 chest CTs of patients admitted to the hospital with clinical suspicion of COVID-19 in whom RT-PCR was performed. Eight observers assessed the scans using CO-RADS.

Results: There was absolute agreement among observers in 573 (68.2%) of 840 observations. Fleiss' kappa was 0.47 (95% confidence interval (CI) 0.45-0.47), with the highest kappa for CO-RADS categories 1 and 5. The average AUC was 0.91 (95% CI 0.85-0.97) for predicting RT-PCR outcome and 0.95 for clinical diagnosis. The false negative rate for CO-RADS 1 was 9/161 and the false positive rate for CO-RADS 5 was 1/286 (0.3%, 95% CI 0-1.0%).

Fig. 14

	Level of suspicion for pulmonary involvement of COVID-19	Summary
CO-RADS 0	not interpretable	scan technically insufficient for assigning a score
CO-RADS 1	very low	normal or non-infectious
CO-RADS 2	low	typical for other infection but not COVID-19
CO-RADS 3	equivocal / unsure	features compatible with COVID-19, but also other diseases
CO-RADS 4	high	suspicious for COVID-19
CO-RADS 5	very high	typical for COVID-19
CO-RADS 6	proven	RT-PCR positive for SARS-CoV-2

Conclusion: CO-RADS is a categorical assessment scheme for pulmonary involvement of COVID-19 on non-enhanced chest CT providing very good performance for predicting COVID-19 in patients with moderate to severe symptoms and has a substantial inter-observer agreement, especially for categories 1 and 5.

Bayer comment: *Important step to an improved standardization and reporting for COVID-19 related chest CT. Potential to improve communication with treating physicians.*

30. Kandemirli et al. Brain MRI Findings in Patients in the Intensive Care Unit with COVID-19 Infection. Radiology (May 2020)[30]

Aim: The purpose of this study is to describe brain MRI findings in the evaluation of patients in the intensive care unit with COVID-19 pneumonia.

Materials and Methods: In this retrospective study of patients scanned between 1 March and 18 April 2020 were evaluated. All MRI images were reviewed by two neuroradiologists.

Results: 50 of 235 ICU patients developed neurological symptoms and had brain MRI performed. 44% had acute MRI findings. 37% had cortical FLAIR abnormalities. In 56% MRI did not reveal any COVID-19 related or acute intracranial findings.

Bayer comment: *Good report to look for brain abnormalities in MRI linked with ICU patients in COVID-19. Not a conclusive study, since ICU patients have multiple co-morbidities and it was retrospective and multicenter in nature.*

31. Grillet et al. Acute Pulmonary Embolism Associated with COVID-19 Pneumonia Detected by Pulmonary CT Angiography. Radiology (April 2020)[31]

Aim: Chest CT plays an important role in optimizing the management of patients with COVID-19 while also eliminating alternate diagnoses or added pathologies, particularly for acute pulmonary embolism. A few studies and isolated clinical cases of COVID-19 pneumonia with coagulopathy and pulmonary embolus have recently been published. The main objective of our study was to evaluate pulmonary embolus in association with COVID-19 infection using pulmonary CT angiography.

Materials and Methods: A single center retrospective study including patients with suspected or confirmed SARS-CoV-2 infection, chest CT scan was performed when clinical features of severe disease were present (e.g., requirement for mechanical ventilation [IMV]) or underlying comorbidities). Patients with non-contrast chest CT scans were excluded.

Results: 129 of 280 (46%) hospitalized patients underwent CT scan (9 ± 5 days after symptom onset). 100 COVID-19 patients and severe clinical features were examined with contrast enhanced CT. 23 of 100 (23%) patients had acute pulmonary embolism (Figure 15). Patients with pulmonary embolus were more frequently in the critical care unit than those without pulmonary embolus, required mechanical ventilation more often and had longer delay from symptom onset to CT diagnosis of pulmonary. In multivariable analysis, requirement for mechanical ventilation remained associated with acute pulmonary embolus.

Fig. 15

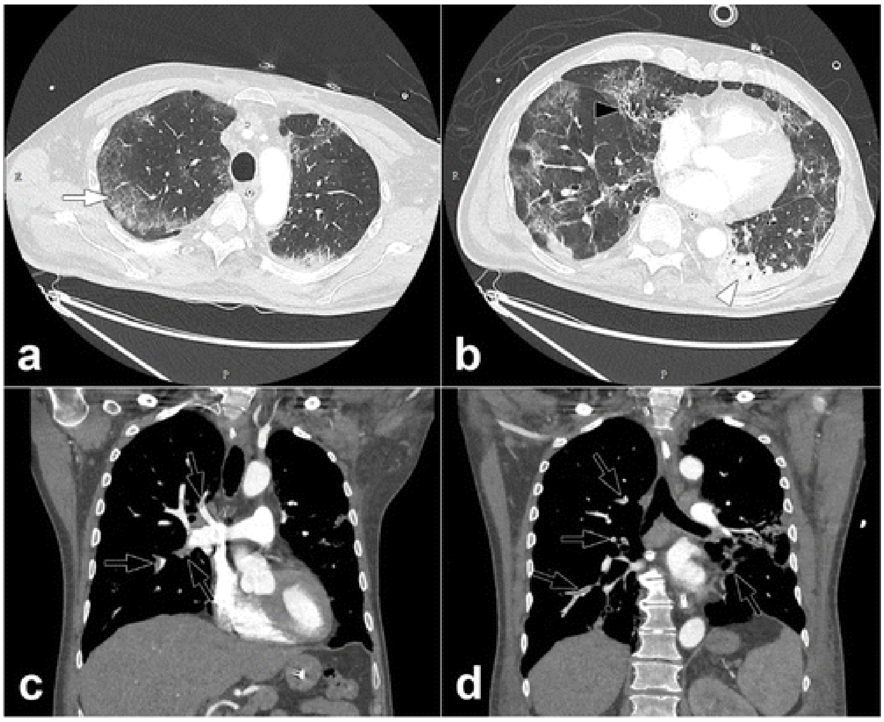


Figure 15: Pulmonary CT angiography of a 68-year-old male. The CT scan was obtained 10 days after the onset of COVID-19 symptoms and on the day the patient was transferred to the intensive care unit. Axial CT images (lung windows) (a,b) show peripheral ground-glass opacities (arrow) associated with areas of consolidation in dependent portions of the lung (arrowheads). Interlobular reticulations, bronchiectasis (black arrow) and lung architectural distortion are present. Involvement of the lung volume was estimated to be between 25% and 50%. Coronal CT reformations (mediastinum windows) (c,d) show bilateral lobar and segmental pulmonary embolism (black arrows).

Bayer comment: *These results suggest that patients with severe clinical features of COVID-19 may have associated acute pulmonary embolus. Therefore, the use of contrast enhanced CT rather than routine non-contrast CT may be considered for these patients.*

32. Qu et al. Infection Control for CT Equipment and Radiographers’ Personal Protection During the Coronavirus Disease (COVID-19) Outbreak in China. AJR (May 2020)[32]

Aim: Describe the modifications to the CT examination process to effectively evaluate infection prevention and control management in COVID-19 at one institution.

Infection prevention and Control in CT: Describe modification to the CT examination process, guidance of CT examination room disinfection including use of air disinfection, use of movable UV light for disinfection, use of floor disinfectant on the scanning room floor at least twice a day, discarding all patient waste as infectious medical waste.

Personal Protection measures for radiographers: The hospital strengthened special biohazard training and regular supervision, with constant optimization of clinical workflow to minimize infection of medical staff. Our radiographers put on protective equipment items in the clean zone and discard them in the buffer zone after a shift is complete. disposable work caps, antifog safety goggles (preferably non-vented) with or without face shields, medical protective masks, protective gowns, disposable gloves, and disposable shoe covers.

Conclusion: Strict disinfection of examination rooms, arrangement of waiting areas, and efforts to increase radiographers’ awareness of personal protection made at our institution during the COVID-19 outbreak. In addition, we discuss the potential of using artificial intelligence in imaging patients with contagious diseases.

33. Merkler et al. Risk of Ischemic Stroke in Patients with Covid-19 versus Patients with Influenza. JAMA (May 2020)[33]

Aim: To compare the rate of ischemic stroke between patients with COVID-19 and patients with influenza, a respiratory viral illness previously linked to stroke.

Design and Setting: The study was a retrospective cohort study and included adult patients with emergency department visits or hospitalizations with COVID-19 from March 4, 2020 through May 2, 2020. The comparison cohort included adult patients with emergency department visits or hospitalizations with influenza A or B from January 1, 2016 through May 31, 2018.

Exposures: COVID-19 infection confirmed by evidence of severe acute respiratory syndrome coronavirus 2 in the nasopharynx by polymerase chain reaction and laboratory-confirmed influenza A/B.

Main outcomes and measures: A panel of neurologists adjudicated the primary outcome of acute ischemic stroke and its clinical characteristics, mechanisms, and outcomes. We used logistic regression to compare the proportion of patients with COVID-19 with ischemic stroke vs. the proportion among patients with influenza.

Results: Among 1916 patients with emergency department visits or hospitalizations with COVID-19, 31 (1.6%; 95%CI, 1.1%-2.3%) had an acute ischemic stroke. The median age of patients with stroke was 69 years (interquartile range, 66-78 years); 18 (58%) were men. Stroke was the reason for hospital presentation in 8 cases (26%). In comparison, 3 of 1486 patients with influenza (0.2%; 95%CI, 0.0%-0.6%) had an acute ischemic stroke. After adjustment for age, sex, and race, the likelihood of stroke was higher with COVID-19 infection than with influenza infection (odds ratio, 7.6; 95%CI, 2.3-25.2). The association persisted across sensitivity analyses adjusting for vascular risk factors, viral symptomatology, and intensive care unit admission.

Conclusions and Relevance: In this retrospective cohort study from 2 New York City academic hospitals, approximately 1.6% of adults with COVID-19 who visited the emergency department or were hospitalized experienced ischemic stroke, a higher rate of stroke compared with a cohort of patients with influenza. Additional studies are needed to confirm these findings and to investigate possible thrombotic mechanisms associated with COVID-19.

34. Abdel-Mannan et al. Neurologic and Radiographic Findings Associated With COVID-19 Infection in Children. JAMA Neurology (July 2020)[34]

Aim: To report the neurological manifestations of children with COVID-19.

Design and setting: Case-series study with SARS-CoV-2 patients (>18 years) and neurological symptoms. Infection was confirmed by either a quantitative RT-PCR assay by nasopharyngeal swab or a positive test result for IgG antibodies against SARS-CoV-2 in serum.

Results: Of the assessed 50 COVID-19 pediatric patients, 27 children had symptoms suggesting multisystem inflammatory syndrome. Four of these 27 (14.8%) who were previously healthy had new-onset neurological symptoms such as encephalopathy, headaches, brainstem and cerebellar signs, muscle weakness, and reduced reflexes. All 4 patients required intensive care unit admission for the treatment of COVID-19 pediatric multisystem inflammatory syndrome. Splenium signal changes were seen in all 4 patients on brain MRI. In the 2 patients whose CSF was tested, samples were acellular, with no evidence of infection on RT-PCR or culture (including negative SARS-CoV-2 PCR results) and negative oligoclonal band test results. In all 3 patients who underwent electroencephalography, a mild excess of slow activity was found. Tests for N-methyl-D-aspartate receptor, myelin oligodendrocyte glycoprotein, and aquaporin-4 autoantibodies had negative results in all patients. In all 3 patients who underwent nerve conduction studies and electromyography, mild myopathic and neuropathic changes were seen. Neurological improvement was seen in all patients, with 2 making a complete recovery by the end of the study.

Conclusion: Children with COVID-19 presented with new and secondary neurological symptoms involving both the central and peripheral nervous systems and splenial changes on imaging, in the absence of respiratory symptoms. 4 of 27 children with COVID-19 show a clinical phenotype involving both the CNS and the peripheral nervous system and lesions of the splenium of the corpus collosum (SCC). The negative CSF results, the response to immunosuppression, and the clinical overlap with hemophagocytic lymphohistiocytosis suggest that this is likely to be immune mediated. Although the imaging finding is not specific to SARSCoV-2, in that it has been previously seen with other viral infections, clinicians should be adding SARS-CoV-2 to their differential diagnosis for children presenting with new neurologic symptoms and this imaging finding while still exploring other possible causes. Additional research is needed to assess the association of neurological symptoms with immune-mediated changes among children with COVID-19.

Fig. 16

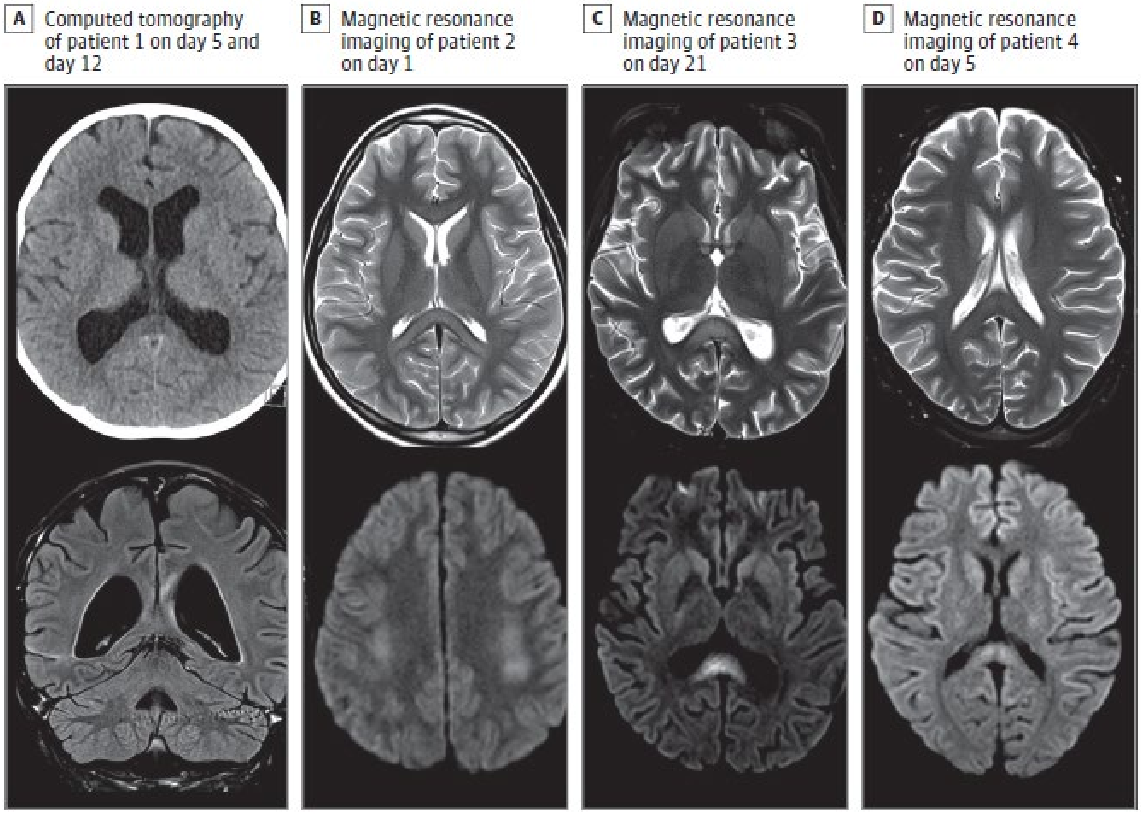


Figure 16: Neuroimaging Findings in Association with Coronavirus Disease 2019 in Children. A, CT image of patient 1 on day 5 (top), during intensive care admission, showing hypodensity of the splenium of the corpus collosum (SCC). Coronal fluid-attenuated inversion recovery performed on day 12 (bottom) shows resolution of the changes previously seen on computed tomography, with persistent signal changes in the genu and SCC without restricted diffusion (not shown). B, Axial T2 MRI of patient 2 on day 1, showing signal changes of the genu and SCC (top) and bilateral centrum semiovale with restricted diffusion (bottom). Repeated imaging on day 6 (not shown) demonstrated resolution of the restricted diffusion, with minimal signal changes remaining on T2-weighted imaging. C, Axial T2 MRI of patient 3 on day 21, showing hyperintensities (top) with restricted diffusion (bottom) in the SCC and bilateral centrum semiovale (not shown). D, Axial T2 MRI of patient 4 on day 5 (top), showing signal change in the SCC with mild restricted diffusion (bottom).

35. Mahammedi et al., Imaging in Neurological Disease of Hospitalized COVID-19 Patients: An Italian Multicenter Retrospective Observational Study. Radiology (May 2020)[35]

Aim: Only a few case reports have described COVID-19 associated neuroimaging findings. The purpose of our study was to systematically characterize neurological symptoms and neuroimaging features in hospitalized COVID-19 patients from multiple institutions in Italy.

Design and patient population: Retrospective, multicenter study design from three major institutions in Italy. Inclusion criteria: 1. Hospitalized patients who were positive for COVID-19 via (RT-PCR) of respiratory secretions obtained by bronchoalveolar lavage, endotracheal aspirate, nasopharyngeal swab, or oropharyngeal swab. 2. Presence of acute neurological symptoms during hospital stay. 3. Any neuroimaging studies, including brain or spine imaging.

Image Acquisition: All imaging was obtained as per standard of care protocols. The MRI brain and spine scans were performed on 1.5-T scanners with standardized protocols using 0.1 mmol/kg gadobutrol.

Results: Of 725 consecutive hospitalized COVID-19 patients, 108 (15%) had acute neurological symptoms requiring neuroimaging. Of them, 107 (99%) were examined with non-contrast brain CT, 17 (16%) head and neck CT angiography (CTA) and 20 (18%) brain MRI. Of these, 10 (50%) patients had brain MRI with and without IV contrast, 10 (50%) patients had head and neck MRA and 3 patients had additional MRI of the whole spine for evaluation of lower extremity weakness. Table 1 shows the demographics, past medical history and neurological characteristics. The most common neurological symptoms were altered mental status in 64 (59%) patients and ischemic stroke in 34 (31%) patients. Of the 108 patients, 31(29%) had no known past medical history and 77 (71%) had at least one of the following chronic disorders: coronary artery disease 25 (23%), cerebrovascular disease 15 (14%), hypertension 55 (51%) and diabetes 30 (28%). Of the 31(29%) patients without known past medical history (age range 16 - 62 years), 10 had acute ischemic infarcts and 2 had intracranial hemorrhage. Of the 108 patients, 71(66%) had no acute findings on brain CT, out of which 7 (35%) brain MRI demonstrated acute abnormalities. There was a statistically significant association (72±11 vs. 64±18 years with P=0.007) between the prevalence of altered mental status and age of patient.

Conclusion: Neuroimaging features of hospitalized COVID-19 patients are variable, without specific pattern but dominated by acute ischemic infarcts and intracranial hemorrhages. MR neuroimaging spectrum may include posterior reversible encephalopathy syndrome, hypoxic-ischemic encephalopathy, exacerbation of demyelinating disease and nonspecific cortical pattern of T2 FLAIR hyperintense signal with associated restriction diffusion that may be caused by systemic toxemia, viremia and/or hypoxic effects. Currently, there is a poor mechanistic understanding of the neurological symptoms in COVID-19 patients, whether these are arising from critical illness or from direct CNS invasion of SARS-CoV-2. Accumulating evidence suggests that a subgroup of patients with severe COVID-19 might have a cytokine storm syndrome which could be a trigger for ischemic strokes, probably related to the prothrombotic effect of the inflammatory response.

Our results showed a lower prevalence of CNS symptoms than the Wuhan experience (15% versus 25%), however the prevalence of ischemic strokes was higher in our study (31% vs 11%). Furthermore, the findings also support the suggested potential COVID-19 associated Guillain-Barré syndrome (GBS) and variants. None of our cases showed abnormal parenchymal or leptomeningeal enhancement. In conclusion, neurologists and neuro-radiologists should be familiar with the broad-spectrum of neuroimaging patterns associated with COVID-19.

Fig. 17

Table 2: Neuroimaging characteristics of hospitalized patients with new onset of neurological symptoms following COVID-19

Neuroimaging characteristics	**All patients** (N = 108)
	CT or MRI
Acute ischemic infarcts	34/108 (31)
Large vascular territory	19/108 (18)
Small infarcts	11/108 (10)
Basal ganglia	7/108 (6)
Watershed zone	4/108 (4)
Cardioembolic	3/108 (3)
Hypoxic-ischemic encephalopathy	1/108 (1)
Intracranial hemorrhages	6 /108(6)
Large	2/108 (2)
Small	1/108 (1)
Subarachnoid	3/108 (3)
Enhancement (MRI with and without IV contrast)	
Cranial nerves*	1/10 (10)
Cauda equina*	2/10 (20)
Leptomeningeal	0/10 (0)
Parenchymal	0/10(0)
Acute encephalopathy†	1/20 (5)
PRES	1/20 (5)
Nonspecific encephalopathy	2/20 (10)
MS plaque exacerbation‡	2/20(10)
T2/FLAIR Signal Hyperintensity	
Nonspecific but likely chronic white matter disease	7/20 (35)
Basal ganglia	2/20 (10)
Subcortical	3/20 (15)
Cerebral venous thrombosis (CTA)	2/17 (12)

Numbers in Parentheses are Percentages.

* Miller-Fisher syndrome, a regional variant of Guillain–Barré syndrome. A 62 year-old-man presented with bilateral facial nerve palsy, ophthalmoplegia, areflexia and polyradiculopathy, rRT-PCR assay of the CSF was negative for SARS-CoV-2.

† Acute encephalopathy. A 60 year-old-man without history of seizures presenting with first time convulsion (Figure 2), rRT-PCR assay of the CSF was negative for SARS-CoV-2.

‡ Exacerbation of Multiple Sclerosis (MS). A 53 year-old-woman presented with seizures and altered mental status.

Figure 17: Neuroimaging characteristics of hospitalized patients with new onset of neurological symptoms following COVID-19.

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