World Health Organization

Use of artificial intelligence in chest imaging

some reflections

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Radiation and Health Unit

Health and Artificial Intelligence: Law, Ethics and Society
Workshop 1: Ethical Considerations and Policy Development
7th December 2020 (virtual event)

World Health Organization: function

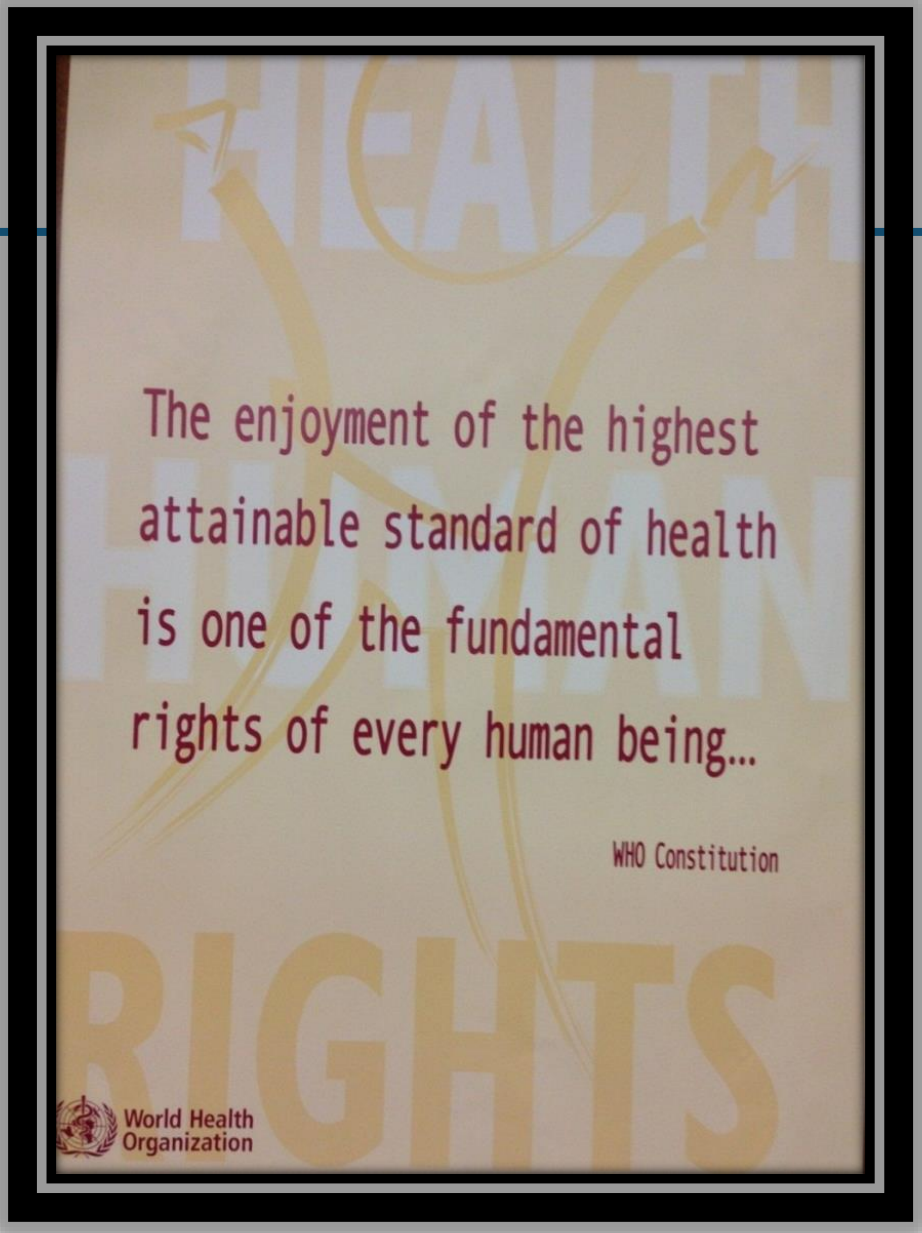
The WHO is the UN agency with a specific public health mandate as the directing and coordinating authority of *international health work*

World Health Organization: objective

- **Objective**: attainment by all peoples of the *highest possible level of health*

*"**Health** is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity."*
(*WHO Constitution,1948*)

World Health Organization



Health is a human right

The right to health includes access to timely, acceptable, and affordable health care of appropriate quality

World Health Organization

Universal Health Coverage

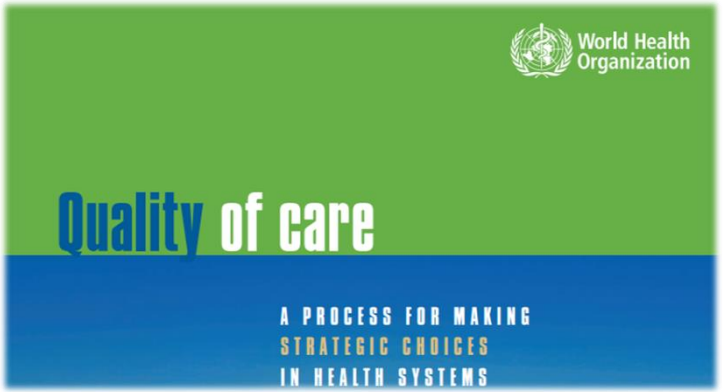
- **Universal Health Coverage** (UHC) is a high priority for WHO and its Member States
- UHC includes **safety and quality** of health services
- Ensuring safe and appropriate use of radiation in medicine contributes to achieving UHC

World Health Organization

Health Care Quality Dimensions

- Appropriateness
- Accuracy
- Affordability
- Accountability
- Safety
- Timeliness
- Patient centricity

The safe and appropriate use of radiation for diagnosis and treatment of disease and injuries is embedded in the concept of **health care quality**



Use of Radiation in Health Care

- Advanced radiation imaging technology has opened new horizons for clinical diagnostics and has improved patient care.
- Benefits for patients gain recognition the use of radiation in the diagnosis and treatment of human diseases increases.
- Inappropriate use and/or unsafe handling may result in unnecessary and preventable radiation risks in patients and staff.

Radiation benefits and risks

- Need to control and minimize radiation health risks, while maximizing the benefits.
- Achieving this balance becomes particularly challenging in medicine.
- The benefit outweighs the risk when the procedure is:
  - appropriately prescribed
  - properly performed

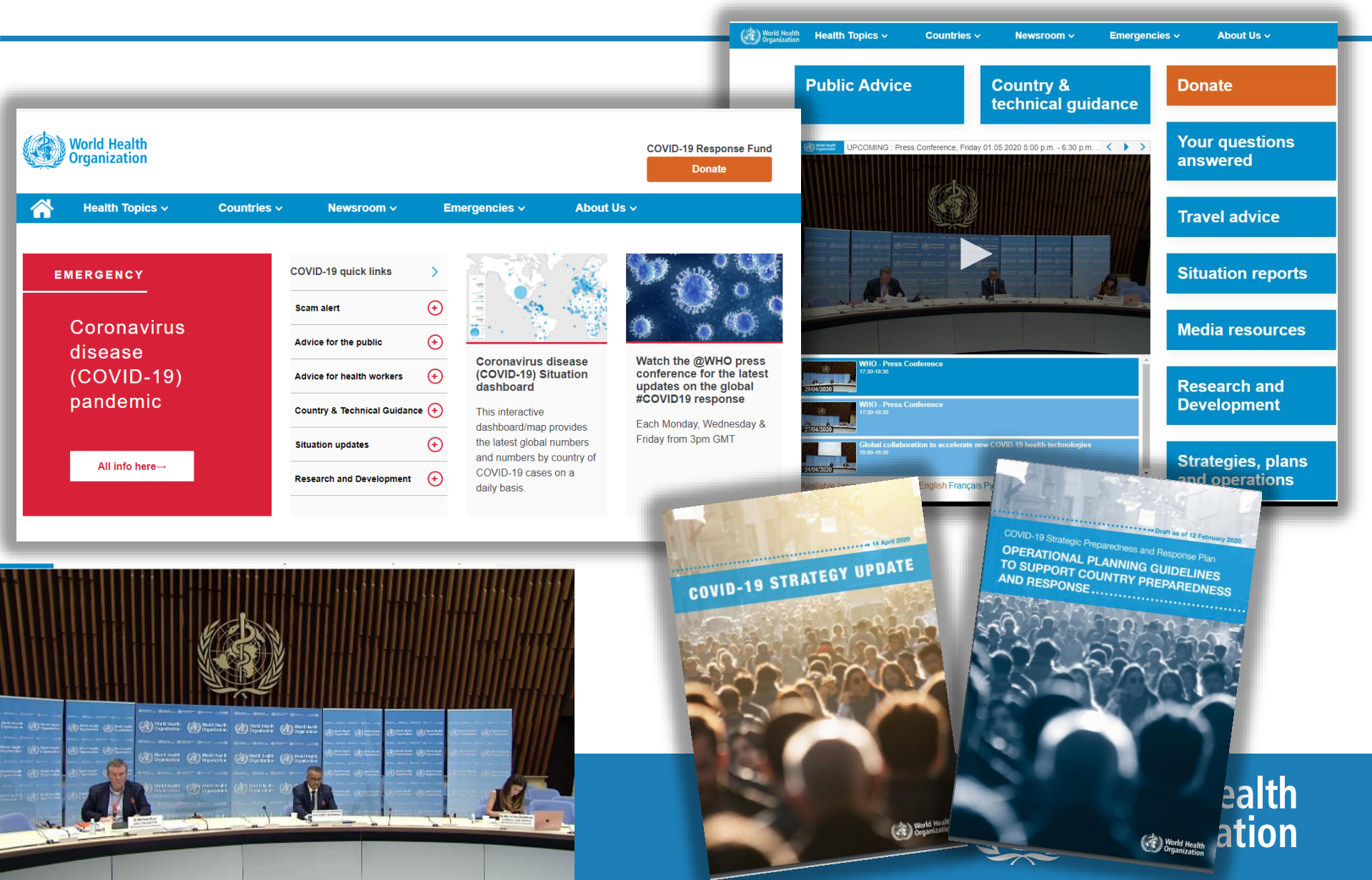
Bonn Call for Action: 10 actions to improve RP in medicine in the decade 2012-2022

1. Enhancing implementation of **justification** of procedures
2. Enhancing implementation of **optimization** of protection and safety
3. Strengthening **manufacturers**' contribution to radiation safety
4. Strengthening RP **education and training** of health professionals
5. Shaping & promoting a **strategic research agenda** for RP in medicine
6. Improving **data collection** on radiation exposures of patients and workers
7. Improving primary **prevention of incidents and adverse events**
8. Strengthening radiation **safety culture** in health care
9. Fostering an improved radiation **benefit-risk-dialogue**
10. Strengthening the implementation of safety requirements (**BSS**) globally

http://www.who.int/ionizing_radiation/about/med_exposure/en
https://rpop.iaea.org/RPOP/RPoP/Content/News/bonn-call-for-action-joint-position-statement.htm

These priority actions continue being essential during the response to the pandemic and in the post-COVID-19 time

COVID-19, WHO response



About Rene Francois Magritte (1898-1967)

- Internationally acclaimed surrealist artist well known for creating thought-provoking images, often depicting ordinary objects in an unusual context. By using simple graphics and everyday objects he gave new meanings to familiar things.

- In his self-portrait «*The clairvoyance*» (1936) Magritte is looking at an egg and painting a bird, which is more than what is right in front of him: he is painting the possibility, potential, the future.

About Dr. Victor Tseng

- Young pulmonary and critical care physician from USA with interest/ expertise in chronic respiratory failure, mechanical ventilation, unexplained dyspnea, exercise physiology, high altitude medicine, pulmonary hypertension, pulmonary complications of liver disease, and interstitial lung diseases.

Also involved with teaching of residents and medical students; doing clinical research; member of a number of professional societies. In his free time he enjoys alpinism, traveling, music composition, ski racing, and playing the piano and violin in chamber ensembles…

What do painter and physician have in common?

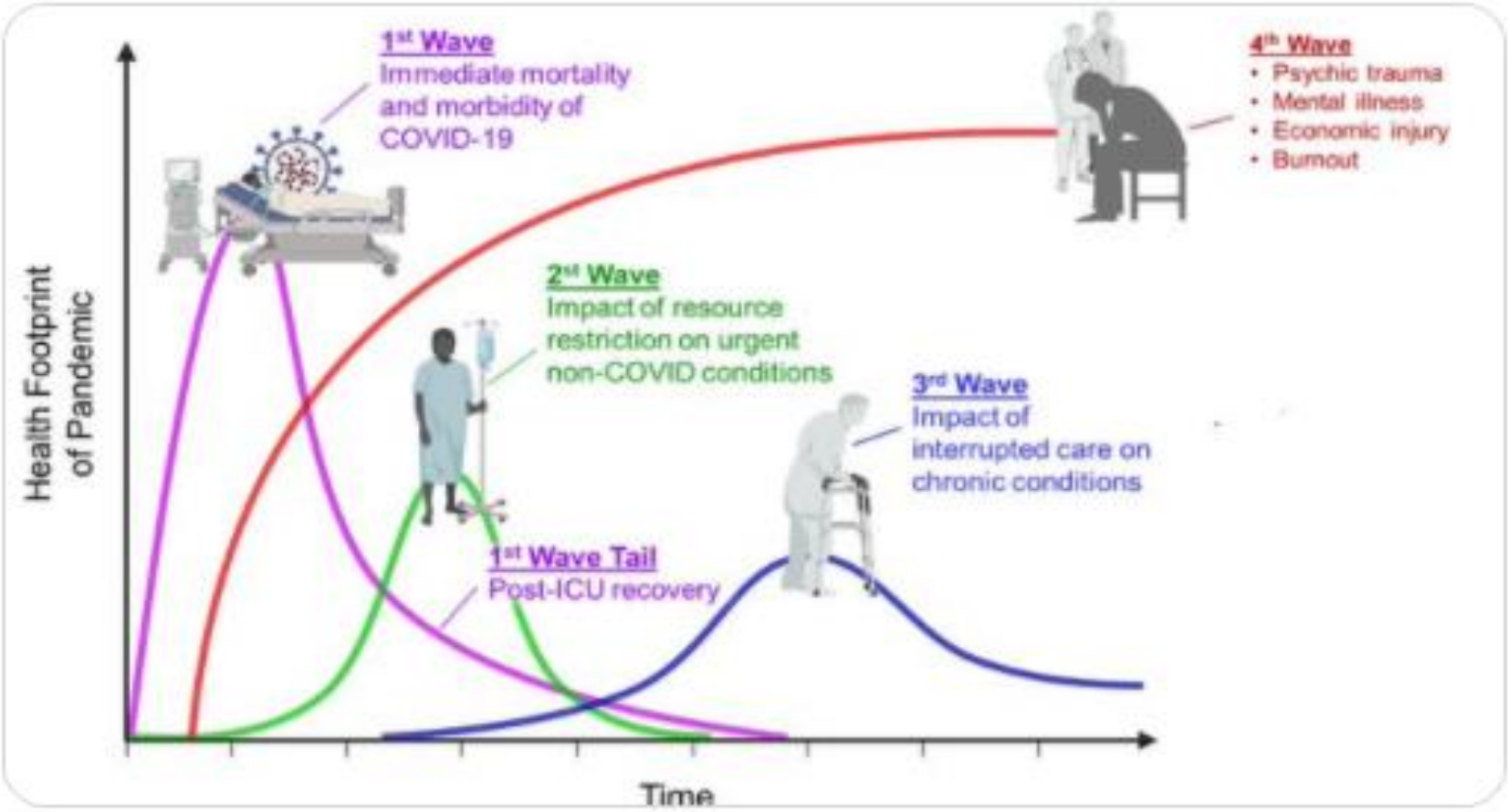
World Health Organization

Tweet

In March 2020 Dr Tseng's tweet about the future

Victor Tseng @VectorSting · Mar 30

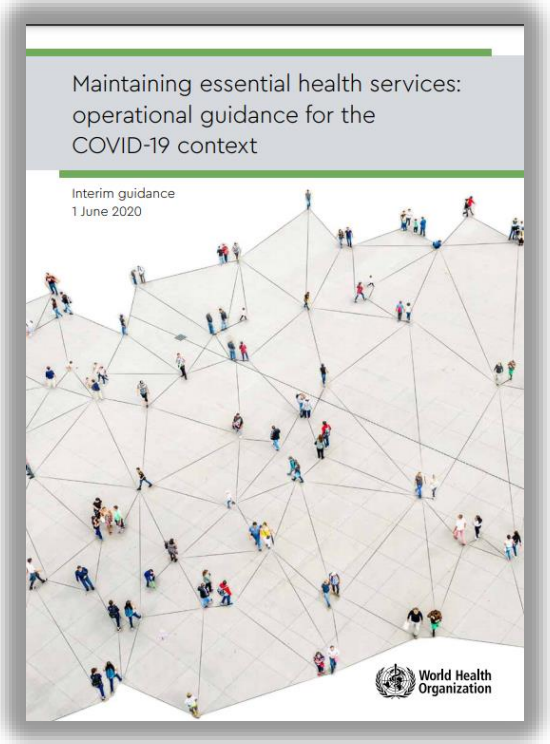
As our friends and colleagues brave the font lines, we must also get ready for a series of aftershocks. It's very hard to plan this far ahead while we're in survival mode. We must prepare early and strategize our response to the collateral damage of #COVID19



Mantaining essential health services

- In the early phases of the COVID-19 outbreak, health systems could maintain service delivery in addition to managing a relatively limited COVID-19 case-load.

- As COVID-19 demands on systems have surged and health workers themselves have increasingly been affected by COVID-19 infection and indirect consequences of the pandemic, **strategic adaptations** have become urgent to balance the demands of **responding directly to the COVID-19 pandemic** with the need to maintain the delivery of other **essential health services**.



https://www.who.int/publications/i/item/WHO-2019-nCoV-essential-health-services-2020.1

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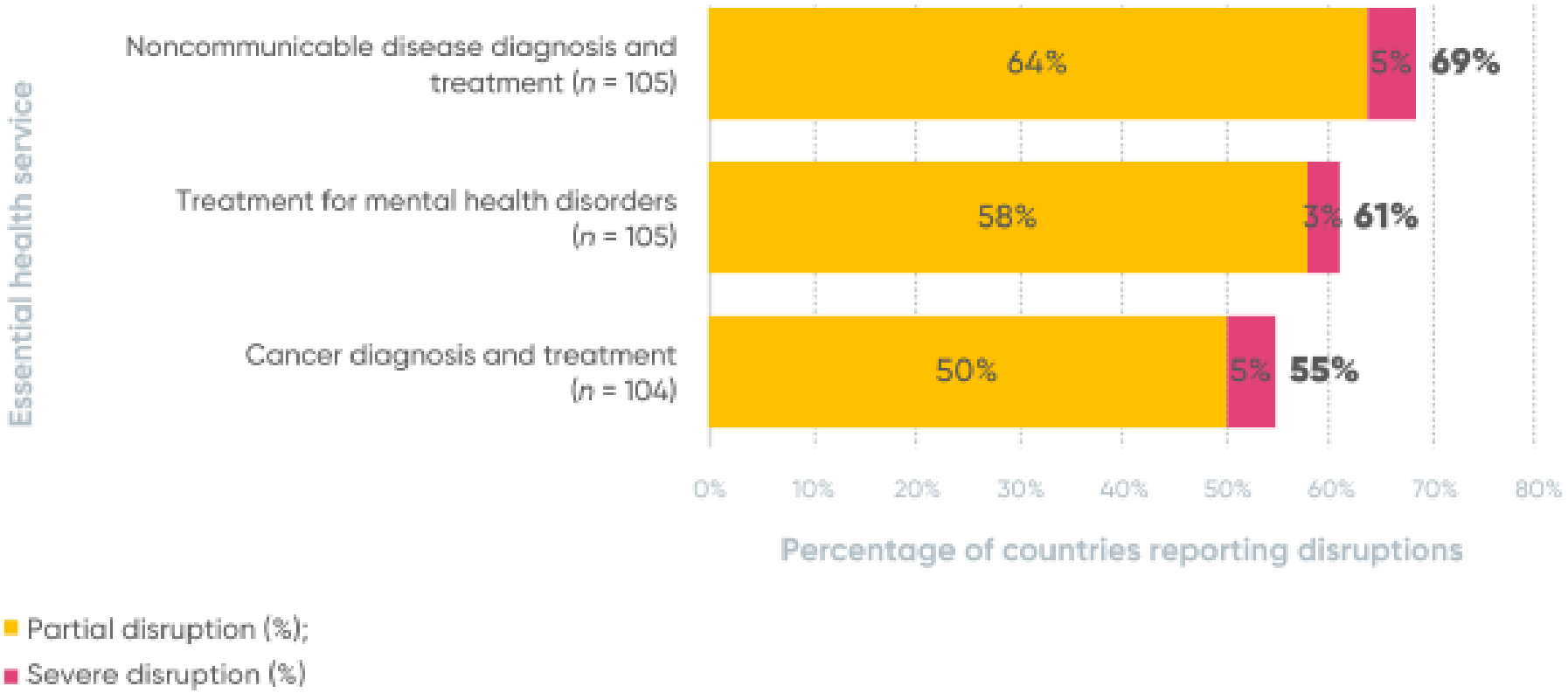
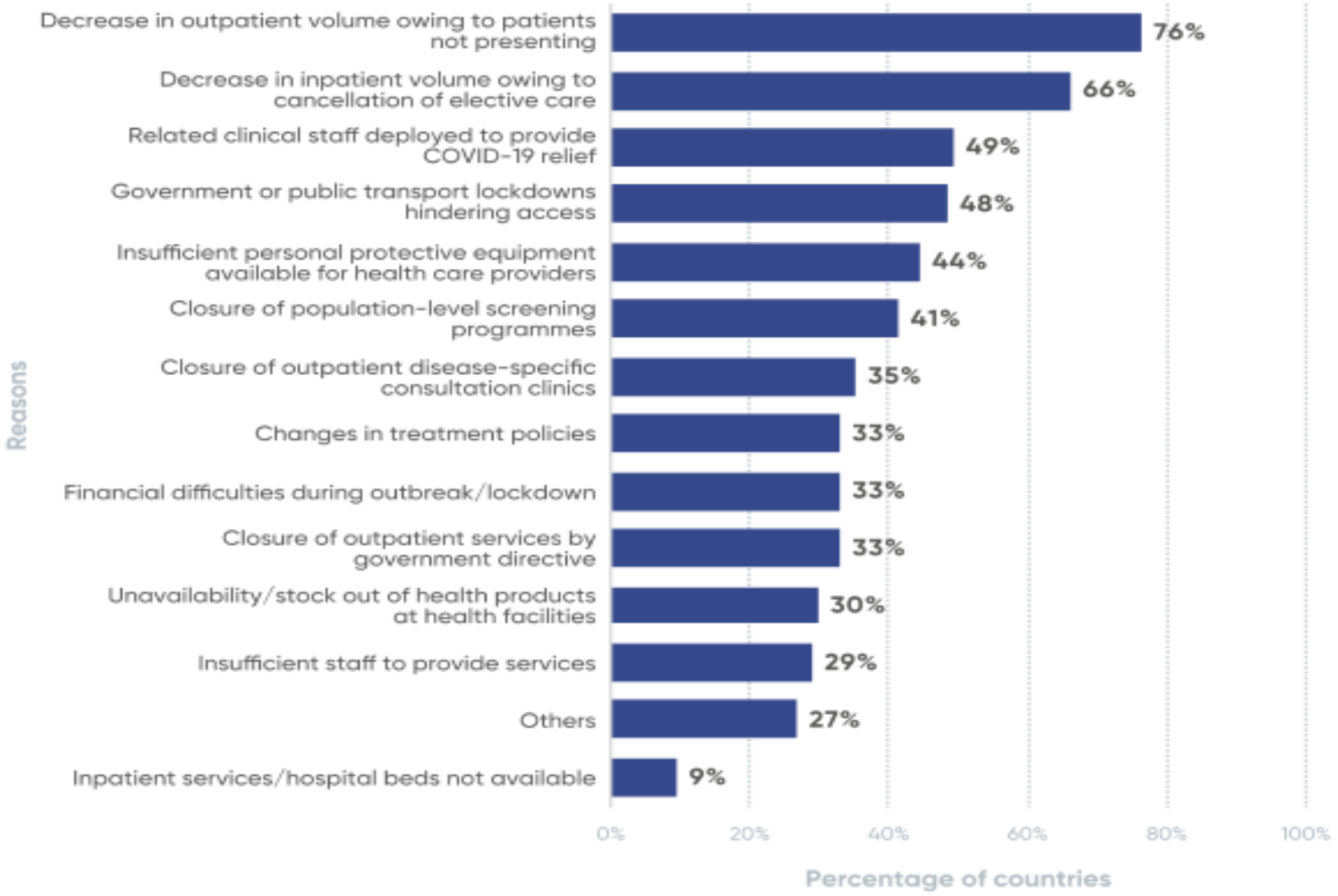
% of countries reporting disruption in NCD and mental health services



https://www.who.int/publications/i/item/WHO-2019-nCoV-EHS_continuity-survey-2020.1

SOURCE: WHO pulse survey on continuity of essential health services during the COVID-19 pandemic, Aug 2020

World Health Organization



Reasons for service disruption

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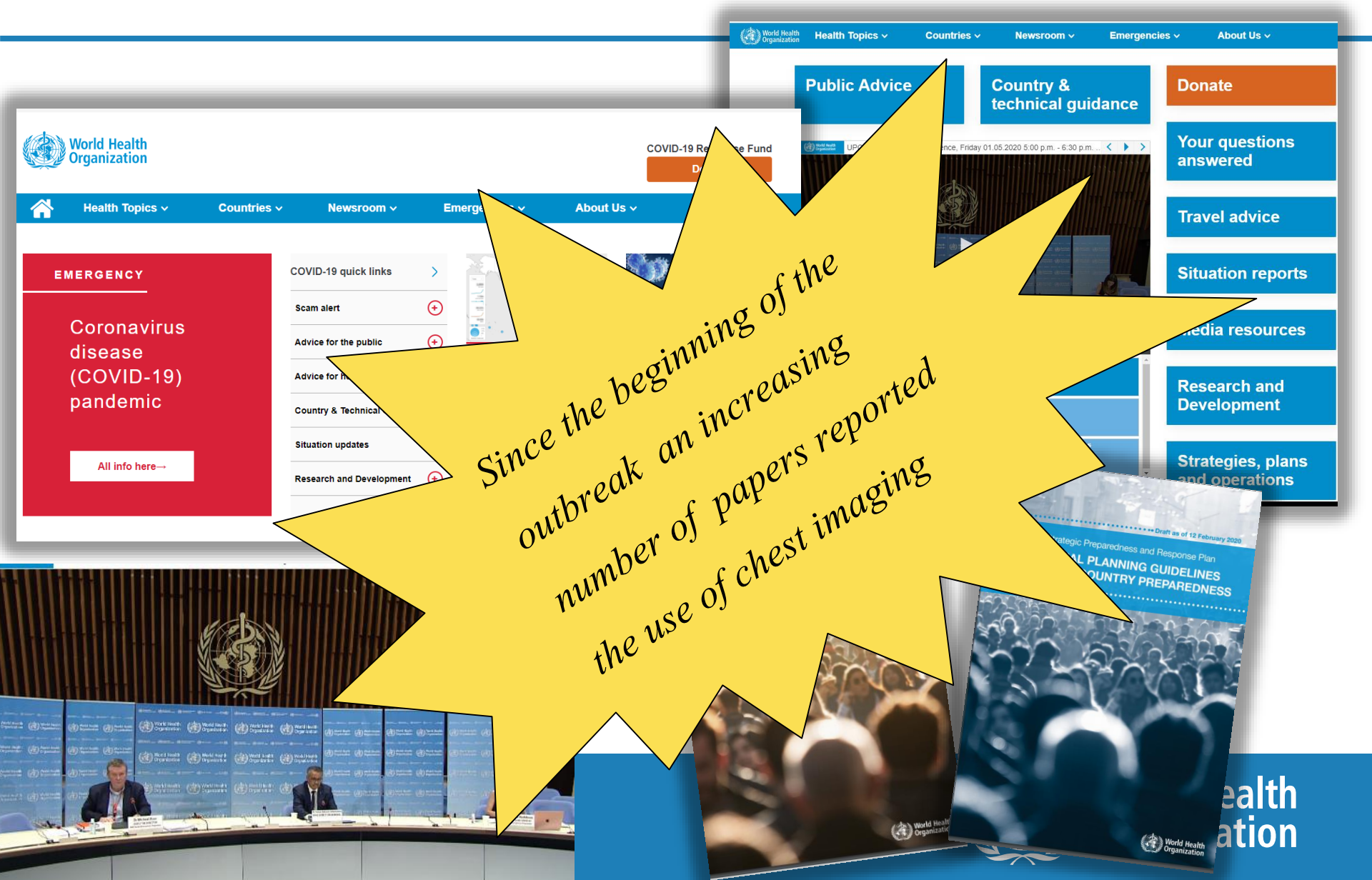
COVID-19, WHO response and chest imaging



World Health Organization | Health Topics | Countries | Newsroom

A rapid advice guide

11 June 2020 | COVID-19: Clinical care

Use of chest imaging in COVID-19: a rapid advice guide

Web Annex A. Imaging for COVID-19: a rapid review

Chou R, Pappas M, Buckley D, McDonagh M, Totten A, Flor N, Sardanelli F, Dana T, Hart E, Wasson N, Nelson H

Pacific Northwest Evidence-Based Practice Center, Oregon Health and Science University, Portland, Oregon, USA

Use of chest imaging in COVID-19: a rapid advice guide

Web Annex B. GRADE evidence-to-decision tables

in asymptomatic individuals to critically ill patients.

in different situations, remarks are provided to

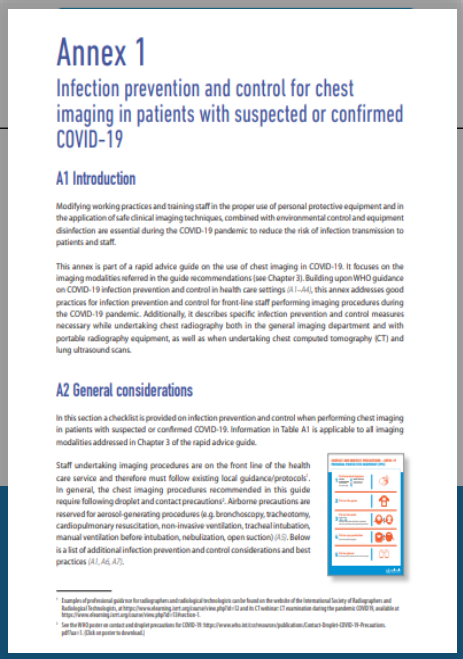
ld benefit patients. The guide also includes

stions for impact monitoring and evaluation and

Also available in Arabic | Chinese | Russian | Spanish | French | Portugues

Download link to Annex A

Download link to Annex B


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 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 is part of a rapid advice guide on the use of chest imaging in COVID-19. It focuses on the imaging modalities referred in the guide recommendations (see Chapter 3). Building upon WHO guidance on COVID-19 infection prevention and control in health care settings (A1–A4), 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 scans.

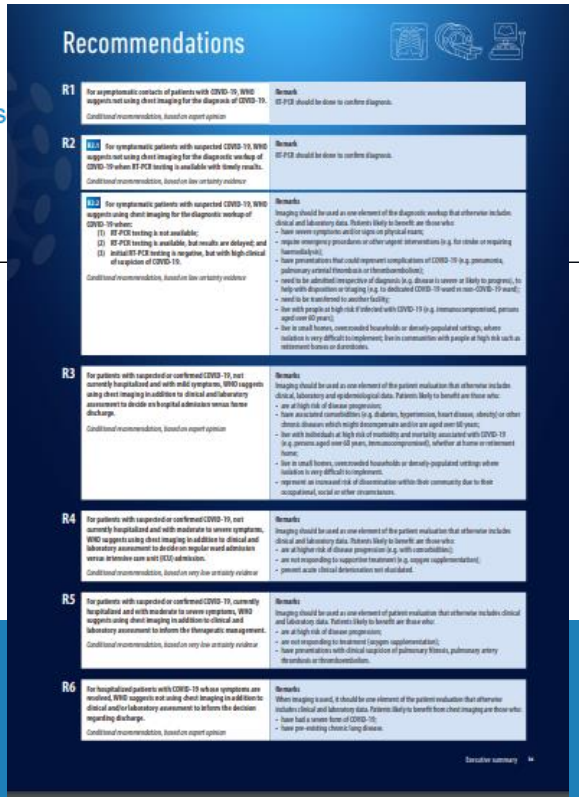
A2 General considerations

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 is applicable to all imaging modalities addressed in Chapter 3 of the rapid advice guide.

Staff undertaking imaging procedures are on the front line of the health care service and therefore must follow existing local guidance/protocols[1]. In general, the chest imaging procedures recommended in this guide require following droplet and contact precautions[2]. 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) (A3). Below is a list of additional infection prevention and control considerations and best practices (A1, A6, A7).

[1] 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.radiography.isrrt.org/course/view.php?id=12 and its CT webinar: CT examination during the pandemic COVID19, available at https://www.elearning.isrrt.org/course/view.php?id=11#section-3.

[2] 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. (Click on poster to download.)


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 expert opinion. Remark: RT-PCR should be done to confirm diagnosis.

R2 R2.1 For symptomatic patients with suspected COVID-19, WHO suggests not using chest imaging for the diagnostic workup of COVID-19 when RT-PCR testing is available with timely results. Conditional recommendation, based on low certainty evidence. Remark: RT-PCR should be done to confirm diagnosis.

R2.2 For symptomatic patients with suspected COVID-19, WHO suggests using chest imaging for the diagnostic workup of COVID-19 when: (1) RT-PCR testing is not available; (2) RT-PCR testing is available, but results are delayed; and (3) initial RT-PCR testing is negative, but with high clinical suspicion of COVID-19. Conditional recommendation, based on low certainty evidence. Remarks: Imaging should be used as one element of the diagnostic workup that otherwise includes clinical and laboratory data. Patients likely to benefit are those who: - have severe symptoms and/or signs on physical exam; - require emergency procedures or other urgent interventions (e.g. for stroke or requiring 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 of infected with COVID-19 (e.g. immunocompromised, persons 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 expert opinion. Remarks: Imaging should be used as one element of the patient evaluation that otherwise includes clinical, laboratory and epidemiological data. Patients likely to benefit are those who: - are at high risk of disease progression; - 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. persons 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 very low certainty evidence. Remarks: Imaging should be used as one element of the patient evaluation that otherwise includes clinical and laboratory data. Patients likely to benefit are those who: - are at higher risk of disease progression (e.g. with comorbidities); - are not responding to supportive treatment (e.g. oxygen supplementation); - present 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 very low certainty evidence. Remarks: Imaging should be used as one element of patient evaluation that otherwise includes clinical and laboratory data. Patients likely to benefit are those who: - are at high risk of disease progression; - are not responding to treatment (oxygen supplementation); - have presentations with clinical suspicion of pulmonary fibrosis, 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 and/or laboratory 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.

Executive summary

WHO developed guidance on use of chest imaging in COVID-19

Translation into Persian is ongoing, other translations considered…

Published in English, translated into 7 other languages: Arabic, Chinese, French, Japanese, Portuguese, Russian and Spanish

Use of Chest Imaging in COVID-19: scenarios considered

3 recommendations for diagnostic work-up

4 recommendations for patient management

- Asymptomatic patients — CHEST IMAGING
- Symptomatic patients with available RT-PCR testing — CHEST IMAGING
- Symptomatic patients with no RT-PCR available — CHEST IMAGING
- Admitting or discharging patients with mild symptoms — CHEST IMAGING
- Patients with moderate-to-severe symptoms — CHEST IMAGING
- Therapeutic management of hospitalized patients — CHEST IMAGING
- Discharging hospitalized patients — CHEST IMAGING

NEW: updated literature reviews, qualitative study on contextual factors and consider use of chest imaging after hospital discharge

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Summary of WHO guidance (I)

- Chest imaging used in diagnostic workup and management of patients with COVID-19
- Chest imaging as one element of the patient evaluation that otherwise includes clinical and laboratory data.
- Chest imaging not suggested:
  - to diagnose COVID-19 in asymptomatic patients
  - to diagnose COVID-19 in symptomatic patients when RT-PCR testing is available and timely
  - to help inform discharge decisions for hospitalized patients whose symptoms have resolved

Summary of WHO guidance (II)

- Chest imaging is suggested **to diagnose COVID-19** in symptomatic patients:
  - when RT-PCR testing is not available
  - has delayed results
  - when an initial RT-PCR test is negative, but there is high clinical suspicion of COVID-19

- Chest imaging is also suggested:
  - for decision to **admit or discharge** patients with mild symptoms
  - for decision about **normal ward or ICU** (moderate-to-severe symptoms)
  - to **help inform the therapeutic management** of hospitalized patients with moderate-to-severe symptoms.

Chest imaging as one element of the evaluation that otherwise includes clinical and laboratory data

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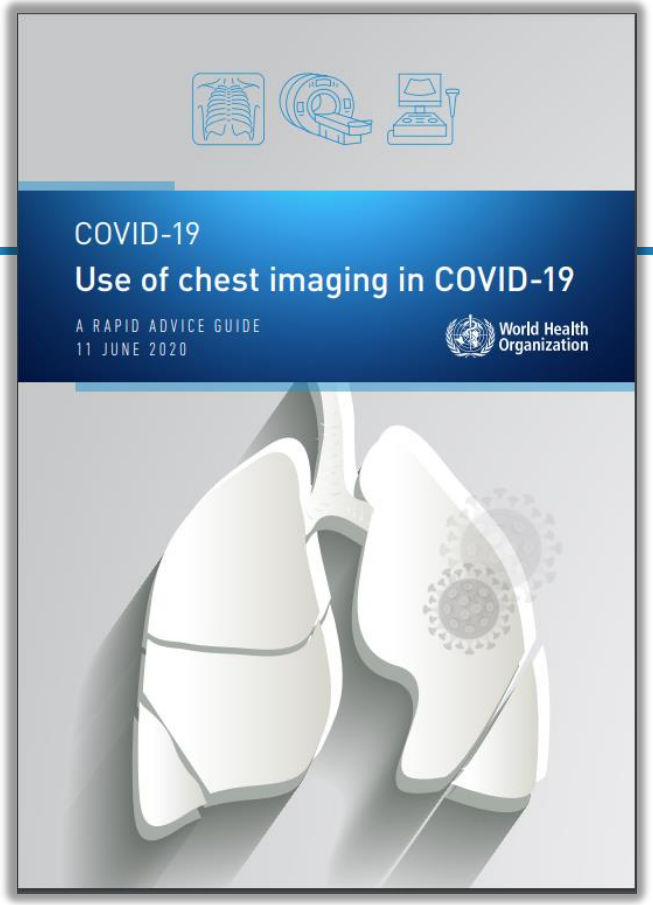

ECRI Guidelines Trust ® | Guideline Brief

Use of chest imaging in COVID-19: a rapid advice guide.

Guideline ID: 1826 Published: 2020 Jun 11

World Health Organization (WHO)

World Health Organization (WHO). Use of chest imaging in COVID-19: a rapid advice guide. Geneva (Switzerland): World Health Organization (WHO); 2020 Jun 11. 42 p. [16 references]

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Use of Chest Imaging in the Diagnosis and Management of COVID-19: A WHO Rapid Advice Guide

Elie A. Akl, Ivana Blazic, Sally Yaacoub, Guy Frija, Roger Chou, John Adabie Appiah, Mansoor Fatehi, Nicola Flor, Eveline Hitti, Hussain Jafri, Zheng-Yu Jin, Hans Ulrich Kauczor, Michael Kawooya, Ella Annabelle Kazerooni, Jane P. Ko, Rami Mahfouz, Valdair Muglia, Rose Nyabanda, Marcelo Sanchez, Priya B. Shete, Marina Ulla, Chuansheng Zheng, Emilie van Deventer, Maria del Rosario Perez Show fewer authors

Working Group on Lung Ultrasound in COVID-19 (LUS WG)

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Priority medical devices list for the COVID-19 response and associated technical specifications

20 November 2020 | COVID-19: Essential resource planning

Download (1.6 MB)

Overview

This document describes the medical devices required for the clinical mana
COVID-19, selected and prioritized according to the latest available evidenc
guidelines. This includes: oxygen therapy, pulse oximeters, patient monitors
infusion and suction pumps, X-ray, ultrasound and CT scanners as well as p
protective equipment. In order to facilitate access to quality assured priority
devices, the document also includes technical and performance characteris
standards, accessories and consumables. It is intended for policy-makers a
officers in Ministries of Health, procurement and regulatory agencies, interg
international agencies as well as the medical device industry.

This document is an update to the List of priority medical devices for COVI
management and Technical specifications for invasive and non-invasi ventilators for COVID-19.

This document complements the Technical specifications of personal protective equipment for COVID-19.

GUIDANCE PUBLISHED ON 19 NOVEMBER 2020

In June 2020, WHO published a rapid advice guide on the use of medical imaging in the context of the COVID-19 pandemic.[1] The guide makes recommendations for the use of chest imaging in the acute care of adult patients with suspected, probable or confirmed COVID-19, based on available evidence. The imaging modalities considered are ultrasound, radiography and computed tomography (CT), for use within the care pathway.

In view of the urgency to produce a complementary document of technical specifications of equipment to support the rapid advice guide, a working group was established with staff and consultants on imaging technologies from WHO and the International Atomic Energy Agency (IAEA). The draft was sent to experts and nongovernmental organizations for review and comment.

WHO Academy learning app

WHO free app available in seven languages – Arabic, Chinese, English, French, Portuguese, Russian and Spanish- in the Apple App Store and the Google Play Store

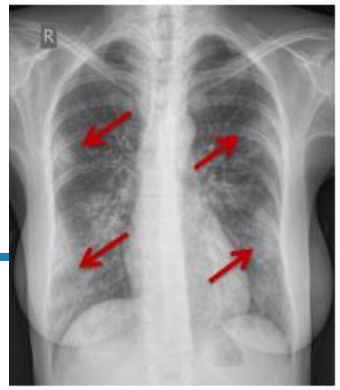
3 modules on chest imaging coming soon

www.academy.who.int

Typical COVID-19 imaging findings

- Chest imaging useful in diagnostic work-up and management of patients with suspected or confirmed COVID-19, in association with history of exposure, clinical and laboratory data. Typical imaging findings:
  - Interstitial thickening, ground-glass opacities and consolidation zones in chest radiography and chest CT.
  - Irregular borders of the pleural line, confluent hyperechoic vertical lines (so-called B-lines), interstitial
  - Bilateral, multiple, with peripheral and posterior localization, usually with basal predominance.

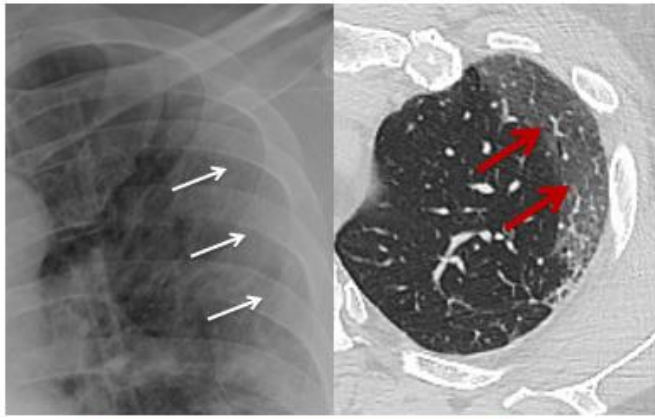
World Health Organization



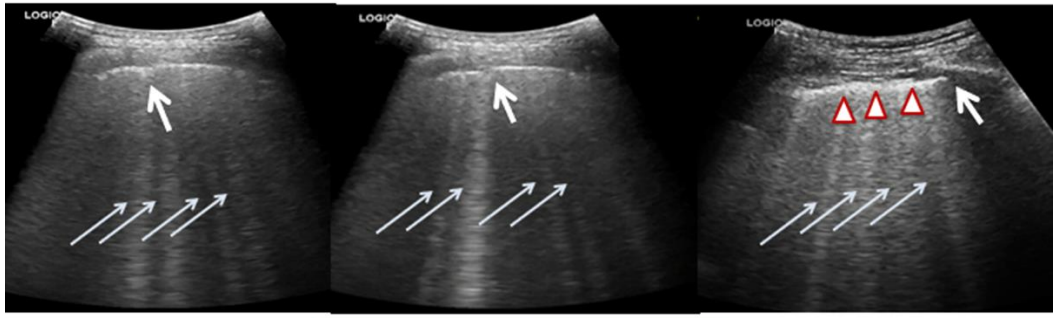
Ground-glass Opacities

Interstitial Thickening

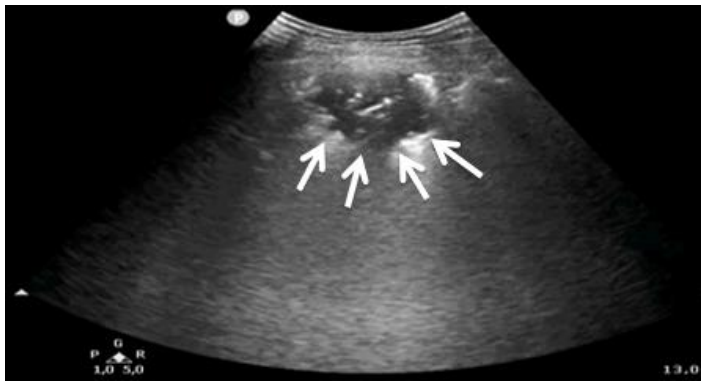
Parenchymal Consolidation



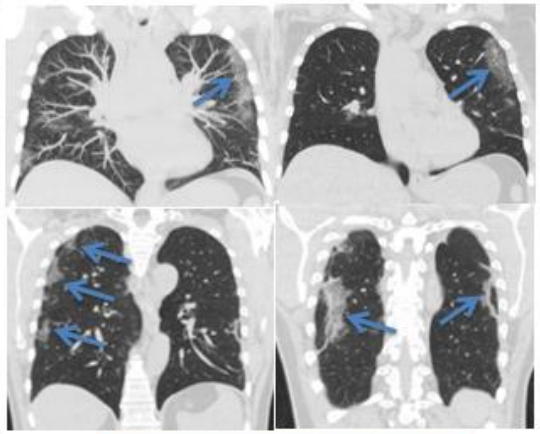
Ground-glass Opacities



Irregular Pleural Line / B-lines



Images courtesy of:
Chiara Beatrice Cogliati, MD, Director of Unità Operativa di Medicina Interna a Indirizzo Fisiopatologico, Ospedale Luigi Sacco, Università degli Studi di Milano
Nicola Flor, MD, Radiologist, Unità Operativa di Radiologia Luigi Sacco University Hospital, Milan, Italy
Ivana Blazic, MD, PhD, Radiologist, Clinical Hospital Centre Zemun, Belgrade, Serbia



Ground-glass Opacities

Artificial intelligence in COVID-19

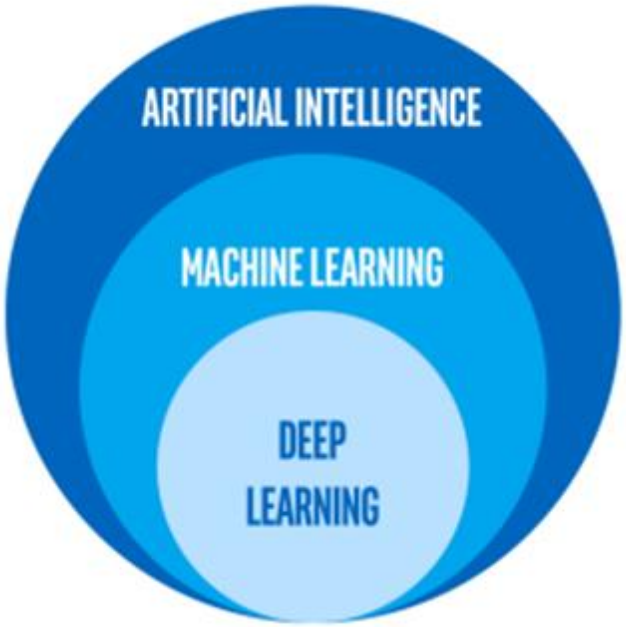
- The COVID-19 outbreak motivated a large scale clinical and imaging data collection to generate evidence to inform decision-making.

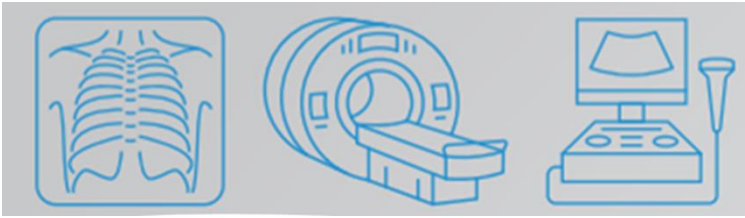
- Innovative solutions were proposed to fight against COVID-19 pandemic using artificial intelligence for:
  - Tracking and predicting how COVID-19 would spread over time and space;
  - Identifying possible treatments and vaccines;
  - Supporting social distancing (e.g. infrared thermal scanning, enforcing social lockdown measures);
  - Diagnosis and prognosis of the disease (e.g. chest radiography, CT scans and lung ultrasound).

AI in chest imaging in COVID-19

- Visual interpretation of chest images by radiologists at a larger scale is time-consuming and require prior knowledge about the typical imaging findings of the disease.

- Automated methods using Artificial Intelligence (AI) technologies, mostly Deep Learning (DL) algorithms have been developed to enhance the power of chest imaging and reduce the workload of radiologists.





Deep learning (DL) in chest imaging

- **DL** utilizes **algorithms** composed of artificial neurons and multiple data processing layers in an architecture referred to as a Deep Neural Network (DNN), including a subtype called **Convolutional Neural Networks** (**CNNs**).

- The algorithms can make **data-driven predictions or decisions** by building a mathematical model based on **input data**, which usually comes from three datasets: **training dataset**, **validation dataset** and **final test dataset**.

- The *data of interest* is *input* to the network along with its *ground truth label* e.g. the pixel data of a chest x-ray along with the diagnosis “COVID-19 pneumonia”

DL for chest imaging in COVID-19

- **DL models** for detection of COVID-19 associated patterns have been mostly used in chest x-rays and chest CT scans, and their use was also reported in lung ultrasound.
  - **Diagnostic performance** of the AI systems comparable to that of practicing radiologists with significant clinical experience and could assist and improve the performance of junior radiologists.
  - Need for large **imaging datasets** with solid ground truth.
  - Transfer learning strategies used at early stages, AI algorithms integrating chest imaging findings with clinical symptoms or exposure history, initiatives to publicly disseminate imaging dataset (e.g. RSNA open database), research projects (e.g. NIH MIDRC).

Assessing literature about AI in chest imaging for COVID-19: some caveats

- It is difficult to conduct systematic reviews of the literature about use of AI in chest imaging for COVID-19:
  - Many studies evaluate images from databanks, limited clinical information (except having the condition or not) and even those using “clinical” data set reporting limited clinical characteristics. Studies typically use a case-control design (bias issues).
  - The reporting of the AI algorithms is often suboptimal, there are many and there is often lack of independent validation.
  - Frequently the AI algorithms are not available for clinical use and/or it is unclear if they are freely available.
  - AI regulation varies across countries- where AI is treated like a “medical device” there is some kind of review/approval process, not much information on what is being done in other countries

Ethical and legal implications of AI

- The EU General Data Protection Regulation (GDPR) entered into force in 2018 unified the provisions on the processing of personal data (i.e. all information concerning a person who can be identified directly or indirectly).
  - In response to the COVID-19 pandemic, the European GDPR allows personal data collection and analysis, as long as it has a clear and specific public health goal.
  - While prompt gathering and analysis of big data is essential in fighting pandemic, many people might feel uncomfortable if the authorities collect personal data.
  - This has implications for AI and it is crucial that all the involved actors handling such data carefully (ethical and legal issues).

Need for a balanced approach

- There is an unprecedented opportunity to leverage AI for societal benefit- its efficacy will depend on:
  - Reliability and relevance of the **data available**, robust testing and verification of AI systems.
  - Effective strategies for **delivery and implementation**.
  - Balance between the potential of AI to do more good than harm (i.e. beneficence/ non maleficence) against confidentiality, data ownership, health inequities, fairness and others (i.e. dignity and justice). **Ethical considerations** as part of the process of developing new AI applications (i.e. think ahead, “ethics by design”).

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Developing a delivery science for artificial intelligence in healthcare

Ron C. Li[1,2✉], Steven M. Asch[3,4] and Nigam H. Shah[2]

Artificial Intelligence (AI) has generated a large amount of excitement in healthcare, mostly driven by the emergence of increasingly accurate machine learning models. However, the promise of AI delivering scalable and sustained value for patient care in the real world setting has yet to be realized. In order to safely and effectively bring AI into use in healthcare, there needs to be a concerted effort around not just the creation, but also the delivery of AI. This AI "delivery science" will require a broader set of tools, such as design thinking, process improvement, and implementation science, as well as a broader definition of what A practice, which includes not just machine learning models and their predictions, but also the new systems fo they enable. The careful design, implementation, and evaluation of these AI enabled systems will be importa understand how AI can improve healthcare.

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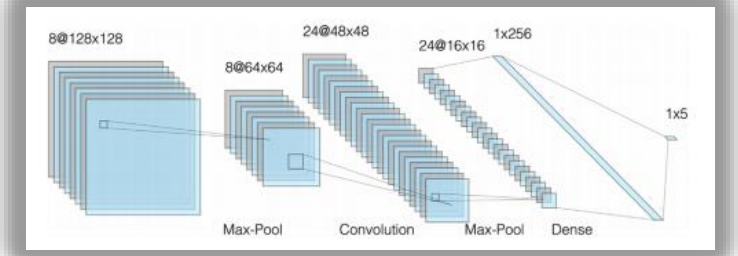


COST OF DIGITAL X-RAY AFFECTS POOR PATIENTS

Ahmedabad Mirror | Jun 10, 2015, 02.00 AM IST

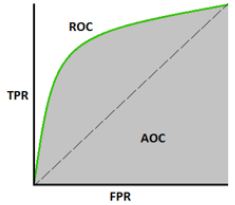
AUROC

- Sensitivity or True Positive Rate (TPR)

$$\frac{TP}{TP + FN}$$

- Specificity

$$\frac{TN}{TN + FP}$$



- False Positive Rate (FPR)

$$FPR = 1 - Specificity = \frac{FP}{TN + FP}$$

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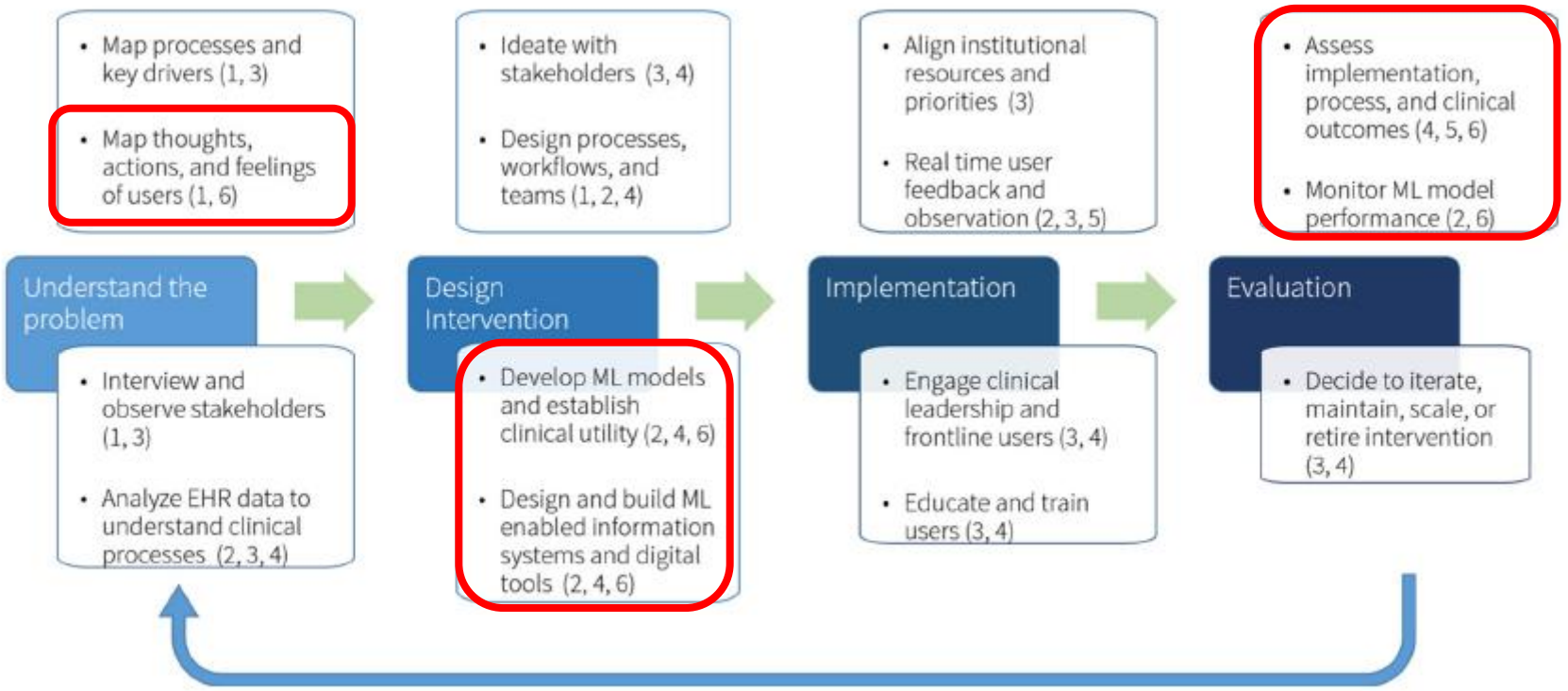
World Health Organization

A multidisciplinary process



- Creating, implementing and evaluating an AI enabled system for healthcare:1) user experience design, (2) data science, (3) healthcare operations, (4) clinical informatics, (5) evaluation, and (6) ethical integrity.

Deploying AI solutions

- Limitations in local equipment and infrastructure (imaging equipment, hardware capacity, internet connectivity, electrical instability), radiology workforce (radiologists, radiographers and medical physicists), personnel expertise, data-rights frameworks and public policies difficult the participation in AI production and validation in LMICs.

- An integrated strategy for AI adoption in resource-poor institutions to address health care disparities has been proposed, including 3 components:
  1. clinical radiology education;
  2. infrastructure implementation, and
  3. phased AI introduction.

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AI in chest imaging - the way forward

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Many thanks !!!

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