WHO guidelines on the use of chest imaging in COVID-19

World Health Organization

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ISBN 978-92-4-005570-4 (electronic version)
ISBN 978-92-4-005571-1 (print version)

The original version of these guidelines was published under WHO reference number WHO/2019-nCoV/Clinical/Radiology_imaging/2020.1.

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Acknowledgements

The Radiation and Health Unit of the World Health Organization (WHO) gratefully acknowledges the contributions by many individuals and organizations to the development of this rapid advice guide.

Guideline development group

WHO appreciates the expert contributions from several stakeholders during the development of these recommendations. The following individuals served as members of the guideline development group: John Adabie Appiah, Ivana Blazic, Mansoor Fatehi, Nicola Flor, Eveline Hitti, Hussain Jaffri, Zheng-Yu Jin, Hans Ulrich Kauczor, Michael Kawooya, Ella Annabelle Kazerooni, Jane Ko, Rami Mahfouz, Valdair Muglia, Rose Nyabanda, Marcelo Sanchez, Priya Shete, Marina Ulla, Huadan (Danna) Xue, Chuansheng Zheng. Special thanks to Guy Frija for chairing the guideline development group and Elie Akl for serving as vice-chair and for providing methodological guidance.

External review group

WHO thanks the following members of the external review group for peer reviewing the rapid advice guide and providing valuable inputs: Deniz Akata, Salah Bendib, Jocelyne Basseal, Jeffrey Burns, Bin Cao, Luis Donoso, David Hui, Dina Husseiny Salama, David Koff, Boudjema Mansouri, Stephanie Newell, Deepak Patkar, Mathias Prokop, Francesco Sardanelli, Arthur Soares Souza Jr, Jacob Sosna, Evangelina Vazquez Curiel, Mingxing Xie, Hwan Seok Yong.

Systematic review team

WHO extends our sincere thanks to the systematic review team for their prompt assistance and collaboration in preparing this work: Roger Chou from the Pacific Northwest Evidence-based Practice Center at Oregon Health and Science University, United States of America, and his team, including: David Buckley, Tracy Dana, Elain Graham, Erica Hart, Marian McDonagh, Heidi Nelson, Miranda Pappas, Annette Totten and Ngoc Wasson (for the first systematic review) and Tracy Dana, Erica Hart, Miranda Pappas and Shelley Selph (for the second systematic review).

WHO also acknowledges Xuan Yu from Lanzhou University (WHO Collaborating Centre for Guideline Implementation and Knowledge Translation) from China, who assisted in searching and translating the Chinese language databases for the first systematic review.

Nicola Flor[1] and Francesco Sardanelli from Italy contributed as technical resource experts for the first systematic review, and their assistance is greatly acknowledged.

Qualitative research team

WHO sincerely thanks Gladys Honein-Abou Haidar from the Global Health Institute of the American University of Beirut, Lebanon for designing and conducting the qualitative study on contextual factors, in collaboration with Imad Bou Akl (Lebanon). Ivana Blazic (Serbia) and Elie Akl (Lebanon) contributed as technical resource experts and their assistance is also acknowledged. Hussain Jaffri is acknowledged for contributing to the qualitative study on contextual factors by facilitating patient enrolment.

[1] Nicola Flor was also member of the Guideline Development Group and was not involved in the design of any of the systematic reviews.

External partners

WHO acknowledges the International Society of Radiology, a non-state actor in official relations with WHO, which provided technical support for data collection on imaging practices in COVID-19 management including the development and dissemination of a survey. WHO also thanks the staff of the European Society of Radiology for their provision of virtual meeting assistance and rapporteur services, in particular Martina Szucsich and Monika Hierath. WHO thanks to the American University of Beirut (AUB), in particular to Sally Yaacoub for assisting with the design and analysis of surveys on contextual factors and outcome rating, and for facilitating the virtual GRADEpro sessions in collaboration with Joanne Khabsa.

Contributors to Annex 1

WHO thanks the International Society of Radiographers and Radiological Technologists (ISRRT), the World Federation for Ultrasound in Medicine and Biology (WFUMB) and the International Society of Radiology (ISR), three non-state actors in official relations with WHO, for their technical assistance in the development of the guidance on infection prevention and control in imaging practices presented in Annex 1. WHO thanks the ISRRT members Donna Newman and Stewart Whitley, the WFUMB member Jacques Abramowicz and the ISR member Ivana Blazic.

WHO acknowledges the colleagues from the Clinical Management pillar, led by Janet Diaz, for their instrumental guidance. In particular we express our gratitude to Jacobus Preller and Joan B. Soriano, for their technical input and suggested edits in the second edition of the guide.

WHO also acknowledges the WHO colleagues from the Infection Prevention and Control pillar, led by April Baller, for their technical advice. In particular WHO expresses its appreciation to Victoria Willet and Fernanda Lessa, members of the WHO Infection Prevention and Control team at headquarters and to Jocelyne Basseal, member of the WHO Infection Prevention and Control team in the Regional Office for the Western Pacific, for their review and valuable suggestions on Annex 1.

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WHO acknowledges Susan Norris and her colleagues from the WHO Guideline Review Committee Secretariat, for their technical advice for the first edition of this guide.

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The core group included Maria Del Rosario Perez, Emilie van Deventer, Guy Frija, Elie Akl, Ivana Blazic and Sally Yaacoub.

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Ivana Blazic was the lead writer of this guide under the overall guidance and leadership of Maria del Rosario Perez and Emilie van Deventer. Technical editing was provided by Kai Lashley, Further Consulting, the Netherlands.

Funding

This project has been funded by a voluntary contribution from the Government of Japan. The views of the funders have not influenced the development and content of this guide.

Abbreviations

Ag-RDT	antigen-detecting rapid diagnostic test
AI	artificial intelligence
ARDS	acute respiratory distress syndrome
AUROC	area under the receiver operating characteristic (curve)
CDR	computed digital radiography
COVID-19	coronavirus disease 2019
CO-RADS	COVID-19 Reporting and Data System
CT	computed tomography
DDR	direct digital radiography
EtD	Evidence to Decision (framework)
GDG	guideline development group
GRADE	Grading of Recommendations Assessment, Development and Evaluation (approach)
ICU	intensive care unit
ISR	International Society of Radiology
ISRRT	International Society of Radiographers and Radiological Technologists
LUS	lung ultrasound
NAAT	nucleic acid amplification test
PACS	picture archiving and communication system
PICO	population, intervention, comparator, outcomes (question format)
PPE	personal protective equipment
RT-PCR	reverse transcriptase polymerase chain reaction
SARS-CoV-2	severe acute respiratory syndrome coronavirus-2
SpO_2	oxygen saturation
WFUMB	World Federation for Ultrasound in Medicine and Biology
WHO	World Health Organization

Executive summary

Since its identification in China in December 2019, the severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2), which causes coronavirus disease (COVID-19), has spread rapidly worldwide. COVID-19 manifests with non-specific respiratory symptoms of variable severity and may require advanced respiratory support. The diagnosis of COVID-19 is currently confirmed by virological testing e.g. with reverse transcriptase polymerase chain reaction (RT-PCR) or antigen-detecting rapid diagnostic tests (Ag-RDTs). Chest imaging has been considered as part of the diagnostic workup of patients with suspected or probable COVID-19 where virological testing is not available, or results are delayed or are initially negative in the presence of symptoms suggestive of COVID-19. Imaging has also been considered to complement clinical evaluation and laboratory parameters in the management of patients already diagnosed with COVID-19.

Prior to initiating the development of this guide, several Member States requested advice from WHO on the role of chest imaging in patients with suspected or confirmed COVID-19. A review of imaging practices in patients with suspected or confirmed COVID-19 across the world found wide variations. This motivated the development of global guidance on the use of chest imaging to support Member States in their response to the COVID-19 pandemic.

This rapid advice guide examines the evidence and makes recommendations for the use of chest imaging in adult patients with suspected, probable or confirmed COVID-19, including chest radiography, computed tomography and lung ultrasound. In its first edition this document was intended to be a practical guide for health care professionals involved in the care pathway of COVID-19, from the time of presentation to a health facility to home discharge. This second edition of the guide expands the scope to also address follow-up after hospital discharge. The guidance is relevant to patients with different levels of disease severity, from asymptomatic individuals to critically ill patients.

This rapid advice guide was developed in accordance with the *WHO handbook for guideline development*, supported by a core group, a WHO steering group, a guideline development group and an external review group of international experts. Scoping thematic discussions determined the focus areas and the key questions to be addressed. The relevant evidence was systematically reviewed, and the quality of the evidence for key outcomes was assessed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach. Evidence-to-decision tables were used to interpret health and contextual evidence relating to each of the key questions. A set of online technical consultations of the guideline development group took place between 30 April and 8 May 2020. Prior to the technical consultation, all contributors declared any potential conflicts of interest, and their declared interest forms were reviewed and managed in accordance with the relevant WHO procedures. The guideline development group and external reviewers reviewed the draft rapid advice guide prior to executive clearance of the final version and publication of the first edition of 11 June 2020.The systematic review team updated their search up to mid-October 2020, expanding the scope of the research questions to include the role of chest imaging after hospital discharge (Web Annex A).

This second edition reviews the scientific knowledge and updates and supersedes the first edition. It includes a new research question addressing the use of chest imaging in the follow-up of patients after recovery. This guide provides recommendations for seven different clinical scenarios (shown in the table below). The recommendations in the second edition of the guide and the summaries of the supporting evidence provided after each recommendation have been updated based on the new systematic reviews

(a total of 128 studies up to April 2021). While the newly identified studies did not impact the conclusions of the previous review, for some of the recommendations the certainty of evidence was upgraded.

A qualitative study on contextual factors was conducted for the second edition of the guide to explore the value stakeholders placed on the use of chest imaging for monitoring the development or resolution of COVID-19 sequelae (pulmonary, cardiac) following recovery from an acute episode.

Due to the limited available evidence and the variation in contextual factors the guideline development group made conditional recommendations, which implies that policy-makers need to engage relevant stakeholders when using the recommendations to choose the policy option to implement. Therefore, remarks are included to describe the circumstances under which each policy option would provide optimal benefit to patients. In addition, the document provides considerations about implementation of the recommendations and suggestions for monitoring and evaluation (i.e. some outcome and performance measures were identified for assessing the impact of the adoption of the recommendations). The guideline development group and the external review group identified knowledge gaps meriting further research. Research priorities for each recommendation in areas where the certainty of the available evidence was low or very low, or where evidence was lacking are listed as research topics relevant for diagnostic and/or management recommendations. WHO will closely monitor emerging data on relevant topics addressed in this rapid advice guide, which will be updated if/when warranted by evidence.

Recommendations

R1

For asymptomatic contacts of patients with COVID-19, WHO suggests not using chest imaging for the diagnosis of COVID-19.

Conditional recommendation, based on low certainty evidence

Remark

Virological testing, e.g. with RT- PCR or antigen-detecting rapid diagnostic tests (Ag-RDTs), can be used to confirm diagnosis of COVID-19. Local protocols related to quarantine and testing should be followed.

R2

R2.1 **For symptomatic patients with suspected COVID-19, WHO suggests not using chest imaging for the diagnostic workup of COVID-19 when virological testing is available with timely results.**

Conditional recommendation, based on moderate certainty evidence

Remark

Virological testing can be used to confirm diagnosis of COVID-19. Local protocols related to isolation and testing should be followed.

R2.2 **For symptomatic patients with suspected COVID-19, WHO suggests using chest imaging for the diagnostic workup of COVID-19 when:**

(1) virological testing is not available;
(2) virological testing is available, but results are delayed; and
(3) virological testing is negative, but high clinical suspicion of COVID-19 remains(see remarks).

Conditional recommendation, based on moderate certainty evidence

Remarks

Virological testing (e.g. with RT-PCR or Ag-RDT) can be used to confirm diagnosis of COVID-19. Local protocols related to isolation and testing should be followed. Imaging should be used as one element of the diagnostic workup that otherwise includes clinical and laboratory data. Patients likely to benefit of chest imaging are those who:

- have severe symptoms and/or signs on physical exam;
- require emergency procedures or other urgent interventions (e.g. administration of a thrombolytic therapy or haemodialysis);
- have presentations that could represent complications of COVID-19 (e.g. pneumonia, pulmonary arterial thrombosis or thromboembolism);
- need to be admitted irrespective of diagnosis (e.g. disease is severe or likely to progress), to help with disposition or triaging (e.g. to dedicated COVID-19 ward vs non-COVID-19 ward);
- need to be transferred to another facility;
- live with people at higher risk if infected with COVID-19 (e.g. immunocompromised, people aged over 60 years);
- live in small homes, overcrowded households or densely populated settings, where isolation is very difficult to implement;
- live in communities with people at high risk such as retirement homes or dormitories.

R3

For patients with suspected or confirmed COVID-19, not currently hospitalized and with mild symptoms, WHO suggests using chest imaging in addition to clinical and laboratory assessment to decide on hospital admission versus home discharge.

Conditional recommendation, based on moderate certainty evidence

Remarks

Imaging should be used as one element of patient evaluation that otherwise includes an assessment of the severity of presentation and of the risk of progression, ideally measured with a validated risk stratification tool. Patients likely to benefit are those who:

- are judged to be at increased risk of disease progression based on risk stratification using a validated prediction tool;
- have associated comorbidities (e.g. diabetes, hypertension, heart disease, obesity) or other chronic diseases which might decompensate and/or are aged over 60 years;
- live with individuals at high risk of morbidity and mortality associated with COVID-19 (e.g. people aged over 60 years, immunocompromised), whether at home or retirement home;
- live in small homes, overcrowded households or densely populated settings where isolation is very difficult to implement.
- represent an increased risk of dissemination within their community due to their occupational, social or other circumstances.

R4

For patients with suspected or confirmed COVID-19, not currently hospitalized and with moderate to severe symptoms, WHO suggests using chest imaging in addition to clinical and laboratory assessment to decide on regular ward admission versus intensive care unit (ICU) admission.

Conditional recommendation, based on moderate certainty evidence

Remarks

Imaging should be used as one element of patient evaluation that otherwise includes an assessment of the severity of presentation and of the risk of progression, ideally measured with a validated risk stratification tool. Patients likely to benefit are those who:

- are judged to be at increased risk of disease progression based on risk stratification using a validated prediction tool;
- are not responding to supportive treatment (e.g. oxygen supplementation);
- are presenting with acute clinical deterioration not elucidated.

R5

For patients with suspected or confirmed COVID-19, currently hospitalized and with moderate to severe symptoms, WHO suggests using chest imaging in addition to clinical and laboratory assessment to inform the therapeutic management.

Conditional recommendation, based on moderate certainty evidence

Remarks

Imaging should be used as one element of patient evaluation that otherwise includes an assessment of the severity of presentation and of the risk of progression, ideally measured with a validated risk stratification tool. Patients likely to benefit are those who:

- are judged to be at increased risk of disease progression based on risk stratification using a validated prediction tool;
- are not responding to treatment (oxygen supplementation);
- have presentations with clinical suspicion of pulmonary fibrosis, pulmonary oedema, pulmonary artery thrombosis or thromboembolism.

R6

For hospitalized patients with COVID-19 whose symptoms are resolved, WHO suggests not using chest imaging in addition to clinical, laboratory and epidemiological assessment to inform the decision regarding discharge.

Conditional recommendation, based on expert opinion

Remarks

When imaging is used, it should be one element of patient evaluation that otherwise includes clinical, laboratory and epidemiological data. Patients likely to benefit from chest imaging are those who:

- have had a severe form of COVID-19;
- have pre-existing chronic lung disease.

R7

In individuals who have recovered from COVID-19, WHO suggests not systematically scheduling chest imaging follow-up at the time of hospital discharge for assessment of long-term post-COVID-19 conditions.

Conditional recommendation, based on expert opinion

Remarks

The ultimate decision needs to take into account the clinical situation of the patient at the time of discharge (i.e. symptoms, signs and medical history). Patient groups who might benefit from periodic follow-up imaging include those:

- with pre-existing chronic lung and/or heart diseases, other comorbidities (e.g. human immunodeficiency virus infection, tuberculosis) or immunocompromising conditions;
- diagnosed with pulmonary arterial thrombosis, pulmonary embolism and/or acute respiratory distress syndrome (ARDS) during their hospital stay;
- with clinical symptoms and/or signs of lung involvement or clinically relevant abnormal imaging findings at the time of hospital discharge.

1. Introduction

1.1 Background

The World Health Organization (WHO) developed the first edition of this rapid advice guide on the use of medical imaging in the context of the COVID-19 pandemic. A cluster of pneumonia cases in Wuhan, China was first reported to the WHO Country Office in China on 31 December 2019 *(1)*. Soon thereafter, a novel coronavirus was identified as the causative agent *(2-4)*. This virus was named severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) and the associated disease was named coronavirus disease 2019 (COVID-19) *(5)*. Since December 2019, COVID-19 has rapidly spread from Wuhan to other parts of China and throughout the world. On 30 January 2020, WHO declared the outbreak a public health emergency of international concern *(6)* and on 11 March 2020, WHO characterized the outbreak as a pandemic *(7)*.

While the SARS-CoV-2 infection can be completely asymptomatic, COVID-19 manifests with non-specific respiratory symptoms of variable severity, ranging from mild to life threatening, which may demand advanced respiratory assistance and mechanical ventilation. The diagnosis of COVID-19 is currently confirmed by identification of viral nucleic acid amplification tests (NAATs) such as reverse transcriptase polymerase chain reaction (RT-PCR) or antigen-detecting rapid diagnostic tests (Ag-RDTs) that detect the presence of viral proteins (antigens). In settings where virological testing is not available or results are delayed or are initially negative in the presence of symptoms attributable to COVID-19, chest imaging has been considered as part of the diagnostic workup of patients with suspected or probable COVID-19 *(8)*. Imaging has also been considered to complement clinical evaluation and laboratory parameters in the management and follow-up of patients already diagnosed with COVID-19 *(9)*.

Several Member States requested advice from WHO on the role of chest imaging for the diagnostic workup of patients with suspected or probable COVID-19 and to inform clinical management of COVID-19 making an appropriate use of chest imaging. Important variations in imaging practices related to COVID-19 across the world have been highlighted in a survey conducted by the International Society of Radiology and the European Society of Radiology *(10)*. In response to this, WHO undertook the development of this rapid advice guide. A first edition was published in June 2020.

This second edition reviews the scientific knowledge and updates and supersedes the first edition.

1.2 Purpose

To support Member States in their response to the COVID-19 pandemic this rapid advice guide provides up-to-date guidance on the use of chest imaging in patients with suspected or confirmed COVID-19. This guide is also expected to promote the quality and safety of X-ray-based and ultrasound-based chest imaging in health facilities, thus enhancing protection and safety of patients and health workers. It is not intended to replace clinical judgment or specialist consultation but rather to support care providers for the clinical management of these patients.

1.3 Scope

This document contains recommendations for the use of chest imaging in contacts of patients with COVID-19, adult[2] patients with probable or confirmed current COVID-19, patients with previous COVID-19 infection, and individuals who have recovered from COVID-19. Chest imaging includes chest radiography, computed tomography (CT) and lung ultrasound (LUS). It is intended to be a practical guide for health care professionals involved in the care pathway of patients with suspected, probable or confirmed COVID-19, from outpatient facility or hospital entry to home discharge and follow-up. The guidance is provided for patients with different levels of disease severity, from asymptomatic individuals to critically ill patients. The document is structured around key questions relevant to the various clinical stages of the disease and different clinical scenarios. Additional guidance on infection prevention and control in medical imaging procedures for COVID-19 management is provided in Annex 1. Infection prevention and control measures include both general measures for all imaging procedures and specific precautions for chest radiography, chest CT and LUS. Imaging of other body sites (e.g. brain, heart, abdomen, kidney) as well as use of other imaging modalities (e.g. magnetic resonance imaging) are outside the scope of this guide.

1.4 Target audience

This document is primarily intended for health professionals working in emergency departments, imaging departments, clinical departments, intensive care units (ICUs) and other health care settings involved in the diagnosis of COVID-19 and in the management of COVID-19 patients. These health professionals include clinicians, radiologists, radiographers, sonographers, nurses and other health-care providers. The document can also be useful for hospital managers and planners, policy-makers, hospital architects, biomedical engineers, medical physicists, logistics staff, water/sanitation and infection prevention and control officers. Health authorities and radiation regulators can use the guide to develop specific national standards relevant to COVID-19 outbreak preparedness, readiness and response in different contexts. Finally, it can be useful to funders that wish to donate equipment and devices as well as funding priority research, such as that discussed in Chapter 5.

1.4 Clinical perspective and health care settings

A variety of chest imaging findings have been described in patients with COVID-19. Imaging could be useful for the diagnostic workup of patients with suspected COVID-19 and for the management of patients diagnosed with COVID-19.

This guide provides recommendations on imaging procedures and, when relevant, considers different levels of COVID-19 probability (Tables 1 and 2) and disease severity (Table 3). It also provides implementation considerations for different resource settings, within and across low- and middle-income countries as well as high-income countries.

[2] While the recommendations apply to adult patients, some considerations about chest imaging in children are included in this guide.

Table 1. Signs and symptoms associated with COVID-19

Presenting signs and symptoms of COVID-19 vary	• Most people experience fever (83–99%), cough (59–82%), fatigue (44–70%), anorexia (40–84%), shortness of breath (31–40%) and myalgias (11–35%). Other non-specific symptoms, such as sore throat, nasal congestion, headache, diarrhoea, nausea and vomiting, have also been reported. Loss of smell (anosmia) or loss of taste (ageusia) preceding the onset of respiratory symptoms has also been reported. • Additional neurological manifestations reported include dizziness, agitation, weakness, seizures, or findings suggestive of stroke including trouble with speech or vision, sensory loss, or problems with balance in standing or walking. • Older people and immunosuppressed patients may present with atypical symptoms such as fatigue, reduced alertness, reduced mobility, diarrhoea, loss of appetite, confusion and absence of fever. • Symptoms such as shortness of breath (dyspnoea), fever, gastrointestinal symptoms or fatigue due to physiologic adaptations in pregnant women, adverse pregnancy events, or other diseases such as malaria, may overlap with symptoms of COVID-19. • Children might not have reported fever or cough as frequently as adults.

Source: Adapted from *(9)*.

Table 2. COVID-19 infection probability and case definitions[a]

Contact	A person who experienced any one of the following exposures from 2 days before to 14 days after the onset of symptoms of a probable or confirmed case of COVID-19:[b] (1) face-to-face contact with a probable or confirmed case within 1 meter and for more than 15 minutes; (2) direct physical contact with a probable or confirmed case; (3) direct care for a patient with probable or confirmed COVID-19 without using proper personal protective equipment; OR (4) other situations as indicated by local risk assessments.
Suspected case	(A) A patient who meets the **clinical criteria** (i.e. acute onset of fever AND cough; OR acute onset of ANY THREE OR MORE of the following signs or symptoms: fever. cough, general weakness/fatigue,[c] headache, myalgia, sore throat, coryza, dyspnoea, anorexia/nausea/vomiting,[c] diarrhoea, altered mental status, anosmia or ageusia with absence of any other identified cause) AND **epidemiological criteria** (i.e. residing or working in an area with high risk of transmission of SARS-CoV-2:close residential settings, humanitarian settings such as camp or camp-like settings for displaced people anytime within the 14 days prior to symptom onset; or residing or travel to an area with community transmission anytime within the 14 days prior to symptom onset; or working in any health care setting, including within health facilities or within the community anytime within the 14 days prior to symptom onset). (B) A patient with severe acute respiratory illness (i.e. acute respiratory infection with history of fever or measured fever of $\geq$ 38°C; and cough; with onset within the last 10 days; and requires hospitalization). (C) Asymptomatic person not meeting epidemiological criteria but with a positiveSARS-CoV-2 antigen-detecting rapid diagnostic test (Ag-RDT).
Probable case	(A) A patient who meets clinical criteria above AND is a contact of a probable or confirmed case, or linked to a COVID-19 cluster.[d] (B) A suspect case with chest imaging showing findings suggestive of COVID-19.[e] (C) A person with recent onset of anosmia (loss of smell) or ageusia (loss of taste) in the absence of any other identified cause. (D) Death, not otherwise explained, in an adult with respiratory distress preceding death AND was a contact of a probable or confirmed case or linked to a COVID-19 cluster.

Table 2. continued

Confirmed case	(A) A person with a positive nucleic acid amplification test (NAAT). (B) A person with a positive SARS-CoV-2 Ag-RDT AND meeting either one of the 4 criteria for probable case definition or meeting criteria A OR B for suspected case definition. (C) An asymptomatic person with a positive SARS-CoV-2 Ag-RDT who is a contact of a probable or confirmed case.

[a] See the WHO website for the most up-to-date case definitions: https://www.who.int/publications/i/item/WHO-2019-nCoV-Surveillance_Case_Definition-2020.2. Updated information about diagnostic testing is available at "Diagnostic testing for SARS-CoV-2" (https://www.who.int/publications/i/item/diagnostic-testing-for-sars-cov-2) and "Antigen detection in the diagnosis of SARS-CoV-2 infection using rapid immunoassays" (https://www.who.int/publications/i/item/antigen-detection-in-the-diagnosis-of-sars-cov-2infection-using-rapid-immunoassays). Note: Clinical and public health judgment should be used to determine the need for further investigation in patients who do not strictly meet the clinical or epidemiological criteria. Surveillance case definitions should not be used as the sole basis for guiding clinical management.

b See WHO interim guidance "Considerations for quarantine of contacts of COVID-19 cases" from 19 August 2020: https://www.who.int/publications/i/item/considerations-for-quarantine-of-individuals-in-the-context-of-containment-for-coronavirus-disease-(covid-19).

[c] Signs separated with forward slash (/) are to be counted as one sign.

d A group of symptomatic individuals linked by time, geographic location and common exposures, containing at least one nucleic acid amplification test (NAAT)-confirmed case or at least two epidemiologically linked, symptomatic (meeting clinical criteria of suspect case definition A or B) people with positive Ag RDT (based on ≥ 97% specificity of test and desired > 99.9% probability of at least one positive result being a true positive).

e Typical chest imaging findings suggestive of COVID-19 include the following: (i) chest radiography: hazy opacities, often rounded in morphology, with peripheral and lower lung distribution; chest CT: multiple bilateral ground glass opacities, often rounded in morphology, with peripheral and lower lung distribution; LUS: thickened pleural lines, B lines (multifocal, discrete, or confluent), consolidative patterns with or without air bronchograms.

Source: Adapted from *(9)*.

Table 3. Summary of typical features of COVID-19 severity

Disease severity	Typical features
Mild disease	Symptomatic patients (Table 1) meeting the case definition for COVID-19 (Table 2) without evidence of viral pneumonia or hypoxia.
Moderate disease	Adolescent or adult with signs of pneumonia (fever, cough, dyspnoea, fast breathing) but no signs of severe pneumonia, including oxygen saturation (SpO_2) ≥ 90% while breathing normal room air.[a] Child with clinical signs of pneumonia (cough or difficulty breathing and fast breathing[b] and/or chest indrawing) and no signs of severe pneumonia present.
Severe disease	Adolescent or adult with clinical signs of pneumonia (fever, cough, dyspnoea, fast breathing) plus one of the following: respiratory rate > 30 breaths/min; severe respiratory distress; or SpO_2< 90% while breathing normal room air. Child with clinical signs of pneumonia (cough or difficulty in breathing) and at least one of the following: • central cyanosis or SpO_2< 90% while breathing normal room air; severe respiratory distress (e.g. fast breathing, grunting, very severe chest indrawing); general danger sign: inability to breastfeed or drink, lethargy or unconsciousness, or convulsions. • fast breathing for age.[b]
Critical disease	Acute respiratory distress syndrome (ARDS), sepsis (i.e.in adults: acute life-threatening organ dysfunction caused by a dysregulated response to suspected or proven infection), septic shock, acute thrombosis (i.e. acute venous thromboembolism, acute coronary syndrome, acute stroke), multisystem inflammatory syndrome in children and adolescents temporally related to COVID-19.[c]

[a] The oxygen saturation threshold of 90% to define severe COVID-19 was arbitrary and should be interpreted cautiously. Clinicians must use their judgment to determine whether low oxygen saturation is a sign of severity or is normal for a given patient with chronic lung disease. Similarly, saturation > 90–94% on room air is abnormal (inpatients with lungs functioning normally) and can be an early sign of severe disease, if patient is on a downward trend.

[b] Child fast breathing (in breaths/min): < 2 months: ≥ 60; 2–11 months: ≥ 50; 1–5 years: ≥ 40.

[c] See WHO scientific brief on multisystem inflammatory syndrome in children and adolescents with COVID-19: https://www.who.int/publications-detail/multisystem-inflammatory-syndrome-in-children-and-adolescents-with-covid-19.

Source: Adapted from *(9)*.

To support the implementation of the recommendations, consideration was given to various risk factors for disease progression, such as age over 60 years (increasing with age), comorbidities (e.g. hypertension, cardiovascular disease, cerebrovascular disease, cancer, diabetes, obesity, chronic pulmonary disease, tuberculosis), immunosuppressive conditions (e.g. human immunodeficiency virus infection and acquired immunodeficiency syndrome), smoking and special groups (pregnancy, children). Additional implementation considerations include the availability of human resources (health workforce and qualified staff) and physical resources (personal protective equipment (PPE) and other infection prevention and control measures, laboratory testing, hospital beds and imaging equipment/devices).

2. Guideline development

The development of this rapid advice guide followed the process outlined in the *WHO handbook for guideline development (11)*. Given the nature of the emergency, the initial process for the publication of the first edition was implemented within a time frame of two months. The process included identifying priority questions and outcomes, retrieving and synthesizing the evidence, assessing the certainty of evidence, formulating the recommendations, and planning for dissemination and implementation. The guideline development process considered resource use and cost implications of implementing the recommendations from a public health perspective. The current update was performed six months later.

2.1 Contributors to the guide

In conformity with the WHO process, the following bodies were established: a WHO steering group, a guideline development group (GDG) and an external review group. In addition, a systematic review team was contracted to conduct a rapid systematic review of the evidence (Web Annex A) and a core group oversaw the prompt management of the project. The names and affiliation of the members of the different groups are listed in Annex 2, which also includes a list of contributors to the development of the guidance on infection prevention and control provided in Annex 1.

WHO steering group

The WHO steering group was composed of relevant staff members from WHO headquarters, including from the departments of Country Readiness Strengthening (CRS), Digital Health and Innovation (DHI), Environment, Climate Change and Health (ECH), Global Infectious Hazard Preparedness (GIH), Health Product Policy and Standards (HPS), Integrated Health Services (IHS) and Maternal, Newborn, Child and Adolescent Health and Ageing (MCA), as well as the Regional Advisor on Radiological Health in the WHO Regional Office for the Americas. The WHO steering group helped identify the GDG and external review group members. It contributed to the formulation of the key questions and reviewed the recommendations and the final document.

Guideline development group

The GDG included experts and relevant stakeholders from multiple disciplines: a guideline methodologist, experts in the field of medical imaging, emergency medicine, intensive care, pulmonology and molecular diagnostics, as well as a representative from a patient advocacy organization. The GDG provided input at all stages of the process and played the main role in development of recommendations. The composition of the GDG ensured geographic representation from five of the six WHO regions, gender balance and absence of conflicts of interest.

External review group

The external review group was composed of experts in the field of medical imaging and pulmonary diseases, and representatives of patient advocacy groups and civil society. The experts reviewed the recommendations developed by the GDG and the final document, and commented on the technical accuracy, clarity of language, contextual issues and implications for implementation. The group was asked not to modify the recommendations that were formulated by the GDG.

Systematic review team

The systematic review team was composed of experts in the field of systematic reviews with clinical background in internal medicine and content experts in the field of medical imaging. They conducted rapid reviews of the literature and provided a report summarizing the findings and certainty of evidence for each key question (Section 2.3). The systematic review report was shared with members of the GDG. Representatives of the systematic review team attended the GDG meetings to provide an overview of the available evidence and to respond to technical queries from the GDG *(12, 13)*.

Qualitative research team

The qualitative research team was composed of experts in qualitative research, pulmonary medicine, radiology and guideline development. They conducted a rapid interview study relevant to key question 7 (addressed in the second edition of the guide), and shared a report summarizing its findings with the GDG members. The lead investigator attended the relevant GDG meeting, presented the findings and responded to technical queries from the GDG.

Core group

The development of these recommendations under very compressed timelines during the COVID-19 pandemic represented a challenge in the context of unprecedented demands in terms of global and local public health response. Anticipating this challenge, the WHO Secretariat assembled a core group to assist in project management. This group included two methodologists, the chairperson of the GDG and a radiology consultant who worked in close consultation with the WHO Secretariat and participated in daily planning and coordination meetings held virtually. The core group drafted the key questions using the "population, intervention, comparator and outcome" (PICO) format, supervised the syntheses and retrieval of evidence, convened and facilitated the GDG meetings, liaised with all established groups, and drafted and finalized the rapid advice guide. In addition, the core group facilitated survey implementation and assessment of current imaging practices in different regions of the world.

2.2 Management of declaration of interests

The disclosure and appropriate management of relevant financial and non-financial conflicts of interest of GDG members and other external experts and contributors is a critical part of guideline development at WHO. According to WHO regulations, all experts must declare their interests prior to participation in WHO guideline development processes and meetings. All GDG members were therefore required to complete a standard WHO declaration of interests form before engaging in the guideline development process. All declarations were reviewed before finalizing the experts' invitations to participate based on the criteria for assessing the severity of conflicts of interest as outlined in the *WHO handbook for guideline development (11)* to all participating experts. All findings from the declaration of interests forms received were managed in accordance with the relevant WHO guidelines on a case-by-case basis and communicated to the experts at the start of the first GDG meeting. In preparation for the second edition of the guide, the GDG members were requested to update the information provided in their WHO declaration of interests forms if/as appropriate. Annex 3 provides a summary of the declaration of interests and how conflicts of interest declared by invited experts were managed.

2.3 Identification of the key questions

For the first edition of the guide, the core group performed a rapid search for formal consensus statements on the use of chest imaging in COVID-19 management from professional bodies and/or national health authorities, with the assistance of the GDG and the International Society of Radiology. These statements were considered during the development of the key questions. The core group formulated the key questions in PICO format, with the help of the steering group, the GDG and the systematic review team.[3] The following six key PICO questions were identified for the first edition of the guide, and retained for its second edition:[4]

1. In asymptomatic contacts of patients with COVID-19, and in contexts where laboratory testing is not available/results are delayed/results are initially negative, should chest imaging (including chest radiography, CT scan, LUS) vs an alternative chest imaging modality vs no chest imaging be used for the diagnostic workup of COVID-19?

2. In symptomatic patients with suspected COVID-19, and in contexts where laboratory testing is not available/results are delayed/results are initially negative, should chest imaging (including chest radiography, CT scan, LUS) vs an alternative chest imaging modality vs no chest imaging be used for the diagnostic workup of COVID-19?

3. In patients with suspected or confirmed COVID-19, not currently hospitalized and with mild symptoms, should chest imaging (including chest radiography, CT scan, LUS) vs an alternative chest imaging modality vs no chest imaging be used to support the decision on hospital admission versus home discharge?

4. In patients with suspected or confirmed COVID-19, not currently hospitalized and exhibiting moderate to severe symptoms, should chest imaging (including chest radiography, CT scan, LUS) vs an alternative chest imaging modality vs no chest imaging be used to support the decision on regular ward admission versus ICU admission?

5. In patients with suspected or confirmed COVID-19, currently hospitalized and exhibiting moderate or severe symptoms, should chest imaging (including chest radiography, CT scan, LUS) vs an alternative chest imaging modality vs no chest imaging be used to modify the therapeutic management?

6. In patients with COVID-19 whose symptoms are resolved, should chest imaging (including chest radiography, CT scan, LUS) vs an alternative chest imaging modality be added to vs not added to laboratory criteria to support decisions on hospital discharge vs no discharge?

For the second edition of the guide, the core group formulated the following additional key question, with the help of the steering group, the GDG and the systematic review team:

7. In individuals who have recovered from COVID-19, should periodic monitoring with chest imaging (including chest radiography, CT scan, LUS) vs an alternative chest imaging modality vs no chest imaging for the development of long-term COVID-19-related conditions be used vs not used?

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[3] Seven PICO questions were addressed in the first systematic review, including one question "PICO 6" concerning diagnostic accuracy of chest imaging for the diagnosis of pulmonary arterial thrombosis or thromboembolism in patients with suspected or confirmed COVID-19. No studies addressing this question were identified by that systematic review. Therefore, no recommendation was developed regarding this topic in the first edition of the guide and the topic was included in the list of research priorities (see Chapter 5). The six PICO questions for which recommendations were provided in the first edition of the guide were considered in the update, and a new question addressing follow-up after hospital discharge (PICO question 7) was added in the second edition.

[4] In the first edition the PICO questions did not address the comparison between different modalities; this was addressed in the second edition, where the question formulation included the text "vs an alternative modality" to refer to the comparison between chest radiography, chest CT and LUS.

2.4 Identification of the critical outcomes

The core group drafted a list of outcomes relevant for each PICO question. The list included three types of outcomes:

- diagnostic accuracy measures (rates of true positive, true negative, false positive, false negative);
- clinical outcomes, including the "core outcomes" developed for COVID-19 *(14)* (i.e. mortality, respiratory failure, multi-organ failure, shortness of breath, recovery), adverse effects of imaging (e.g. exposure to radiation) and COVID-19 transmission to health care workers;
- health systems outcomes, including service use (length of emergency department stay, length of hospital stay, length of ICU stay), availability of care, access to care and quality of care.

The list of outcomes was circulated to the GDG, which scored the importance of each outcome on a scale of 1 to 9 (1–3: not important; 4–6: important; and 7–9: critical). The average score for each outcome was used to prioritize the outcomes for each PICO question. The outcomes selected for each question and the scores assessing their importance are included in the evidence-to-decision tables presented in Web Annex B.

2.5 Evidence identification and retrieval, quality assessment and synthesis of evidence

In preparation for both the first and second editions of the guide, the systematic review team performed a rapid review of the scientific literature to inform the development of the rapid guidance on the use of chest imaging for patients with COVID-19 (Web Annex A). The core group reviewed and provided input into the protocol and worked closely with the systematic review team to ensure the output of the systematic review met the needs of the guideline development process.

The systematic review did not include literature about use of artificial intelligence (AI) in chest imaging for COVID-19 for a number of reasons. Many of the studies initially identified evaluated images from databanks, most of them with limited clinical information. The studies typically used a case–control design, which increases the risk of bias. The reporting of the AI algorithms was in some cases suboptimal, often lacking of independent validation. The AI algorithms were not freely available for clinical use or the information about their free availability was not provided. Furthermore, regulatory approaches for AI vary across the world: while in some countries AI is treated as a medical device and the same review/approval process is applied, information on what is being done in other countries is very scarce. Therefore, the topic of using AI technologies in chest imaging for COVID-19 was included among the identified research priorities (see Chapter 5).

The systematic review team produced a table summarizing the evidence and its certainty using the GRADE approach, for each PICO question *(12)*. The lead author on the systematic review team attended the GDG meetings to provide a summary of the available evidence for each question and to respond to technical queries from GDG members.

According to the GRADE approach, the certainty of evidence is categorized into "high", "moderate", "low" and "very low". The judgment of certainty is based on the study design, factors that lower the certainty of evidence (risk of bias, indirectness, inconsistency, imprecision, publication bias) and factors that increase the certainty of evidence *(13)*.

A thorough search was initially performed up to 15 April 2020, with subsequent literature surveillance through 29 April 2020. Prior to publication of the first edition of this guide, an update search was conducted on 28 May 2020 that found no evidence judged to impact the originally drafted recommendations.

After publication of the guide, WHO continued monitoring relevant emerging data and prepared a second edition of the guide six months after. The recommendations were updated based on the findings of a new systematic review (13 October 2020), which increased the level of certainty of evidence supporting the recommendations without modifying the main conclusions. Due to more robust evidence, the systematic review applied more selective inclusion criteria; specifically, non-peer reviewed studies, case–control studies, and case-series were excluded. Fifty-seven studies on chest imaging for COVID-19 met inclusion criteria for this literature review. A new recommendation on the use of chest imaging after hospital discharge was included in the second edition of the guide (key question 7).

Prior to publication of this second edition of the guide, the systematic review team updated their search up to 1 April 2021. Given the very large volume of literature published on chest imaging for COVID-19 and availability of more rigorous studies, the search strategy was refined to better target relevant, higher-quality studies. Seventy-one new studies on chest imaging for COVID-19 met inclusion criteria for this update of the literature and were included in updated systematic review *(15-85)*. The systematic review team assessed whether, and to what extent, the newly identified studies modified the body of evidence for each question and judged that the newly identified studies did not impact the main conclusions of their initial review, while for some of the recommendations, the certainty of evidence was upgraded (Web Annex A). Taking this into consideration, the core group determined there was no substantial evidence to warrant re-consideration of the originally drafted recommendations, which were therefore not revised.

2.6 Stakeholder survey

In preparation for the first edition of the guide, the core group conducted an online cross-sectional survey to inform the development of the recommendations considering contextual factors that would be relevant for their implementation. Stakeholders were asked them to rate (i) the importance of the outcomes and (ii) their views on the acceptability, feasibility, impact on equity and resource use of the relevant chest imaging modalities (chest radiography, chest CT and LUS) in the different clinical scenarios (key questions 1–6). The survey was developed by the methodologists at the American University of Beirut, and widely disseminated by the WHO Secretariat with the assistance of the steering group, WHO collaborating centres on radiation and health, and relevant nongovernmental organizations, which have official relations with WHO. A total of 249 respondents from all WHO regions, including patients and the public, health care workers (i.e. clinicians, radiologists, radiographers/radiological technologists, medical physicists and others), regulators, policy-makers and researchers participated in the survey over a period of five days. A summary of the results of this survey for each PICO question has been included in the evidence-to-decision tables provided in Web Annex B.

2.7 Qualitative study on contextual factors

In preparation for the second edition of the guide, the core group commissioned a study on contextual factors to inform the recommendation addressing PICO question 7 of the second edition of the guide. The study used a qualitative approach to explore the value stakeholders placed on chest imaging policy for monitoring the development or resolution of COVID-19 sequelae (pulmonary, cardiac) following recovery from an acute episode *(86-88)*.

The study was designed and conducted by a researcher of the Global Health Institute, American University of Beirut, with the assistance of a scientist from this university. A patient representative member of the GDG helped with participant recruitment.

The in-depth interviews explored stakeholders' perspectives on factors influencing guideline implementation. Informants included health care professionals involved in the management and follow-up of patients with COVID-19 and individuals who have recovered from COVID-19. The Evidence to Decision (EtD) framework was used to guide data collection and analysis, including the following constructs: values, preferences, equity, acceptability and feasibility of policy implementation. In addition, the study explored the facilitators and barriers of imaging.

A total of 33 participants from 15 countries from 5[5] of the six WHO regions were recruited between 27 October and 26 December 2020, including 23 providers (11 pulmonologists, 5 radiologists, 3 nephrologists, 1 general practitioner, 2 intensivists, 1 family physician) and 9 patients; one participant contributed as a patient and as a pulmonology fellow.

A summary of the results of this qualitative study on contextual factors for PICO question 7 has been included in the evidence-to-decision tables provided in Web Annex B.

2.8 Additional data

Information about the use of chest imaging in patients with suspected, probable or confirmed COVID-19 around the world was gathered at the beginning of the project to assess current imaging practices and identify clinical scenarios for which global guidance was most needed.

Existing guidance on use of chest imaging in patients with COVID-19 was reviewed and summarized. The following eligibility criteria were adopted: national or international/multinational formal consensus statements on use of chest imaging, established for the management of the COVID-19 pandemic, and developed or endorsed by national or international professional societies and/or health authorities. A total of 33 guidance documents from 22 organizations from all WHO regions[6] were identified.

A survey conducted by the International Society of Radiology and the European Society Radiology on current imaging practices in the management of COVID-19 received responses from 52 imaging services from 31 countries representing all WHO regions.[7] The information collected helped to understand current practice heterogeneities and to identify relevant scenarios to formulate the research questions *(10)*.

2.9 Formulation of the recommendations

Once the evidence had been identified and synthesized and its quality assessed, the GDG was tasked with formulating the recommendations based on evidence. GRADE provides a framework to accomplish this task, with explicit consideration of specific factors that may affect the direction and strength of each

[5] African Region, Region of the Americas, Eastern Mediterranean Region, European Region, South-East Asia Region.

[6] That is, 46% from the European Region, 32% from the Region of the Americas, 7% from the Western Pacific Region, 7% from the Eastern Mediterranean Region, 4% from the South-East Asia Region, and 4% from multiregional organizations that are based in the African Region and elsewhere in the world.

[7] Region of the Americas: 10 services from 2 countries; African Region: 8 services from 4 countries; Eastern Mediterranean Region: 3 services from 3 countries; South-East Asia Region: 1 service from 1 country; Western Pacific Region: 7 services from 5 countries; European Region: 23 services from 16 countries.

recommendation. The direction (whether "in favour of" or "against" an intervention) and strength (whether "conditional" or "strong") of the recommendations reflects the GDG's degree of confidence as to whether the desirable effects of the intervention being considered outweigh the undesirable effects. Table 4 provides the interpretation of strong and conditional recommendations from the perspectives of patients, clinicians and policy-makers.

Table 4. Interpretation of the strength of recommendations by different stakeholders

	Strong recommendation	Conditional recommendation
Patients	Most individuals in this situation would want the recommended course of action; only a small proportion would not.	Most individuals in this situation would want the suggested course of action, but many would not.
Clinicians	Most patients should receive the recom-mended course of action.	Be prepared to help patients to make a deci-sion that is consistent with their own values.
Policy-makers	The recommendation can be adopted as a policy in most situations.	Policy-making will require substantial debate and involvement of various stakeholders.

Due to the COVID-19-related lockdown measures in most countries during the development of the rapid advice guide, physical meetings of the GDG could not be held. Therefore, the members of the GDG were invited to attend a series of online meetings. For the first edition of the guide, five online GDG meetings of around 2 hours each were held on 30 April, 4 May, 5 May, 7 May and 8 May 2020. The first meeting was dedicated to introducing the project and its process. The four subsequent meetings were devoted to formulating the recommendations.

The methodologists developed an evidence-to-decision table for each PICO question using the GRADEpro software. Each table includes sections on the following criteria: benefits and harms, the certainty of the evidence, values and preferences, resource use, equity, acceptability and feasibility *(89-90)*. The tables were pre-populated with the summary of evidence provided in the systematic review report (Web Annex A), and the results of the stakeholders' survey included in the GRADE tables (Web Annex B).

The GDG developed the recommendations based on the PICO questions, and used the evidence-to-decision tables to guide discussions *(91)*. For each PICO question, the GDG reviewed the information pre-populated in the evidence-to-decision tables. First, the systematic review team leader presented the evidence identified by the systematic review. Then the lead methodologist discussed the interpretation of the evidence with the GDG. Next, the methodologist in charge of the stakeholders' survey on acceptability, feasibility, impact on equity and resource use of each of the three chest imaging modalities presented the survey results to the GDG.

The GDG then contributed additional considerations for each of the evidence-to-decision criteria, which were included in the evidence-to-decision tables (Web Annex B).

The GDG voted on each of the evidence-to-decision factors, then on the direction and strength of the recommendation using an online voting tool (menti.com). The voting results served as the starting point for building consensus. None of the GDG members expressed opposition to the final strength or direction of any of the recommendations. When the systematic review identified no relevant evidence for the PICO question, the recommendation was stated as "based on expert opinion".

The GDG also contributed remarks and implementation considerations for each of the recommendations. After the meetings, the core group circulated the draft recommendations and the accompanying remarks and implementation considerations to the GDG and the external review group for feedback prior to incorporation into the final version of the rapid advice guide.

The second edition followed a similar process through three online GDG meetings (23–25 November 2020) involving the same members of the GDG. The systematic review team conducted an update of the systematic review and of the summary evidence tables. For the six key questions covered in the first edition, the Adolopment[8] module of GRADEPro was used *(92)* to provide the GDG members with an overview of i) the evidence, additional considerations, judgments, and recommendation statement from the first edition; and ii) the findings of the update of the systematic review. Then the GDG members decided through a consensus approach whether to keep or change the judgment for the EtD criteria and the recommendation and the accompanying remarks. For key question 7 not previously covered in the first edition, a process identical to the one used in the first edition was followed. That included the review of the findings of the systematic review and of the qualitative study.

2.10 Document preparation and review

The process below was followed for the preparation and review of both editions.

Prior to the online meetings, the core group shared relevant documents and supporting materials with the GDG by email and through shared folders online. Following the virtual meetings, the core group first shared the draft recommendations with the GDG to ascertain that they clearly and accurately reflected the deliberations and decisions made. At that point, the recommendations and remarks were also shared with the steering group and the external review group for their review and input.

In a second step, the core group prepared a full draft of the guide. The draft document was sent to the GDG, the steering group and the external review group for review, and then finalized based on the feedback received. Further modifications made to the document consisted only of addition of the updated review of available evidence, corrections of factual errors and language editing to improve clarity. The final draft was professionally edited for clearance and publication.

2.11 Future update of the guide

These recommendations have been produced in response to the COVID-19 pandemic. WHO will closely monitor emerging data on relevant topics addressed in this guide, which will be updated if/when warranted by evidence. The Radiation and Health Unit in the Department of Environment, Climate Change and Health at WHO headquarters in Geneva will be responsible for any update as appropriate.

[8] In this context the term "adolopment" refers to the combined use of adoption, adaptation and "de novo" recommendations to provide trustworthy guidelines.

3. Recommendations

This chapter presents the recommendations the GDG developed to answer the key PICO questions (detailed in section 2.3) on the use of chest imaging in the diagnostic workup and clinical management of patients with COVID-19 for different clinical scenarios addressed in the second edition of the guide (including contacts, suspected or confirmed cases). All developed recommendations are conditional, which means that the desirable effects likely outweigh the undesirable effects under certain conditions, some of which are summarized in the remarks following each recommendation. The conditions reflect what the GDG discussed as important to optimizing the benefits of the intervention under consideration. The main implication is that policy-makers need to engage relevant stakeholders when using the recommendation to choose the policy option to implement.

This chapter also provides consideration about the implementation of the recommendations. The implementation considerations reflect what the GDG discussed as important for the intervention to translate into the expected benefits when implemented. Membership of the GDG and the external review group included experts from 10 high-income countries and 14 low- and middle-income countries who developed and/or reviewed the implementation considerations linked to each recommendation. They provided comments reflecting the variability of resource settings within and between countries. Availability of resources when choosing the imaging modalities, particularly in low-resource settings and in low- and middle-income countries, was a recurrent theme in the discussion of the different recommendations. Accordingly, this issue was discussed for all recommendations, including its effect on their implementation.

Each recommendation is followed by a succinct summary of the supporting evidence. These summaries have been updated in the second edition based on the findings of the new systematic review. More detailed information is provided in the systematic review report in Web Annex A. The recommendations should be read alongside the remarks and implementation considerations that follow each recommendation.

The recommendations provided in this chapter can be complemented with the guidance on infection prevention and control when performing chest imaging procedures in patients with suspected or confirmed COVID-19 provided in Annex 1. This guidance includes general measures for all imaging procedures and specific precautions for chest radiography, chest CT and LUS.

3.1 Recommendation 1

R1	**For asymptomatic contacts of patients with COVID-19, WHO suggests not using chest imaging for the diagnosis of COVID-19.** *Conditional recommendation, based on low certainty evidence*	***Remark*** Virological testing, e.g. with RT-PCR or antigen-detecting rapid diagnostic tests (Ag-RDTs), can be used to confirm diagnosis of COVID-19. Local protocols related to quarantine and testing should be followed.[9]

Evidence

The systematic review (detailed in Web Annex A) identified no direct evidence evaluating the diagnostic accuracy of imaging in asymptomatic contacts of patients with COVID-19.Indirect evidence identified consisted of a new study that evaluated the diagnostic accuracy of CT in patients without COVID-19 symptoms who were admitted to a tertiary medical centre for other conditions or procedures *(93)*). The prevalence of SARS-CoV-2 infection in this population was 5.3%. CT was associated with a sensitivity of 0.18 (95% CI 0.10–0.30) and a specificity of 0.98 (95% CI 0.97–0.99) for diagnosis of SARS-CoV-2 infection based on a COVID-19 Reporting and Data System (CO-RADS) score of 4 or 5. The sensitivity was 0.32 (95% CI 0.20–0.45) and the specificity was 0.94 (95% CI 0.93–0.96) based on a CO-RADS score of 3 to 5. The positive predictive value ranged from 0.24 to 0.32 and the negative predictive value was 0.96 at both thresholds. CO-RADS is a standardized assessment scheme for pulmonary involvement of COVID-19 that allows for the comparison of data across institutions and populations *(94)*.

The certainty of evidence was judged to be low for comparing the use of CT versus no CT (judged as very low in the first edition), very low for assessing the use of chest radiography versus no chest radiography (same as in the first edition), and very low for the comparison of LUS versus no LUS (same as in the first edition) (Web Annex A).

An interactive summary of findings was created – CT scan vs no CT scan; chest radiography vs no chest radiography; and LUS vs no LUS[10] – based on the findings of the updated systematic review in terms of sensitivity and specificity. The interactive summary table provides estimations for different measures in the setting of three different prevalence levels of COVID-19 (1%, 10% or 50%). A plain language explanation is also provided.

The update of the review conducted before the publication of this second edition of the guide identified five new eligible studies. The synthesized evidence (as well as its associated level of certainty) is provided in the report of the updated literature review. The originally drafted recommendation and the certainty of its evidence base were judged to remain unchanged (Web Annex A).

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[9] Virological testing with RT-PCR can be done to confirm diagnosis of COVID-19. While a positive PCR is confirmatory for COVID-19, a negative PCR in an asymptomatic contact does not rule out infection/infectivity. The individual may still be incubating an infection and would need to be tested several times over a 10-day period. As such, contacts of cases often get put in self-quarantine without testing. WHO guidance for quarantine of contacts of COVID-19 cases is available at https://www.who.int/publications/i/item/considerations-for-quarantine-of-individuals-in-the-context-of-containment-for-coronavirus-disease-(covid-19).

[10] CT scan vs no CT scan: https://gdt.gradepro.org/presentations/#/isof/isof_793066fb-d5d0-49c4-bc32-a78b07c71aaa-1607200084194?_k=ohk500; chest radiography vs no chest radiography: https://gdt.gradepro.org/presentations/#/isof/isof_2e44e4c5-612a-49e4-816f-7da3c8deafaa-1607199819789?_k=4px8pj; LUS vs no LUS: https://gdt.gradepro.org/presentations/#/isof/isof_ca07d2cb-f819-4e09-bec1-1a6514556be7-1607200495736?_k=kzam8h

Implementation considerations

1. Consider whether virological testing is available and, if the test is performed, whether the results are positive or negative.
2. Consider the use of chest imaging in asymptomatic contacts who progress to develop respiratory symptoms (body temperature monitoring).
3. Consider assessing for incidental pulmonary findings suspicious of COVID-19 on imaging performed for other reasons (e.g. thoracic spine radiography, cardiac CT, any other radiography or CT scan including part of the thorax) in countries/regions with previous or current high COVID-19 prevalence.

3.2 Recommendation 2

R2.1	**For symptomatic patients with suspected COVID-19, WHO suggests not using chest imaging for the diagnostic workup of COVID-19 when virological testing is available with timely results.** *Conditional recommendation, based on moderate certainty evidence*	***Remark*** Virological testing, e.g. with RT-PCR or antigen-detecting rapid diagnostic tests (Ag-RDTs), can be used to confirm diagnosis of COVID-19. Local protocols related to isolation and testing should be followed.[11]
R2.2	**For symptomatic patients with suspected COVID-19, WHO suggests using chest imaging for the diagnostic workup of COVID-19 when: (1) virological testing is not available; (2) virological testing is available, but results are delayed; and (3) initial virological testing is negative, but high clinical suspicion of COVID-19 remains.** *Conditional recommendation, based on moderate certainty evidence*	***Remarks*** Virological testing (e.g. with RT-PCR or Ag-RDT) can be used to confirm diagnosis of COVID-19. Local protocols related to isolation and testing should be followed. Imaging should be used as one element of the diagnostic workup that otherwise includes clinical and laboratory data. Patients likely to benefit from chest imaging are those who: • have severe symptoms and/or signs on physical exam; • require emergency procedures or other urgent interventions (e.g. administration of a thrombolytic therapy or haemodialysis); • have presentations that could represent complications of COVID-19 (e.g. pneumonia, pulmonary arterial thrombosis or thromboembolism); • need to be admitted irrespective of diagnosis (e.g. disease is severe or likely to progress), to help with disposition or triaging (e.g. to dedicated COVID-19 ward vs non-COVID-19 ward); • need to be transferred to another facility; • live with people at high risk if infected with COVID-19 (e.g. immunocompromised, people aged over 60 years); • live in small homes, overcrowded households or densely populated settings, where isolation is very difficult to implement; • live in communities with people at high risk such as retirement homes or dormitories. When choosing the imaging modalities, consider the following • The evidence supporting chest CT has a certainty level that is higher than that of other imaging modalities. Chest CT can be useful in patients with some pre-existing pulmonary diseases. However, the absence of radiological signs of pneumonia cannot completely exclude a viral infection. Chest CT is less preferred in settings with a high prevalence of COVID-19 as this might lead to its increased utilization and diversion of resources from non-COVID-19 patients, taking also in consideration the time needed for disinfection of the CT equipment after any suspected or confirmed COVID-19 case. • Chest radiography is less-resource intensive, is associated with lower radiation doses, is easier to repeat sequentially for monitoring disease progression, and can be performed with mobile equipment at the point of care (which minimizes the risk of cross-infection related to patient transport).If feasible, the option of performing the chest radiography through a glass door may reduce the risk of COVID-19 transmission and the use of PPE *(95)*. • LUS has low-certainty evidence supporting its diagnostic accuracy but might be helpful with the appropriate expertise as a supplemental or alternative modality (e.g. in pregnant women, children). LUS can be done at the point of care but requires closer physical proximity of the operator to the patient for a longer period and requires specific infection prevention and control precautions. • The most appropriate imaging modality should be chosen considering the differential diagnoses for each specific case (e.g. CT angiography for pulmonary arterial thrombosis or thromboembolism, LUS for pleural effusions and echocardiography for heart conditions). • Choice should be made through shared decision-making involving the referring physician, the radiologist and the patient whenever possible. If feasible, the patient should be provided with information regarding the imaging modality to be used and the likelihood of requiring subsequent imaging procedures. Responsibility for patients' well-being includes physical and emotional aspects. Psychologically comforting the patient while providing medical information contributes to reducing the patient's anxiety. • Even when chest imaging is used in the initial diagnostic workup of COVID-19, virological testing should be considered to confirm the diagnosis of COVID-19.

[11] Virological testing with RT-PCR can be done to confirm diagnosis of COVID-19. While a positive PCR is confirmatory for COVID-19, a negative PCR in an asymptomatic contact does not rule out infection/infectivity. The individual may still be incubating an infection and would need to be tested several times over a 10-day period. As such, contacts of cases often get put in self-quarantine without testing. WHO guidance for quarantine of contacts of COVID-19 cases is available at https://www.who.int/publications/i/item/considerations-for-quarantine-of-individuals-in-the-context-of-containment-for-coronavirus-disease-(covid-19)

Evidence

The systematic review (Web Annex A) identified 37 studies that evaluated the diagnostic accuracy of three imaging modalities in symptomatic patients with suspected COVID-19, against a reference standard (Web Annex A) including chest CT (n=29, chest radiography (n=6) and LUS (n=4). The prevalence of SARS-CoV-2 infection was high in these studies. These studies are detailed in Web Annex A.

Regarding chest CT *(93, 94, 96-121)*, two studies were rated as low risk of bias, one study was rated as high risk of bias and the rest were all rated as moderate risk of bias. Based on more stringent criteria for classifying imaging findings as positive for COVID-19 (i.e. CO-RADS category 4 or 5), chest CT was associated with a pooled sensitivity of 0.89 (95% CI 0.85–0.91) and pooled specificity of 0.81 (95% CI 0.73–0.88), based on 22 studies, for a positive likelihood ratio of 4.77 (95% CI 3.29–6.91) and negative likelihood ratio of 0.14 (95% CI 0.11–0.17). Based on less stringent criteria for classifying imaging findings as positive for COVID-19 (e.g. CO-RADS category 3 to 5), chest CT was associated with a pooled sensitivity of 0.92 (95% CI 0.89–0.94) and pooled specificity of 0.71 (95% CI 0.59–0.81) based on 11 studies (n=4143), for a positive likelihood ratio of 3.22 (95% CI 2.21–4.71) and negative likelihood ratio of 0.11 (95% CI 0.09–0.15).

Regarding chest radiography *(122-127)*, one study was rated as low risk of bias, one study was rated as moderate risk of bias and four studies were rated as high risk of bias. The presence of imaging findings suggestive of COVID-19 was associated with a pooled sensitivity of 0.72 (95% CI 0.56–0.84) and pooled specificity of 0.71 (95% CI 0.51–0.86) for a positive likelihood ratio of 2.50 (95% CI 1.38–4.51) and negative likelihood ratio of 0.40 (95% CI 0.25–0.64).

Regarding LUS *(126-129)*, two studies were rated as moderate risk of bias and two studies were rated as high risk of bias. LUS was associated with a pooled sensitivity of 0.78 (95% CI 0.71–0.84) and pooled specificity of 0.76 (95% CI 0.55–0.89) for a positive likelihood ratio of3.24 (95% CI 1.63–6.46) and negative likelihood ratio of 0.28 (95% CI 0.21–0.39), based on four studies.

The certainty of evidence was judged to be moderate for CT versus no CT (judged as low in the first edition), and low for chest radiography versus no chest radiography (judged as very low in the first edition), and low for LUS versus no LUS (judged as very low in the first edition) (Web Annex A).

An interactive summary of findings was created to compare CT scan vs no CT scan; chest radiography vs no chest radiography; and LUS vs no LUS[12] based on the findings of the updated systematic review (Web Annex A) in terms of sensitivity and specificity. The interactive summary table provides estimations for different measures for three different prevalence levels of COVID-19 (20%, 50% and 80%). A plain language explanation is also provided.

The update of the review conducted before the publication of this second edition of the guide identified 35 new eligible studies evaluating the diagnostic accuracy of chest imaging in symptomatic populations. The synthesized evidence (as well as its associated level of certainty) is provided in the report of the updated literature review. Both the originally drafted recommendations and the associated certainty were judged to remain unchanged (Web Annex A).

[12] CT scan vs no CT scan: https://gdt.gradepro.org/presentations/#/isof/isof_793066fb-d5d0-49c4-bc32-a78b07c71aaa-1607200084194?_k=ohk500; chest radiography vs no chest radiography: https://gdt.gradepro.org/presentations/#/isof/isof_2e44e4c5-612a-49e4-816f-7da3c8deafaa-1607199819789?_k=4px8pj; LUS vs no LUS: https://gdt.gradepro.org/presentations/#/isof/isof_ca07d2cb-f819-4e09-bec1-1a6514556be7-1607200495736?_k=kzam8h

Implementation considerations

1. Implement the recommendations based on equipment availability. Consider the resources needed (budget, health workforce, PPE, imaging equipment), the need to adapt the clinical workflow and the need to deprioritize other indications for imaging.
2. Consider the use of locally developed flow charts, infographics and other decision-support tools to facilitate implementation.
3. Bear in mind that recommendations for imaging depend on severity of symptoms and that chest imaging is an essential investigation in those who develop respiratory symptoms or hypoxia.
4. Monitor respiratory symptoms and physical exam findings to guide timing of chest imaging.
5. Consider the use of mobile equipment for performing chest radiography at the point of care in hospitals and health care facilities. Consider the use of portable equipment for chest radiography and/or LUS, combined with virological testing, in the case of outreach interventions, and interventions in people far from health centres (i.e. assisted living facilities, nursing homes, retirement residences, rural areas/villages). Consider the use of portable ultrasound for lung examination in the case of home healthcare.
6. Mitigate the risk of infection transmission to health care workers and to other patients associated with patient transport to the imaging department (e.g. use of point-of-care imaging mobile equipment). (See infection prevention and control precautions in Annex 1.)
7. Consider the possibility of false negative imaging results in patients for whom chest imaging indicates no findings suspicious of COVID-19 (particularly during the first 2 days after symptom onset; chest imaging, especially chest radiography, may be suboptimal in obese patients and may also be a source of false negative imaging results).
    a. If discharged from the emergency department or other outpatient assessment setting, patients need to abide by the local public health measures (e.g. quarantine, social distancing) until diagnosis is established.
    b. If the patient is admitted, health care workers need to consider appropriate clinical precautions until diagnosis is established.
8. When performing chest radiography and chest CT, minimize radiation dose while maintaining diagnostic image quality (e.g. low-dose scanning protocols). For radiography, prefer digital imaging rather than film-screen equipment whenever possible *(130)*.
9. Consider the potential harms from exposure to ionizing radiation, in particular for pregnant women and children.
10. Ensure proper use of PPE by health care workers and proper disinfection of equipment and devices (see Annex 1).
11. Provide appropriate training to radiologists and technologists on infection prevention and control practices, including equipment disinfection procedures; such training should include the efficient management of typical imaging findings of COVID-19 through accepted local protocols.
12. Consider the transfer of images for remote reporting (teleradiology) as needed (e.g. settings where radiologists are not available for on-site reporting).
13. Provide information to patients about safety provisions adopted by the facility for infection prevention and control (see Annex 1) as well as for radiation protection *(130)*. Consider posting in critical areas written briefs for patients describing the disinfection procedures.
14. Make provisions to ensure that all patients get the imaging services they need without suffering financial hardship.

3.3 Recommendation 3

R3

For patients with suspected or confirmed COVID-19, not currently hospitalized and with mild symptoms, WHO suggests using chest imaging in addition to clinical and laboratory assessment to decide on hospital admission versus home discharge.

Conditional recommendation, based on moderate certainty evidence

Remarks

Imaging should be used as one element of patient evaluation that otherwise includes an assessment of the severity of presentation and of the risk of progression, ideally measured with a validated risk stratification tool *(131, 132)*. Patients likely to benefit are those who:

- are judged to be at increased risk of disease progression based on risk stratification using a validated prediction tool;
- have associated comorbidities (e.g. diabetes, hypertension, heart disease, obesity) or other chronic diseases which might decompensate and/or are aged over 60 years;
- live with individuals at high risk of morbidity and mortality associated with COVID-19 (e.g. people aged over 60 years, immunocompromised), whether at home or retirement home;
- live in small homes, overcrowded households or densely populated settings where isolation is very difficult to implement.
- represent an increased risk of dissemination within their community due to their occupational, social or other circumstances.

When choosing the imaging modalities, consider the following.

- Chest CT can be useful in patients with some pre-existing pulmonary diseases. However, the absence of radiological signs of pneumonia cannot completely exclude a viral infection. Chest CT is less preferred in settings with a high prevalence of COVID-19 as this might lead to its increased utilization and diversion of resources from non-COVID-19 patients, taking also in consideration the time needed for disinfection of the CT equipment after any suspected or confirmed COVID-19 case.
- Chest radiography is less resource intensive, is associated with lower radiation doses, is easier to repeat sequentially for monitoring disease progression, and can be performed with portable equipment at the point of care (which minimizes the risk of cross-infection related to patient transport). If feasible, the option of performing the chest radiography through a glass door may reduce the risk of COVID-19 transmission and the use of PPE *(95)*.
- LUS has low-certainty evidence supporting its diagnostic accuracy but might be helpful with the appropriate expertise as a supplemental or alternative modality (e.g. in pregnant women, children). It can be done at the point of care but requires closer physical proximity of the operator to the patient for a longer period and requires specific infection prevention and control precautions.
- The most appropriate imaging modality should be chosen considering the differential diagnoses for each specific case (e.g. CT angiography for pulmonary arterial thrombosis or thromboembolism, ultrasound for pleural effusions and heart conditions).
- Choice should be made through shared decision-making involving the referring physician, the radiologist and the patient whenever possible. If feasible, the patient should be provided with information regarding the imaging modality to be used and the likelihood of requiring subsequent imaging procedures.
- When there is a clinical deterioration,[13] the multi-organ systemic involvement of COVID-19 should be considered, in particular heart, brain, kidney and gastrointestinal localizations.

[13] Clinical deterioration of a patient without mechanical ventilation: abrupt worsening of hypoxia, oedema or erythema of an extremity, unexplained shortness of breath out of proportion to oxygen saturation, increased tachycardia. For mechanically ventilated patients: increased dead space fraction out of proportion to change in lung compliance.

Evidence

The systematic review (Web Annex A) identified four observational studies evaluating the association between chest CT conducted in the emergency department prior to hospitalization in patients diagnosed with COVID-19 and subsequent clinical outcomes *(133-136)*. These studies are detailed in Web Annex A. One study found a CT severity score of 18 or greater associated with increased likelihood of mortality, after adjusting for age (adjusted hazard ratio (HR) 3.74, 95% CI 1.10–12.77). Three studies reported the area under the receiver operating characteristic (AUROC) curve with values ranging from 0.75 to 0.83.

Regarding chest radiography, three studies evaluated the association between imaging findings on chest radiography conducted in the emergency department prior to hospitalization in patients diagnosed with COVID-19 and subsequent clinical outcomes *(124, 137, 138)*. In one study, the chest radiography severity score of 2 or greater (range 0–12) was associated with increased likelihood of hospital admission (adjusted odds ratio (OR) 6.2, 95% CI 3.5–11). The extent of lung involvement on chest radiography was associated with intubation with adjusted OR of 4.7 (95% CI 1.8–13) in one study and HR of 3.69 (95% CI 2.25–6.07) in another study. Also, the extent of lung involvement on chest radiography was also associated with ICU admission, intubation or death (AUROC 0.77–0.84. Two studies reported no association or negative association with length of stay.

Regarding LUS, three studies evaluated the association between its use prior to hospitalization in patients diagnosed with COVID-19 and subsequent clinical outcomes *(139-141)*. One study found an association between having at least three upper site B-lines on LUS and likelihood of ICU admission (adjusted OR 1.6, 95% CI 1.2–2.1) or ARDS (adjusted OR 1.7, 95% CI 1.3–2.3), but found no association with mortality. Another study found the LUS severity score to have a sensitivity of 0.81 and specificity of 0.59 for hospitalization; however there was poor accuracy for death or intubation. A study conducted in a nursing home found that LUS severity score was associated with a sensitivity of 0.58 (95% CI 0.28–0.85) and a specificity of 0.64 (95% CI 0.46–0.79) and AUROC of 0.60 (95% CI 0.42–0.79).

The update of the review conducted before the publication of this second edition of the guide identified 31 new eligible studies evaluating the association between chest imaging findings and subsequent clinical outcomes. The synthesized evidence (as well as its associated level of certainty) is provided in the report of the updated literature review. While originally drafted recommendation was judged to remain unchanged, its associated certainty was judged to be moderate (Web Annex A).

The certainty of evidence was judged to be moderate for the comparison of CT versus no CT (judged as very low in the first edition), moderate for that of chest radiography versus no chest radiography (judged as very low in the first edition), and low for evaluation of LUS versus no LUS (judged as very low in the first edition).

Implementation considerations

1. Implement the recommendations based on equipment availability. Consider the resources needed (budget, health workforce, PPE, imaging equipment), the need to adapt the clinical workflow and the need to deprioritize other indications for imaging.
2. Consider performing virological testing of suspected cases within 24 hours and implement precautions until results are available.
3. Consider that home isolation may not be feasible in certain settings (e.g. overcrowded households, densely populated cities).
4. If available, low-dose CT can be performed on adult patients. For paediatric patients, chest radiography would be favoured.

5. Consider the potential harms from exposure to ionizing radiation, in particular for pregnant women and children.
6. Favour the use of portable equipment for performing chest imaging in isolated rooms in the emergency department.
7. Consider the possibility of false negative imaging results in patients for whom chest imaging indicates no findings suspicious of COVID-19 (particularly during the first 2 days after symptom onset; chest imaging may be suboptimal in obese patients and may also be a source of false negative imaging results).
    a. If discharged from the emergency department or other outpatient assessment setting, patients need to abide by the local public health measures (e.g. quarantine, social distancing) until a diagnosis is established.
    b. If the patient is admitted, health care workers need to consider appropriate clinical precautions until a diagnosis is established.
8. When performing chest radiography and chest CT, minimize radiation dose while maintaining diagnostic image quality (e.g. low-dose scanning protocols). For radiography, prefer digital imaging rather than film-screen equipment whenever possible *(130)*.
9. When performing chest radiography, consider using mobile equipment, and if feasible, a unit dedicated to patients with COVID-19.
10. Ensure proper use of PPE by health care workers and proper disinfection of equipment and devices (see Annex 1).
11. Provide appropriate training to radiologists and technologists on infection prevention and control practices, including equipment disinfection procedures; such training should include the efficient management of typical imaging findings of COVID-19 through accepted local protocols.
12. Consider the transfer of images for remote reporting (teleradiology) as needed (e.g. settings where radiologists are not available for on-site reporting).
13. Set policy/pathway for use of imaging related to COVID-19 illustrated with flow charts, infographics and/or other decision-support tools locally developed and accepted.
14. Inform the patient about safety provisions for infection prevention and control (see Annex 1) as well as for radiation protection *(130)*.
15. Make provisions to ensure that all patients get the imaging services they need without suffering financial hardship.

3.4 Recommendation 4

R4	**For patients with suspected or confirmed COVID-19, not currently hospitalized and with moderate to severe symptoms, WHO suggests using chest imaging in addition to clinical and laboratory assessment to decide on regular ward admission versus intensive care unit (ICU) admission.** *Conditional recommendation, based on moderate certainty evidence*	***Remarks*** Imaging should be used as one element of patient evaluation that otherwise includes an assessment of the severity of presentation and of the risk of progression, ideally measured with a validated risk stratification tool *(131, 132)*. Patients likely to benefit are those who: • are judged to be at increased risk of disease progression based on risk stratification using a validated prediction tool; • are not responding to supportive treatment (e.g. oxygen supplementation); • present acute clinical deterioration not elucidated. When choosing the imaging modalities consider the following. • Chest CT can be useful in patients with some pre-existing pulmonary diseases. However, the absence of radiological signs of pneumonia cannot completely exclude a viral infection. Chest CT is less preferred in settings with a high prevalence of COVID-19 as this might lead to its increased utilization and diversion of resources from non-COVID-19 patients. • Chest radiography is less resource intensive, is associated with lower radiation doses, is easier to repeat sequentially for monitoring disease progression, and can be performed with portable equipment at the point of care (which minimizes the risk of cross-infection related to patient transport).If feasible, the option of performing the chest radiography through a glass door may reduce the risk of transmission and the use of PPE *(95)*. • LUS has low-certainty evidence supporting its diagnostic accuracy but might be helpful with the appropriate expertise as a supplemental or alternative modality (e.g. in pregnant women, children, patients on mechanical ventilation). It can be done at the point of care but requires closer physical proximity of the operator to the patient for a longer period and requires specific infection prevention and control precautions. • The most appropriate imaging modality should be chosen considering the differential diagnoses for each specific case (e.g. CT angiography for pulmonary arterial thrombosis or thromboembolism, ultrasound for pleural effusions and heart conditions). • Choice should be made through shared decision-making involving the referring physician, the radiologist and the patient whenever possible. If feasible, the patient should be provided with information regarding the imaging modality to be used and the likelihood of requiring subsequent imaging procedures. • When there is a clinical deterioration,[14] the multi-organ systemic involvement of COVID-19 should be considered, in particular heart, brain, kidney and gastrointestinal localizations.

Evidence

Studies providing relevant data in the systematic review conducted for this second edition, as well as in the update conducted before its publication, did not clearly distinguish between patients with mild versus moderate or severe symptoms (Web Annex A). Therefore the same evidence used for key question 3 was used for key question 4 (please refer to section 2.3).

[14] Clinical deterioration of a patient without mechanical ventilation: abrupt worsening of hypoxia, oedema or erythema of an extremity, unexplained shortness of breath out of proportion to oxygen saturation, increased tachycardia. For mechanically ventilated patients: increased dead space fraction out of proportion to change in lung compliance.

Implementation considerations

1. Implement the recommendations based on equipment availability. Consider the resources needed (budget, health workforce, PPE, imaging equipment), the need to adapt the clinical workflow, and the need to deprioritize other indications for imaging.
2. Chest CT can support the decision on regular ward admission versus ICU admission. Chest radiographs are preferred for follow-up in regular ward admission. Patients with rapid progression of COVID-19 pneumonia or diffuse lung damage will likely need ICU admission.
3. Consider the possibility of false negative imaging results in patients for whom chest imaging indicates no findings suspicious of COVID-19 (particularly during the first 2 days after symptom onset; chest imaging may be suboptimal in obese patients and may also be a source of false negative imaging results).
4. Health care workers need to consider appropriate clinical precautions until the diagnosis is established. Ensure proper use of PPE and proper disinfection of equipment and devices (see Annex 1).
5. When performing chest radiography and chest CT, minimize radiation dose while maintaining diagnostic image quality (e.g. low-dose CT protocols). For radiography, prefer digital imaging rather than film-screen equipment whenever possible *(130)*.
6. When performing chest radiography, consider using mobile equipment, and if feasible, a unit dedicated to patients with COVID-19.
7. Consider the potential harm from exposure to ionizing radiation, in particular for pregnant women and children.
8. Provide appropriate training to radiologists and technologists on infection prevention and control practices, including equipment disinfection procedures; such training should include the efficient management of typical imaging findings of COVID-19 through accepted local protocols.
9. Consider the transfer of images for remote reporting (teleradiology) as needed (e.g. settings where radiologists are not available for on-site reporting).
10. Set policy/pathway for use of imaging related to COVID-19 illustrated with flow charts or diagrams locally developed and accepted.
11. If clinical condition permits, inform the patient about safety provisions for infection prevention and control (see Annex 1) as well as for radiation protection *(130)*.
12. Make provisions to ensure that all patients get the imaging services they need without suffering financial hardship.

3.5 Recommendation 5

R5

For patients with suspected or confirmed COVID-19, currently hospitalized and with moderate to severe symptoms, WHO suggests using chest imaging in addition to clinical and laboratory assessment to inform therapeutic management.

Conditional recommendation, based on moderate certainty evidence

Remarks

Imaging should be used as one element of patient evaluation that otherwise includes an assessment of the severity of presentation and of the risk of progression ideally measured with a validated risk stratification tool *(131, 132)*. Patients likely to benefit are those who:

- are judged to be at increased risk of disease progression based on risk stratification using a validated prediction tool;
- are not responding to treatment (oxygen supplementation);
- have presentations with clinical suspicion of pulmonary fibrosis, pulmonary oedema, pulmonary artery thrombosis or thromboembolism.

When choosing the imaging modalities consider the following.

- Chest CT can be useful in patients with some pre-existing pulmonary diseases. However, the absence of radiological signs of pneumonia cannot completely exclude a viral infection. Chest CT is less preferred in settings with a high prevalence of COVID-19 as this might lead to its increased utilization and diversion of resources from non-COVID-19 patients.
- Chest radiography is less resource intensive, is associated with lower radiation doses, is easier to repeat sequentially for monitoring disease progression, and can be performed with portable equipment at the point of care (which minimizes the risk of cross-infection related to patient transport).If feasible, the option of performing the chest radiography through a glass door may reduce the risk of COVID-19 transmission and the use of PPE *(95)*.
- LUS might be helpful with the appropriate expertise (e.g. in pregnant women, children, patients with mechanical ventilation). Ultrasound can be useful when assessing for pleural complications and evaluating the condition of the heart. It can be done at the point of care but requires closer physical proximity of the operator to the patient for a longer period and requires specific infection prevention and control precautions.
- The most appropriate imaging modality should be chosen considering the differential diagnoses for each specific case (e.g. CT angiography for pulmonary artery thrombosis or thromboembolism, LUS for pleural effusions).
- Choice should be made through shared decision-making involving the referring physician, the radiologist and the patient whenever possible. If feasible, the patient should be provided with information regarding the imaging modality to be used and the likelihood of requiring subsequent imaging procedures.
- When there is a clinical deterioration,[15] the multi-organ systemic involvement of COVID-19 should be considered, in particular heart, brain, kidney and gastrointestinal localizations.
- Subject to the clinical condition and availability of resources, other imaging modalities might be used to complement patient evaluation for the assessment of cardiac involvement (e.g. echocardiography, coronary CT angiography, cardiac magnetic resonance).

[15] Clinical deterioration of a patient without mechanical ventilation: abrupt worsening of hypoxia, oedema or erythema of an extremity, unexplained shortness of breath out of proportion to oxygen saturation, increased tachycardia. For mechanically ventilated patients: increased dead space fraction out of proportion to change in lung compliance.

Evidence

Fourteen studies evaluated the association between chest imaging findings and subsequent clinical outcomes (chest CT n=11, chest radiography n=1 and LUS n=1; one study evaluated both chest radiography and LUS. These studies are detailed in Web Annex A.

Eleven studies evaluated the predictive utility of chest CT based on the extent of lung involvement using a CT severity score (n=9) or a quantitative (per cent) lung involvement (n=2) *(142, 144-147, 149-154)*. Two studies found good discrimination (AUROC of 0.88–0.99) for predicting mortality. Five studies found an association between the extent of lung involvement on CT and the composite outcome of ICU admission/mechanical intubation or mortality. Three studies evaluated the association between CT imaging findings and other health outcomes such as increased risk of severe pneumonia, adult respiratory distress syndrome, acute kidney injury, liver dysfunction, acute coronary injury, septic shock, arrhythmia or secondary infection.

Two studies evaluated the association between chest radiography findings in hospitalized patients and subsequent clinical outcomes *(143, 148)*. One of these studies, at high risk of bias, found an association between the presence of bilateral involvement and hilar congestion and mortality. The other study, with a moderate risk of bias, reported imprecise estimates for the association between chest radiography severity score greater than 3 (range 0–36) and likelihood of ICU admission (adjusted OR 0.40, 95% CI 0.02–3.63).

Two studies evaluated the association between LUS findings in hospitalized patients and subsequent clinical outcomes, and both were rated as high risk of bias *(128, 148)*. While one study found that LUS severity score was not predictive of mortality, the other study found an association with increased likelihood of intubation, mortality and the composite outcome of intubation or mortality. The presence of pleural effusion, pleural thickening or subpleural consolidations was also associated with increased risk of mortality or intubation. In this study, LUS was more predictive of subsequent adverse clinical outcomes than chest radiography. However, another study found that LUS severity score (range 0–36) was not predictive of mortality.

The update of the review conducted before the publication of this second edition of the guide identified 24 new eligible studies evaluating the association between chest imaging findings and subsequent clinical outcomes in hospitalized patients. The synthesized evidence (as well as its associated level of certainty) is provided in the report of the updated literature review. While originally drafted recommendation was judged to remain unchanged, its associated certainty was judged to be moderate (Web Annex A).

The certainty of evidence was judged to be moderate for CT versus no CT (judged as very low in the first edition), very low for chest radiography versus no chest radiography (same as in the first edition), and very low for LUS versus no LUS (same as in the first edition).

Implementation considerations

1. Bedside LUS can be helpful to explain respiratory gas exchange deterioration and to detect pleural complication in ICU patients.
2. Mobile equipment is preferred for follow-up of ICU patients. Bedside chest radiography can be helpful for dynamic evaluation of COVID-19 pneumonia and its complications. Resolution or progress of lung consolidation seen on a bedside chest radiograph can inform the therapeutic management. Chest imaging can inform management of pneumothorax or pneumomediastinum.
3. Daily chest radiographs in stable patients are not necessary and may increase the risk of viral transmission to health care workers.
4. When complications are suspected, in particular pulmonary arterial thrombosis or thromboembolism, contrast-enhanced CT may be considered, after weighing the potential risks and benefits.

3.6 Recommendation 6

R6	**For hospitalized patients with COVID-19 whose symptoms are resolved, WHO suggests not using chest imaging in addition to clinical, laboratory and epidemiological assessment to inform the decision regarding discharge.** *Conditional recommendation, based on expert opinion*	***Remarks*** When imaging is used, it should be one element of the patient evaluation that otherwise includes clinical and laboratory data. Patients likely to benefit from chest imaging are those who: • have had a severe form of COVID-19; • have pre-existing chronic lung disease. When choosing the imaging modalities consider the following. • Chest CT can be useful in patients with some pre-existing pulmonary diseases. Chest CT is less preferred in settings with a high prevalence of COVID-19 as this might lead to its increased utilization and diversion of resources from non-COVID-19 patients • Chest radiography is less resource intensive, is associated with lower radiation doses, is easier to repeat sequentially for monitoring disease recovery, and can be performed with mobile equipment at the point of care (which minimizes the risk of cross-infection related to patient transport). If feasible, the option of performing the chest radiography through a glass door may reduce the risk of COVID-19 transmission and the use of PPE *(95)*.

Evidence

The systematic review team identified no study that evaluated any chest imaging modality to support the decision on discharge home in the systematic review conducted for this second edition, nor in the update conducted before its publication.

Implementation considerations

1. C1. Consider radiological findings along with clinical and laboratory data.
2. Implement the recommendations based on equipment availability. Consider the resources needed (budget, health workforce, PPE, imaging equipment), the need to adapt the clinical workflow, and the need to deprioritize other indications for imaging.
3. Decision to discharge should be based more on clinical stability and virological testing.
4. Implement re-evaluation for patients who had severe form of the disease, to depict fibrotic changes.
5. Keep a record of the explorations carried out.
6. When performing chest radiography and chest CT, minimize radiation dose while maintaining diagnostic image quality (e.g. low-dose scanning protocols). For radiography, prefer digital imaging rather than film-screen equipment whenever possible *(130)*.
7. When performing chest radiography, consider using portable equipment, and if feasible, a unit dedicated to patients with COVID-19.
8. Consider the potential harm from exposure to ionizing radiation, in particular for pregnant women and children.
9. Ensure proper use of PPE by health care workers and proper disinfection of equipment and devices (see Annex 1).
10. Provide appropriate training to radiologists and technologists on infection prevention and control practices, including equipment disinfection procedures; such training should include the efficient management of typical imaging findings of COVID-19 through accepted local protocols.
11. Consider the transfer of images for remote reporting (teleradiology) as needed (e.g. settings where radiologists are not available for on-site reporting).

12. Set policy/pathway for use of imaging related to COVID-19 illustrated with flow charts, infographics and/or other decision-support tools locally developed and accepted.
13. Provide information to patients about safety provisions adopted by the facility for infection prevention and control (see Annex 1) as well as for radiation protection *(130)*. Consider posting in critical areas written briefs for patients describing the disinfection procedures.
14. Make provisions to ensure that all patients get the imaging services they need without suffering financial hardship.

3.7 Recommendation 7

R7	**In individuals who have recovered from COVID-19, WHO suggests not systematically scheduling chest imaging follow-up at the time of hospital discharge for assessment of long-term post-COVID-19 conditions.** *Conditional recommendation, based on expert opinion*	***Remarks*** The ultimate decision needs to take into account the clinical situation of the patient at the time of discharge (i.e. symptoms, signs and medical history). Patient groups who might benefit from periodic follow-up imaging include those: • with pre-existing chronic lung and/or heart diseases, other comorbidities (e.g. human immunodeficiency virus infection, tuberculosis) or immunocompromising conditions; • diagnosed with pulmonary embolism and/or acute respiratory distress syndrome (ARDS) during their hospital stay; • with clinical symptoms and/or signs of lung involvement or abnormal imaging findings at the time of hospital discharge.

Evidence

The systematic review team identified no study that evaluated any chest imaging modality for assessment of long-term sequelae in the systematic review conducted for this second edition, nor in the update conducted before its publication. A non-systematic review of the literature on the incidence of long-term COVID-19 lung-related sequelae identified four relevant studies suggesting a relatively low incidence in patients who have recovered from COVID-19 *(155-158)*.

The first study found that hospitalized patients with mild-to-moderate forms of COVID-19 are not at risk of developing pulmonary fibrosis *(155)*. The second study reported that hospitalized patients with severe COVID-19, who did not require mechanical ventilation, were unlikely to develop pulmonary long-term impairments, thromboembolic complications or cardiac impairments after discharge. However it found that those patients frequently suffer from symptoms of fatigue *(156)*. The third study reported the development of pulmonary fibrosis in four patients among only 17 who suffered from severe COVID-19 *(157)*. The fourth study reported the presence of lung fibrosis in only two out of 110 patients included in the cohort *(158)*.

Implementation considerations

1. Transportation cost and distance to health centres may be problematic for some patients.
2. Health-care providers need to communicate with each other and ensure coordination of care.
3. Some patients might need escort either because of sickness or older age (e.g. older people living in nursing homes who are typically dependent on others).
4. Provisions for protection of women, nursing women and pregnant women need to be in place in radiology services.
5. Dialysis patients may need to come early or leave late before or after dialysis for testing.

4. Monitoring and evaluation

This chapter identifies some outcome and performance measures that can be used to measure the impact of the recommendations provided in this guide. They include measures that are relevant to all the recommendations provided in Chapter 3 (i.e. for both diagnostic and management recommendations or for specific groups of recommendations alone). They could help set up baseline data against which to assess changes resulting from the implementation of this guide and provide a framework to facilitate the generation of comparable information in a standardized manner.

4.1 Relevant to both diagnostic and management recommendations

- Monitor the number of requested chest imaging investigations related to COVID-19 and judge their adequacy.
- Monitor the impact of COVID-19-related chest imaging in different clinical scenarios on institutional and national resources (human and financial).
- Monitor the appropriate implementation of workflow and practices and measures related to infection prevention and control and equipment disinfection (e.g. PPE).
- Monitor the number of cases and identify the root causes of infections with SARS-CoV-2 among hospital staff attributable to COVID-19-related chest imaging.

4.2 Relevant to diagnostic recommendations

- Compare the results of COVID-19-related chest imaging with the results of virological testing (once available).
- Monitor the impact of chest imaging on patient stratification into different COVID-19-related risk profiles.

4.3 Relevant to management recommendations

- Monitor the use of mobile and/or portable radiography equipment.
- Monitor the request of CT pulmonary angiography in suspected and confirmed COVID-19 patients

4.4 Relevant to follow-up recommendations

- Monitor the number of requested chest imaging follow-up at the time of hospital discharge of patients who recovered from COVID-19.
- Monitor the impact of COVID-19-related chest imaging scheduled at the time of hospital discharge on institutional and national resources (human and financial).
- Monitor the request of CT pulmonary angiography in patients who recovered from COVID-19.

5. Research priorities

This chapter identifies some research priorities in areas where the certainty of the available evidence is low or very low, or where evidence is lacking. They are presented as research topics which are relevant for both the diagnostic and management recommendations, followed by other topics which are relevant for the specified groups of recommendations.

5.1 Relevant to both diagnostic and management recommendations

- Compare the effects of using the different imaging modalities to not performing imaging (in addition to clinical judgement) on clinical and health services outcomes of interest, for the questions addressed in this guide.

- Evaluate access to and health insurance coverage of chest imaging services related to COVID-19 in different settings.

- Study the role of AI in chest imaging in different settings, especially by assessing the added value of AI as a clinical support system in assisting radiologists with different levels of experience with chest imaging and COVID-19 chest imaging, distinguishing the use of AI for diagnosis (COVID-19 versus other pneumonia or normal cases) from the use of AI for prognostication in confirmed COVID-19 patients (with potential impact on therapy planning).

- Assess the incidence and investigate the root causes of COVID-19 infections among hospital staff attributable to chest imaging of patients with COVID-19 (e.g. in radiologists and radiographers) to identify lessons learned and develop strategies for improvement.

- Evaluate the implementation of workflow developed for COVID-19-related chest imaging.

- Evaluate the safety and effectiveness of performing portable chest radiography, with and without virological testing, at home.

- Evaluate the impact of COVID-19-related imaging on institutional and national resources (human and financial).

- Evaluate the impact of COVID-19-related imaging on equity (e.g. high- versus low-resource settings, underserved communities, people least connected to health resources).

- Assess the values and preferences of different stakeholders for relevant chest imaging modalities in different settings.

5.2 Relevant to diagnostic recommendations

- Conduct well-designed studies to assess the diagnostic accuracy measures of the different imaging modalities. These studies should ideally be cohort studies of patients with suspected or confirmed COVID-19 that clearly describe the disease severity and use an adequate reference standard (serial virological testing and/or clinical follow-up) and clearly defined criteria for positive imaging.

- Study the characteristics of the chest imaging findings in suspected COVID-19 cases who eventually turn out to be positive.

- Study the diagnostic value of chest imaging in asymptomatic contacts who eventually become symptomatic.

- Assess the frequency of incidental findings suggestive of COVID-19 in asymptomatic patients who are scheduled for urgent or non-urgent interventions (e.g. cardiac catheterization, surgery, endoscopy) and undergo imaging procedures.

- Study the findings of CT pulmonary angiography in patients with COVID-19, particularly those with severe and moderate symptoms.

5.3 Relevant to management recommendations

- Evaluate the prognostic value of chest imaging findings during hospital admission regarding inpatient clinical outcomes (risk stratification), and duration of hospital stay.

- Evaluate the prognostic value of chest imaging findings upon discharge regarding post-discharge clinical outcomes (risk stratification) and readmission rates.

- Evaluate the correlation between radiological improvement and clinical improvement in patients with COVID-19.

- Assess the proportion of patients with COVID-19 infection who have pulmonary sequelae on follow-up imaging.

- Assess the value of different imaging modalities in assessing the short- and long-term complications of COVID-19.

- Evaluate the COVID-19 community transmission attributed to patients who are discharged based on negative findings in chest imaging.

5.4 Relevant to follow-up recommendations

- Compare, ideally through randomized controlled trials, the effects of scheduling chest imaging follow-up versus no chest imaging, at the time of hospital discharge for the evaluation of long-term COVID-19-related sequelae and include comparisons between chest radiography, CT scan and LUS.

- Evaluate the accuracy of different imaging modalities in assessing the long-term complications of COVID-19.

- Evaluate the frequency of pulmonary sequelae on imaging and the prognostic value of chest imaging findings during hospital admission and stay regarding development of long-term pulmonary sequelae, such as pulmonary fibrosis.

- Monitor the prevalence of conditions that can be caused by COVID-19 such as possible post-infective complications, pulmonary fibrosis and acute pulmonary embolism.

- Assess the proportion of patients with COVID-19 infection who have pulmonary sequelae on follow-up imaging.

- Assess the value of different imaging modalities in assessing the short- and long-term complications of COVID-19.

6. Publication and dissemination

This guide is available online and in print. Web Annex A (the systematic review report) and Web Annex B (the evidence-to-decision tables) have been published exclusively online; links to those annexes can be found under their entries at the end of the guide. WHO will continue to work closely with its regional offices and with technical partners, professional bodies and other relevant stakeholders to ensure wide dissemination of these recommendations. Key steps in the dissemination include publication and translation into other languages, and development of derivative products to support country adaptation, implementation, monitoring and evaluation (e.g. a toolkit). This will be complemented with presentations in conferences and publication of articles in peer-reviewed journals. To facilitate effective implementation, the integration of these recommendations in future relevant WHO guidance documents on COVID-19 will be considered.

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Annex 1

Infection prevention and control for chest imaging in patients with suspected or confirmed COVID-19

A1 Introduction

Modifying working practices and training staff in the proper use of personal protective equipment (PPE) and in the application of safe clinical imaging techniques, combined with environmental control and equipment disinfection are essential during the COVID-19 pandemic to reduce the risk of infection transmission to patients and staff.

This annex was part of a rapid advice guide on the use of chest imaging in COVID-19 published by WHO in June 2020 and it is now included in this second edition of the guide. It focuses on the imaging modalities referred to in the recommendations of the guide (Chapter 3). Since the publication of the first edition, WHO has updated its guidance on COVID-19 infection prevention and control in health care settings *(A1–A4)*. Building upon WHO guidance, this annex addresses good practices for infection prevention and control for front-line staff performing imaging procedures during the COVID-19 pandemic. Additionally, it describes specific infection prevention and control measures necessary while undertaking chest radiography both in the general imaging department and with portable radiography equipment, as well as when undertaking chest computed tomography (CT) and lung ultrasound (LUS) scans.

A2 General considerations

In this section a checklist is provided on infection prevention and control when performing chest imaging in patients with suspected or confirmed COVID-19. Information in Table A1.1 is applicable to all imaging modalities addressed in Chapter 3 of the guide. This table summarizes infection prevention and control measures when performing chest imaging in patients with suspected or confirmed COVID-19. A pattern suggestive of COVID-19 might be identified in imaging tests performed for another reason (e.g. trauma, cancer, cardiovascular disease) thus representing an incidental finding *(A5–A7)*. Front-line staff performing imaging procedures should be aware of that, and apply local protocols to follow up clinical and infection prevention and control actions, if/as required.

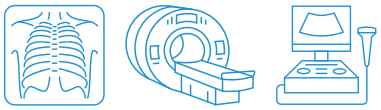

Table A1. Infection prevention and control checklist when performing chest imaging in patients with suspected or confirmed COVID-19

Imaging personnel tasks	Patient considerations	Equipment considerations (fixed and portable)	Environmental considerations of imaging room
Preparation			
• Explore whether the imaging procedure would change patient management, and/or assess if the procedure could be delayed. • Assess whether portable imaging is an option for suspected and confirmed COVID-19 cases. • Evaluate risk factors (age > 60 years, comorbidities, serious underlying medical conditions, immunosuppressive condition, pregnancy, mental health concerns, etc.). • Perform hand hygiene and don PPE following all appropriate steps. • Use PPE during transfer to department when portable imaging equipment is unavailable. • Ensure that the imaging protocol and patient identification procedures are followed.	• Verify imaging request and check whether imaging is required urgently. • Determine whether patient will come to imaging department or whether portable imaging is possible/necessary. • Inform all patients of the need for hand hygiene, and the use of tissues or elbow when coughing or sneezing. • Supply medical masks to patients (and caregivers, if present) upon their arrival for chest imaging, if available and if patient is able to tolerate.	• Ensure infection prevention and control measures are employed when using the imaging equipment. • Subject the imaging equipment to regular cleaning and disinfection, consistent with local infection prevention and control guidance and complete, sign and date cleaning schedules. • Remove unnecessary equipment from imaging room. • Determine whether the examination can be performed with portable imaging equipment. • Cover equipment that cannot be moved with plastic or other suitable material.	• Ensure infection prevention and control measures are employed when using the imaging room. • Subject the imaging room to regular cleaning and disinfection, consistent with local infection prevention and control guidance and complete, sign and date cleaning schedules. • Verify that terminal cleaning and disinfection of the imaging room occurred at end of the previous day. If not done (or not verifiable) ensure that terminal cleaning and disinfection of the imaging room is performed before starting.
During			
• Ensure appropriate PPE is worn. • Employ contact and non-contact radiographer/technologist technique for chest radiography, chest CT and LUS. • Ensure one patient attends the imaging department at a time wherever possible – and undertake further imaging, if this is required.	• Provide medical mask to patient (if feasible), as well as comfort and reassurance.	• Ensure standard operating procedures for infection prevention and control according to local guidance are in place, including contact minimization and barrier precautions (e.g. suitable covers) whenever possible.	• Control access to imaging room or patient area during the portable radiography procedure. • Consider use of appropriate signage/visual alerts in front of imaging room (e.g. patient inside/arriving, ongoing cleaning/disinfection, time of last cleaning/disinfection).
Post procedure			
• Ensure imaging review is made appropriately and apply local protocols to follow up clinical and infection prevention and control actions, if/as required. • If the chest imaging procedure was performed at the imaging department, wear PPE during patient transfer. • Ensure PPE is doffed appropriately, if used.	• Ensure rapid delivery of the imaging results to guide management.	• Ensure appropriate decontamination of medical equipment between patients (applicable to both fixed and portable equipment).	• Ensure appropriate environmental cleaning and disinfection (focus on high-touch surfaces) between patients. Staff performing this task should be trained in cleaning and disinfection and should wear appropriate PPE. • Be aware that, if bedside imaging was performed using portable equipment, room cleaning and disinfection should occur following the protocols applicable for the specific setting (e.g. emergency room, regular ward, intensive care unit).

Staff undertaking imaging procedures are on the front line of the healthcare service and therefore must follow existing local guidance/protocols, taking into consideration existing guidance *(A1-A4)*.[16] In general, the chest imaging procedures recommended in this guide require following droplet and contact precautions.[17] Airborne precautions are reserved for aerosol-generating procedures (e.g. bronchoscopy, tracheotomy, cardiopulmonary resuscitation, non-invasive ventilation, tracheal intubation, manual ventilation before intubation, nebulization, open suction) *(A8)*.

Below is a list of additional infection prevention and control considerations and best practices *(A1-A4, A9, A10)*.

A2.1 General environment

- Schedule appointments to reduce numbers of patients in the waiting room. Designate a waiting area, which should be set up to adopt international guidelines for social distancing of at least 1 metre minimally or whenever possible adapt to local or national guidelines (e.g. 2 metres is adopted in some settings).
- Screen all patients and visitors using standardized checklists for symptoms of acute respiratory infection, significant travel history, occupation, contacts, etc.
- Triage patients to perform imaging in only urgent cases.
- Extend times between scans to allow for cleaning and disinfecting.
- When possible, schedule suspected or confirmed COVID-19 patients at end of clinic day.
- Inform superiors/other healthcare professionals/colleagues which patients are suspected or confirmed prior to imaging.

A2.2 Image acquisition and reporting

- Apply radiation protection principles (justification and optimization) and radiation safety standards where relevant *(A11)*.
- Adjust protocols to reduce exposure and speed up throughput while maintaining quality.
- Always ensure the image quality is diagnostic before leaving the patient.
- In settings where a picture archiving and communication system (PACS) is available, ensure the image is received and available in PACS ready for reporting.
- Images should be reported, and the report communicated to the requesting physician immediately.

A2.3 PPE and hand hygiene

- Health care workers performing chest-imaging procedures should don PPE including long-sleeved gowns, eye or facial protection and gloves *(A1, A2)*. Medical masks are required as part of droplet-contact precautions. For any aerosol-generating procedures respirators (N95 or FFP2 or FFP3 standard, or equivalent) should be used *(A4)*.

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[16] Examples of professional guidance for radiographers and radiological technologists can be found on the website of the International Society of Radiographers and Radiological Technologists, at https://www.elearning.isrrt.org/course/view.php?id=12and its CT webinar: CT examination during the pandemic COVID19, available at https://www.elearning.isrrt.org/course/view.php?id=13#section-1.

[17] See the WHO poster on contact and droplet precautions for COVID-19: https://www.who.int/csr/resources/publications/Contact-Droplet-COVID-19-Precautions.pdf?ua=1.

- Ensure that appropriate PPE is available for staff, that all staff are trained in infection prevention and control measures including hand hygiene, donning and doffing of PPE,[18] and that they know how to use PPE based on local risk assessment and according to national/international guidance *(A1, A2, A4)*.

- Ensure that staff have the resources, training and ability to practice the WHO five moments for hand hygiene.[19] All practitioners should perform hand hygiene before and after all patient contact, contact with potentially infectious material (e.g. linen from patient room), and before donning or doffing PPE including gloves.

- Remember that personal eyeglasses do not provide adequate eye protection. If necessary, a face shield or goggles should be worn over personal eyeglasses. If eyeglasses are worn, be careful not to touch them throughout the procedure, or during doffing of PPE. Personal eyeglasses can be cleaned and disinfected after PPE has been removed if soiling has occurred or there has been potential contamination during the doffing process

A2.4 Staff considerations

- Split staff into multiple shifts to limit exposure of the entire team, ensuring appropriate skill and experience whenever possible. Encourage staff to maintain at least 1 metre distance between one another when working and during breaks.

- When feasible, use contact/non-contact technique in pairs, following infection prevention and control precautions. For procedures performed in the imaging room (e.g. fixed chest radiography, chest CT), this is implemented by having one staff operate the equipment – who would not need PPE if operating the console in an area separate from the patient – and the other staff in contact with the patient wearing appropriate PPE. For procedures performed with portable equipment, the contact/non-contact technique in pairs can be applied but note that bedside imaging may require the use of PPE by both staff.

- Encourage staff to stay home if exhibiting respiratory symptoms or fever. In addition to self-monitoring and reporting for COVID-19 symptoms, the unit supervisor should keep records of the health status of on-site imaging staff when they arrive at work. Do not allow staff who are potentially ill to work.

A2.5 Equipment decontamination

- Separate cold/blue/clean from hot/red/contaminated designated areas.

- Clean and disinfect all high-touch surfaces including patient couches, chairs, door handles in the waiting room and imaging room, following local protocols.

- Ensure protocols for cleaning and disinfection of all medical equipment are in place according to manufacturer's instructions for use.

- Ensure adequate ventilation of the premises. Vacuum/negative air pressures would not be required in routine chest imagine procedures. Where necessary, there may be a room designated for aerosol-generating procedures; this room should be adequately ventilated (i.e. natural ventilation with air flow of at least 160 l/s per patient or in negative-pressure rooms with at least 12 air changes per hour – and

[18] See the WHO poster on how to put on and take off personal protective equipment: https://www.who.int/csr/resources/publications/putontakeoffPPE/en/.

[19] See WHO leaflets on clean care is safer care: five moments for hand hygiene, available at https://www.who.int/gpsc/tools/Five_moments/en/.

controlled direction of air flow when using mechanical ventilation) *(A12)*. Waiting for air exchange is only necessary if an aerosol-generating procedure was performed.

- Keep all surfaces free of unnecessary paper and non-essential material to allow for rapid and effective disinfection-decontamination of areas and equipment.

A2.6 Training and education

- Always work within the scope of practice and job role.
- Consider opportunities for residents, medical and nursing students to help in places where quarantined and infected cases decimated health staff. Remove students/trainees from high-risk scenarios.
- Activate retired/vacationing radiographers/technologists when possible, ensuring appropriate risk assessment, access to supervision and refresher training is available.
- Ensure that all staff are trained in local infection prevention and control protocols, which include donning and doffing of PPE and hand hygiene *(A1–A4)*.

A3 Specific considerations

A3.1 Chest radiography

- The radiographers/radiological technologists performing radiography should follow droplet and contact precautions (airborne precautions required only for aerosol-generating procedures) *(A1, A4)*.
- Where possible, designate a portable imaging device for investigation of suspected or confirmed COVID-19 cases and leave it within the patient care area to reduce transmission risk.
- Use direct digital radiography (DDR) imaging whenever possible to reduce transmission risk and minimize radiographer workload.
- Designate one or two image receptors specifically for patients with COVID-19 if computed digital radiography (CDR) or film/screen technology is to be used.
- Adjust radiography technique in accordance with the patient's condition (e.g. anteroposterior with the patient supine or posteroanterior with the patient prone on intensive care unit wards.
- Cover X-ray detector/cassettes with plastic cover or disposable cellophane wrapper and make sure to clean X-ray cassette between each patient.
- Ensure that positioning sponges of X-ray table or vertical Bucky stand and immobilization straps are covered with plastic protection.
- Remove any radiopaque objects in the region of interest from the patient very carefully to prevent risk of infection transmission.
- Preferably work in pairs with another radiographer to facilitate the contact/non-contact technique.

- Ensure that the radiographer undertaking the radiography with the portable imaging equipment stands outside the controlled area, without physical contact with the team or any object.

- When performing imaging, both within the department and when using portable equipment, wherever possible, one radiographer positions the X-ray tube and makes the exposure, and the second radiographer positions the patient and the covered detector and applies the anatomical marker.

- Image acquisition/exposure should be made by the non-contact radiographer, in consideration of the diagnostic requirements and the principles of justification, optimization, radiation dose limitation as well as the radiographer/radiological technologist ethical code and professional rights at all times *(A11, A13)*.

- If working alone (i.e. not in a pair) use gloves and consider the X-ray equipment and mobile control screen keys as contaminated. Wash hands after removing gloves.

- Check image for optimum quality before sending it to the PACS.

- Clean and disinfect all imaging equipment, including the portable X-ray machine, X-ray couch and vertical Bucky stand between each patient.

A3.2 Chest CT

- The radiographers/radiological technologists performing chest CT should follow droplet and contact precautions (airborne precautions required only for aerosol-generating procedures) *(A1, A4)*.

- Consider implementing a containment zipper (a room isolation tarp barrier with a zipper for room access) to separate the control area from the imaging room. Practice infection control in accordance with national public health guidelines, relevant department policies and instructions from the committees responsible for hospital infectious disease control and hospital waste management.

- Separate clean console control area from contaminated CT scanner room; the radiographer/radiological technologist must remove gloves and wash hands before entering the console control area.

- Consider all equipment in the imaging room as contaminated: CT gantry controls and contrast media injector control screen keys; they must be used with gloves.

- Consider all equipment in the control area as clean: CT console keyboard, mouse and exposure pad as well as the contrast media injector remote control panel; they may be used without gloves.

- Avoid crowding and maintain the safety distance of at least 1 metre.

- Remove any radiopaque objects in the region of interest from the patient very carefully to prevent risk of infection transmission.

- Perform examination (i.e. scanning and intravenous contrast media injection) in consideration of the diagnostic requirements and the principles of justification, optimization, radiation dose limitation as well as the radiographer/radiological technologist ethical code and professional rights at all times *(A11,A13)*.

- Note which personnel are involved in and present during the procedure.

- Ensure that single use CT couch paper cover is removed and disposed of into the corresponding bin according to hospital policy.

- The control panel integrated into the contrast media injector delivery device, which is located in the imaging room, may be covered with a disposable plastic cover.

- When performing CT on patients confirmed with COVID-19, radiographers/radiological technologists must follow the instructions and guidance of the hospital committee responsible for infectious disease control.

- Asymptomatic patients pose a latent threat for medical imaging and therapy departments and hence radiographers/radiological technologists in CT are advised to follow the instructions divided in three stages shown in Table A1.1 (i.e. preparation, during and post procedure).

A3.3 LUS

LUS presents specific challenges in terms of infection prevention and control. The first is physical proximity to the patient: this is usually within 1 metre and may be as little as 30–50 centimetres; ultrasound rooms are typically small, ventilation may be restricted and seldom are there windows; examination time may last between 10 and 60 minutes; patients may be asked to inhale/exhale deeply and hold their breath. Based on the Spaulding classification system, widely adopted in health care, reusable medical devices are categorized into non-critical, semi-critical and critical according to the infection risk and the level of disinfection required, as described below.

- Non-critical devices: ultrasound probes that come in contact with intact skin can be cleaned and disinfected using low- or intermediate-level disinfection.

- Semi-critical devices: ultrasound probes that come in contact with non-intact skin, blood, body fluids and/or mucous membranes should be cleaned and disinfected using the high-level disinfection method. A single use probe cover is mandatory.

- Critical devices: intraoperative or intravascular probes must undergo sterilization if compatible or, if not available, high-level disinfection as per medical facility guidelines. Use of sterile transducer cover is mandatory.

Probes used to perform LUS are typically in contact only with intact skin and are therefore considered non-critical devices, which can be cleaned and disinfected using low- or intermediate-level disinfection. However, in case the probe comes in contact with body fluids (e.g. if the patient coughs or sneezes without respiratory hygiene measures) a high-level disinfection would be required after the procedure. More information about cleaning and disinfection of ultrasound probes is available in the literature *(A14, A15)*. Additional considerations for infection prevention and control when performing LUS in patients with suspected or confirmed COVID-19 are summarized below.

- The ultrasound health care workers should follow droplet and contact precautions (airborne precautions required only for aerosol-generating procedures) *(A1, A4)*.

- If possible, designate a specific ultrasound room, machine and probes for use on patients with suspected or confirmed COVID-19.

- Adjust schedule (appointment times) to avoid crowding in the waiting room and to allow time between appointments for decontamination of the ultrasound system and room.

- Best practice is to have patient attend examination alone.

- Shorten duration of examination by arranging for the most experienced professional available to perform the examination. Single use ultrasound gel sachets should be considered for patients suspected or having COVID-19.

- Reduce the number of probes connected to the ultrasound machine to a minimum and remove all other probes from device or store in closed cabinet to avoid the necessity of high-level disinfection in the event the patient coughs or sneezes during the procedure.

- Separate inpatients on the ward from outpatients.

- Follow manufacturer's recommendation for decontamination of ultrasound system. Clean and disinfect the console, in particular high-touch parts (keyboard, touch screen monitor).[20]

- Follow local protocols for appropriate decontamination of ultrasound probes between patients.

- In the context of COVID-19, the normal practices of high-level disinfection are not changed. The only change in the context of COVID-19 is that all external probes must undergo cleaning followed by low-level disinfection to denature any presence of SARS-CoV-2[21] (as described above).

References

In the interests of specificity during the COVID-19 pandemic – during which new data become available daily – the references below that deal with COVID-19 or SARS-CoV-2 exceptionally include both the day and month of publication (where available). This is meant to assist the reader in quickly determining the exact date of publication.

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[20] Covering the console with disposable plastic may be difficult to source and might encourage less effective alternatives such as cling film. Furthermore, if machines are covered, they might not be regularly wiped clean or disinfected, and it adds to an additional step for cleaning the cover which might be cross contaminated. All the manufacturers for ultrasound machines have a list of approved products for cleaning and disinfecting the console such as high-touch parts (keyboard, touch screen monitor, etc.).

[21] Like other coronaviruses, SARS-CoV-2 is an enveloped virus with a fragile outer lipid envelope that makes it more susceptible to disinfectants compared to non-enveloped viruses *(A3)*.

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Akl	Elie	None declared	Not applicable
Appiah	John Adabie	None declared	Not applicable
Blazic	Ivana	None declared	Not applicable
Fatehi	Mansoor	None declared	Not applicable
Flor	Nicola	None declared	Not applicable
Last name	**First name**	**Declared interests**	**Management of conflicts of interest**
Frija	Guy	Clinical coordinator of EC MEDIRAD project on low dose exposure with research funding to Paris-Descartes uni-versity	The disclosed interest was reviewed, and it was determined that it did not present a conflict of interest for the purpose of this guide
Hitti	Eveline	None declared	Not applicable
Jaffri	Hussain	None declared	Not applicable
Jin	Zheng-Yu	None declared	Not applicable
Kauczor	Hans Ulrich	None declared	Not applicable
Kawooya	Michael	None declared	Not applicable
Kazerooni	Ella Annabelle	None declared	Not applicable
Ko	Jane	Spouse involved in biotech companies involved in cell-based therapies	The disclosed interest was reviewed, and it was determined that it did not present a conflict of interest for the purpose of this guide
Mahfouz	Rami	None declared	Not applicable
Muglia	Valdair	None declared	Not applicable
Nyabanda	Rose	None declared	Not applicable
Sanchez	Marcelo	None declared	Not applicable
Shete	Priya	None declared	Not applicable
Ulla	Marina	None declared	Not applicable
Xue	Huadan (Danna)	None declared	Not applicable
Zheng	Chuansheng	None declared	Not applicable

Web Annex A

Systematic review reports

Available online only: https://apps.who.int/iris/bitstream/handle/10665/361749/9789240055728-eng.pdf

Web Annex B

GRADE evidence-to-decision tables

Available online only: https://apps.who.int/iris/bitstream/handle/10665/361750/9789240055735-eng.pdf

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