COVID-19 Cardiac & Thoracic Imaging

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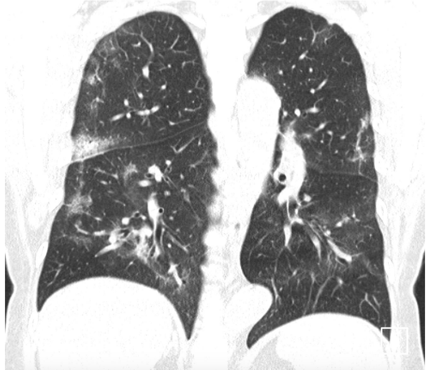
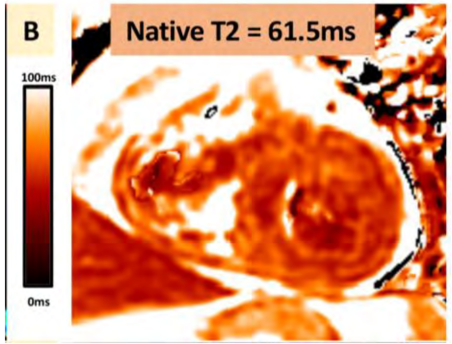
Clinical Assistant Professor

The University of Hong Kong





Disclosures

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- Received funding from Bayer and Circle Cardiovascular Imaging

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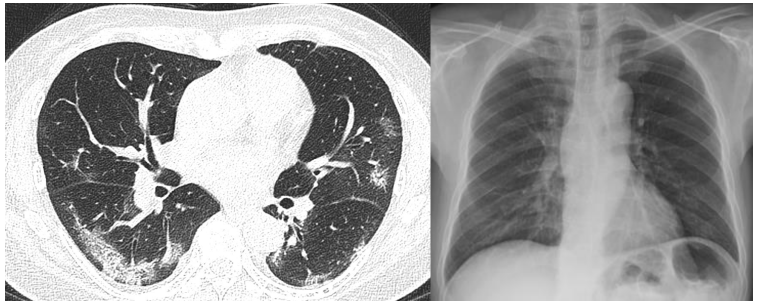
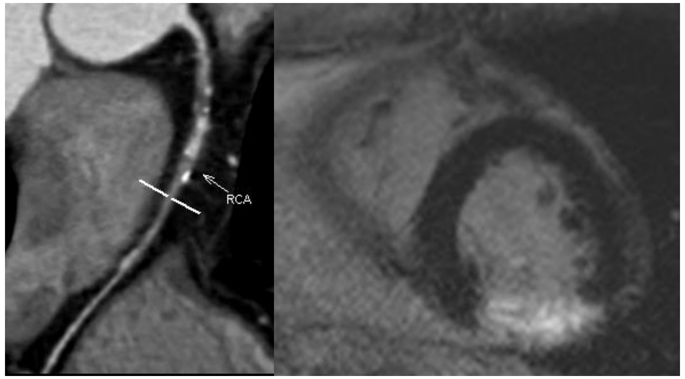
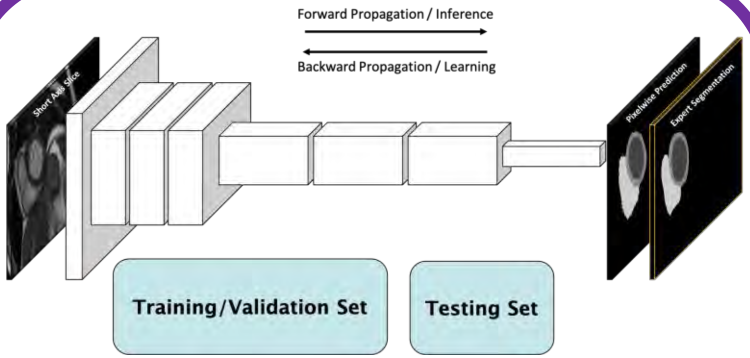


Thoracic Imaging – CXR, CT & ultrasound



Cardiac Imaging – CT & MRI



Predictive Models & Artificial Intelligence

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What are the appearances of COVID-19 on thoracic imaging?

Initial CT Images of COVID-19

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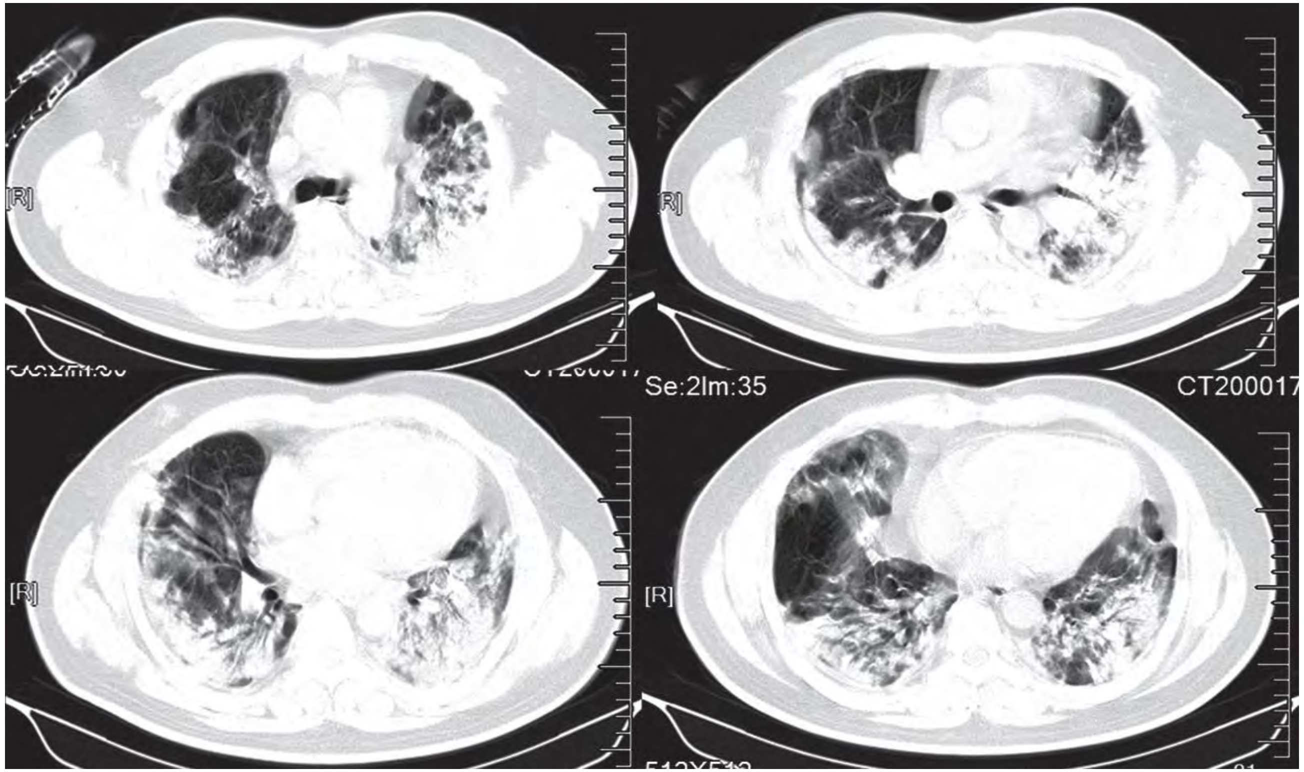
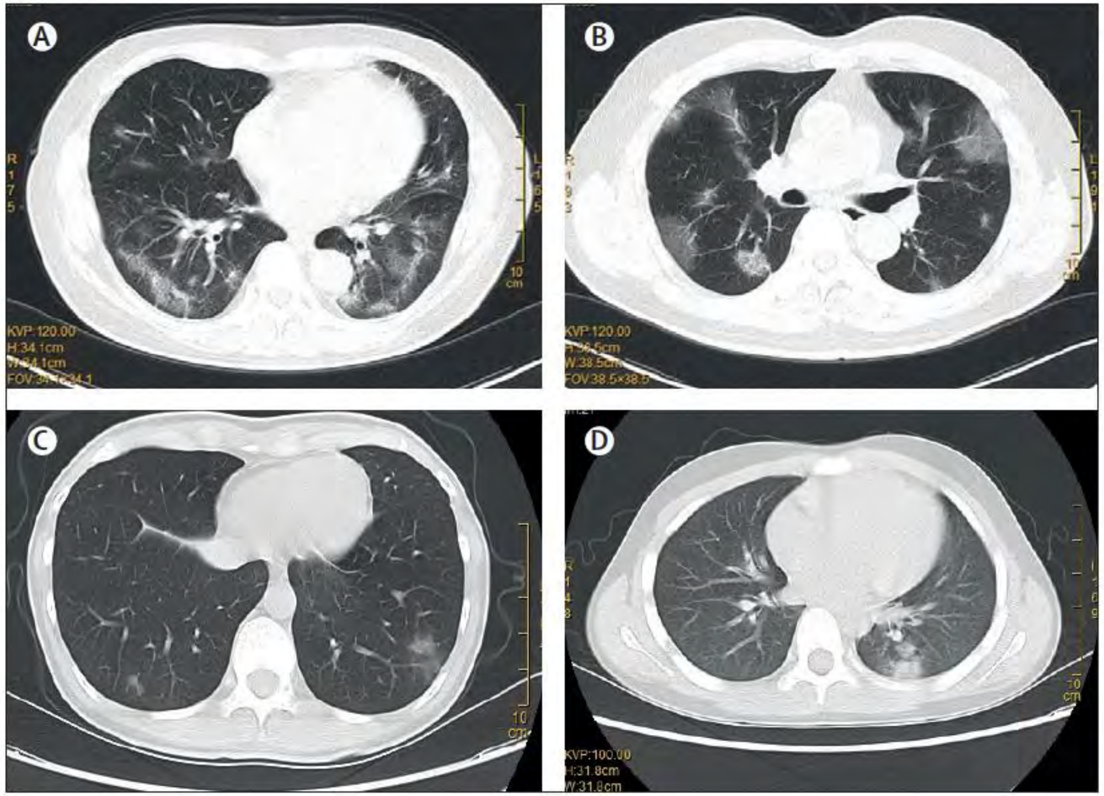


Huang, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China
The Lancet 2020



J Chan, et al. A familial cluster of pneumonia associated with the 2019 novel coronavirus indicating person-to-person transmission: a study of a family cluster
The Lancet 2020

Characteristic Appearances

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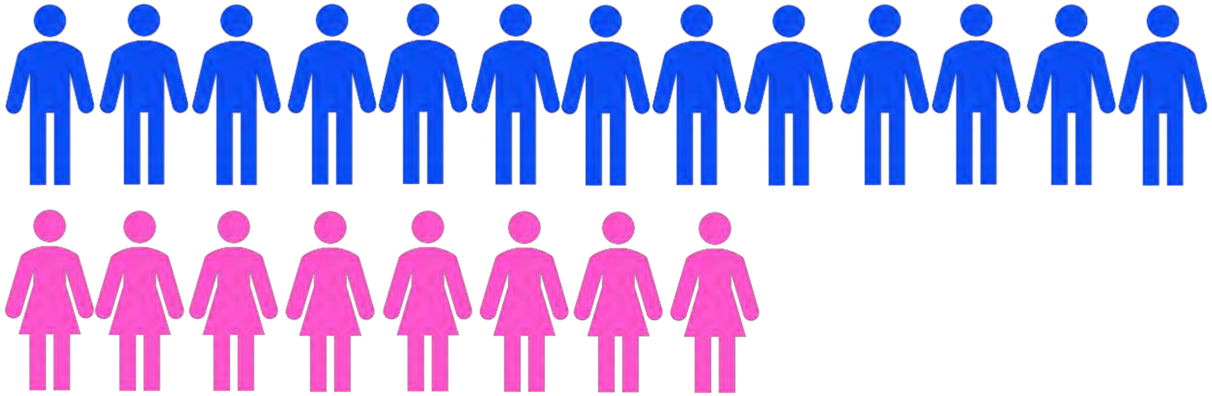

= 21 Patients

Hong Kong

Shenzhen

Characteristic Appearances

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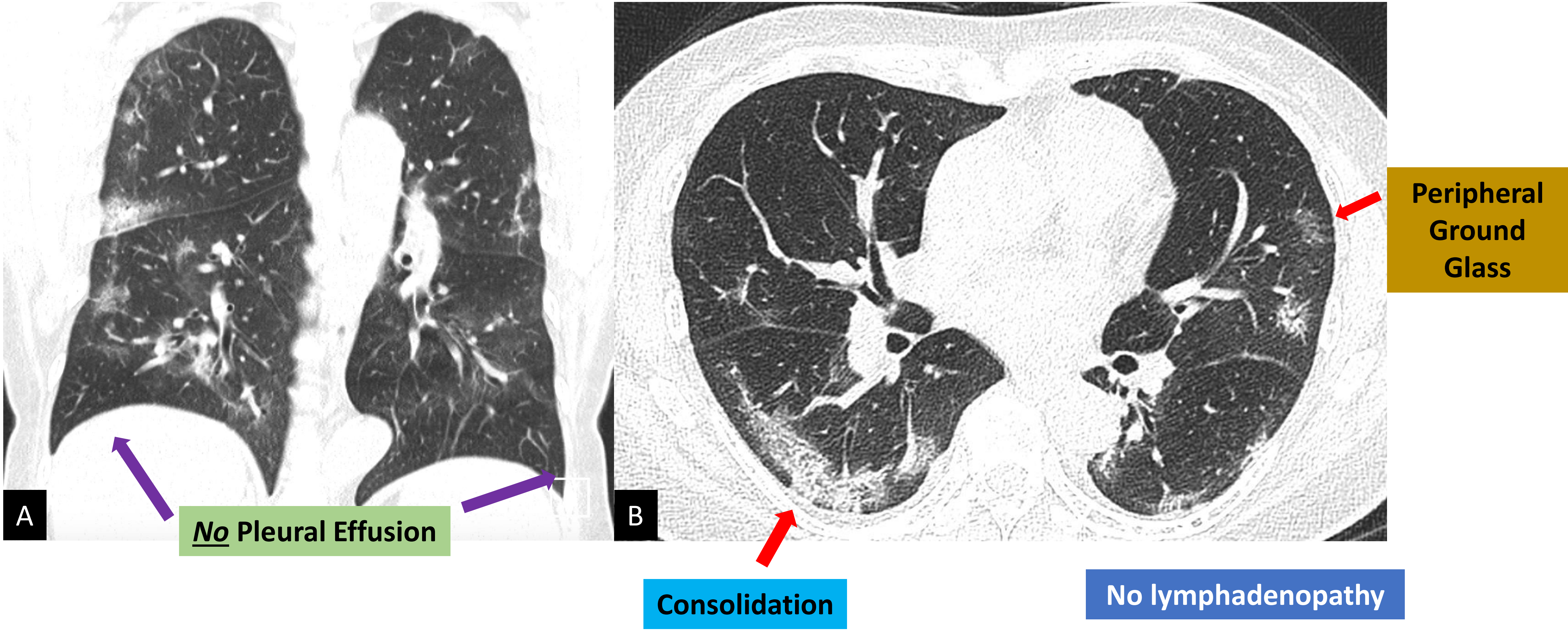

MY Ng, et al. Radiology: Cardiothoracic Imaging 2020

Radiology:Cardiothoracic Imaging

COVID-19 vs other pathogens

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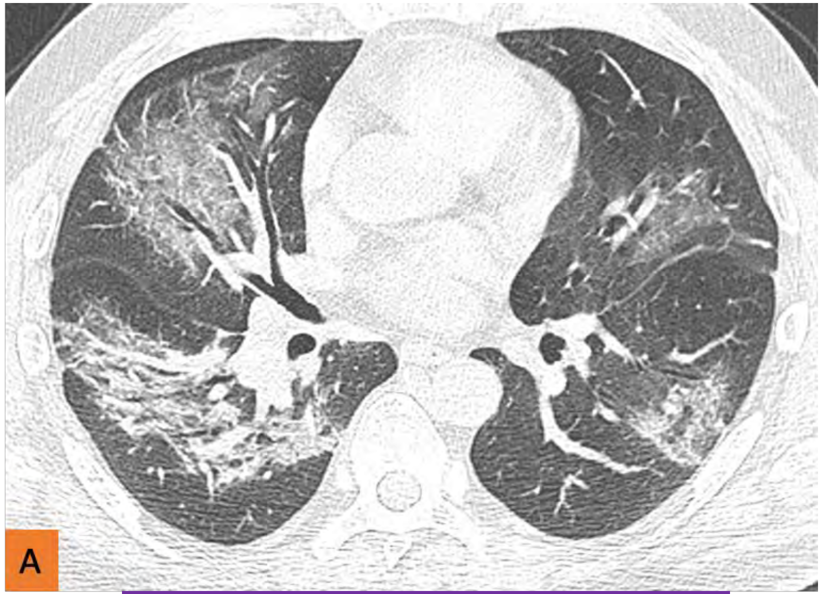
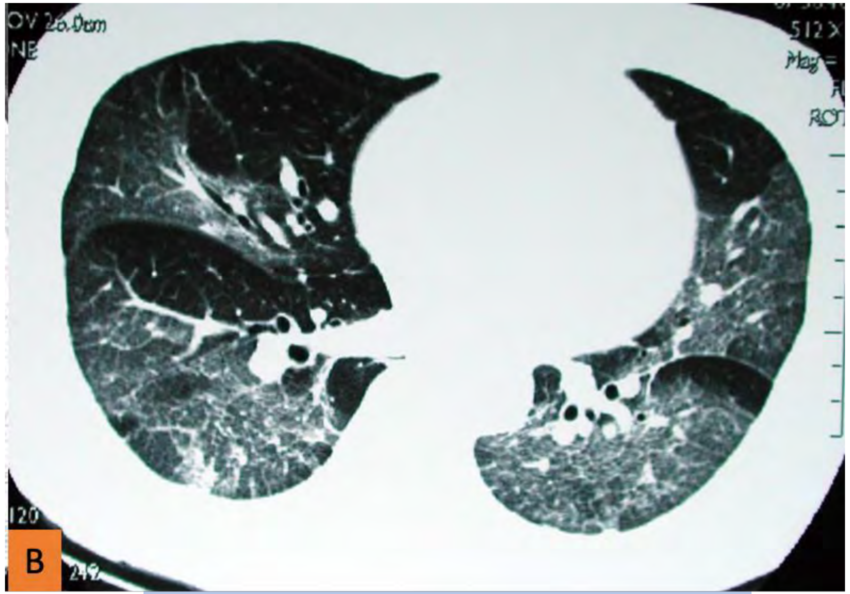


COVID-19



SARS

H1N1

1. MY Ng, et al. Radiology: Cardiothoracic Imaging 2020; 2. S Altmayer, et al. European Radiology 2020

CT - Temporal Changes

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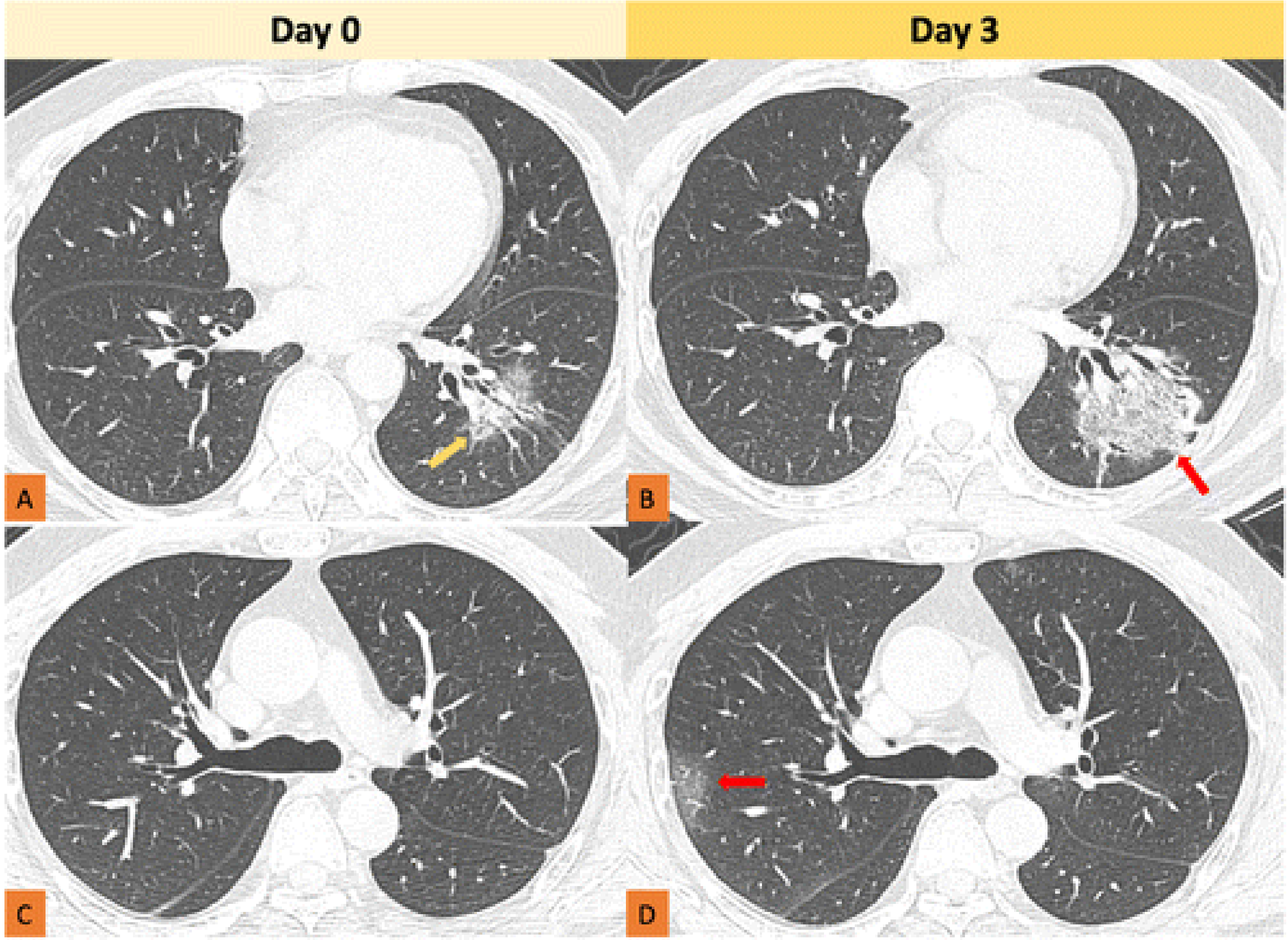

Ground-glass opacities evolve into consolidation

New ground glass changes

MY Ng, et al. Radiology: Cardiothoracic Imaging 2020

CXR - Temporal Changes

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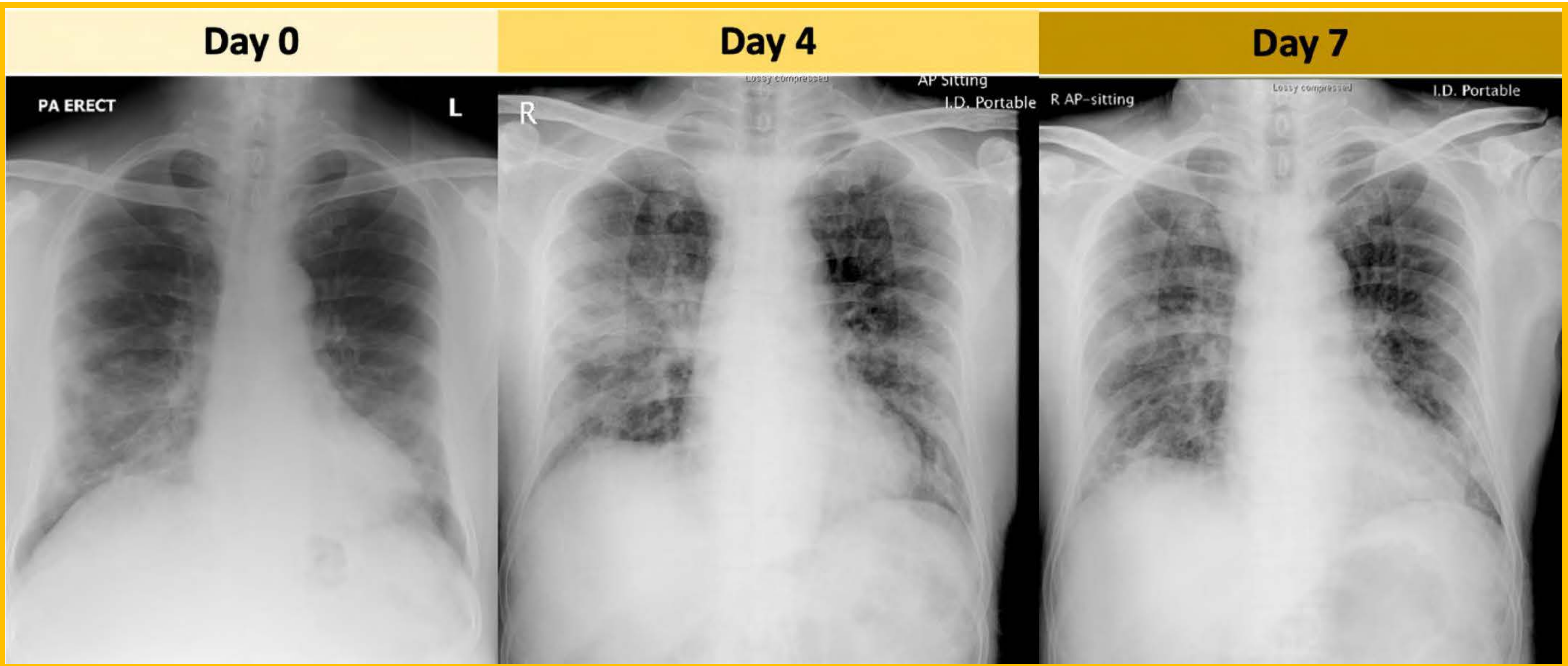

Consolidation/ ground glass worsens then improves

MY Ng, et al. Radiology: Cardiothoracic Imaging 2020

Radiology:Cardiothoracic Imaging

Systematic Review of Papers

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	Current Study	Chen et al[5]	Huang et al[6]	M Chung et al.[7]	Song et al.
No. of Patients	21 patients	99 patients	41 patients	21 patients	51 patients
Age	56 years (IQR 37-65years old)	Mean 55.5 years (SD:13.1)	Median 49 years (IQR: 41-58)	Mean 51 years (range: 29-77years)	Mean 49 (range 16-76 years)
Imaging Modality	CT & CXR	CT & CXR	CT only	CT only	CT only
CXR Findings					
Consolidation	60%	100%			
Pleural Effusion	0	N/A			
Normal CXR	2	0			
CT Findings					
Time Between Onset & 1st CT	Median 3 days (IQR 1-7 days)	N/A	8 days	N/A	Classified as (i) ≤4 days or (ii) >4days
Consolidation	62%	100%	Typically present	29%	59%
Ground Glass	86%	14%	Typically present	86%	77%
Predominant Distribution	Peripheral (86%) Lower Zone (38%) Similar Upper & Lower Zone (38%)	Bilateral (75%)	Bilateral (98%)	Peripheral (33%) Bilateral (76%)	Peripheral (86%) Bilateral (86%) Lower lobes (90%)
Lymphadenopathy	0%	N/A	N/A	0%	6%

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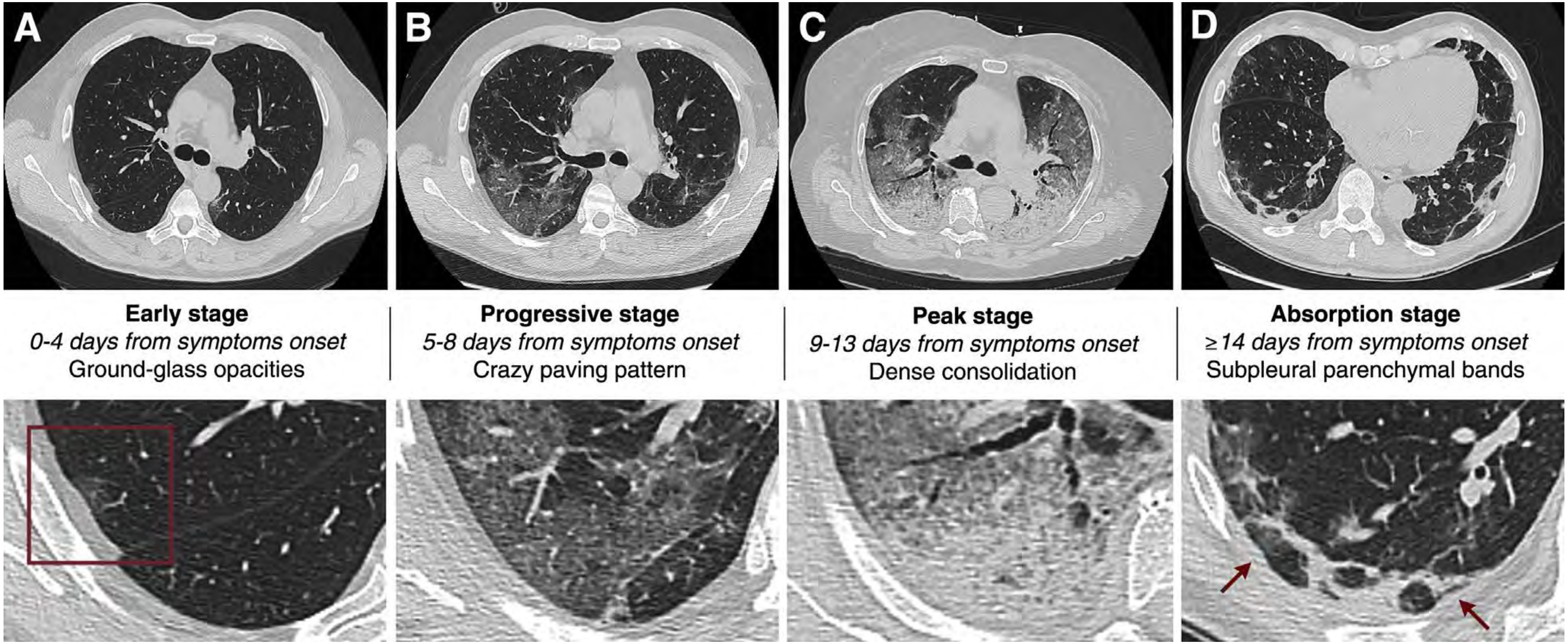
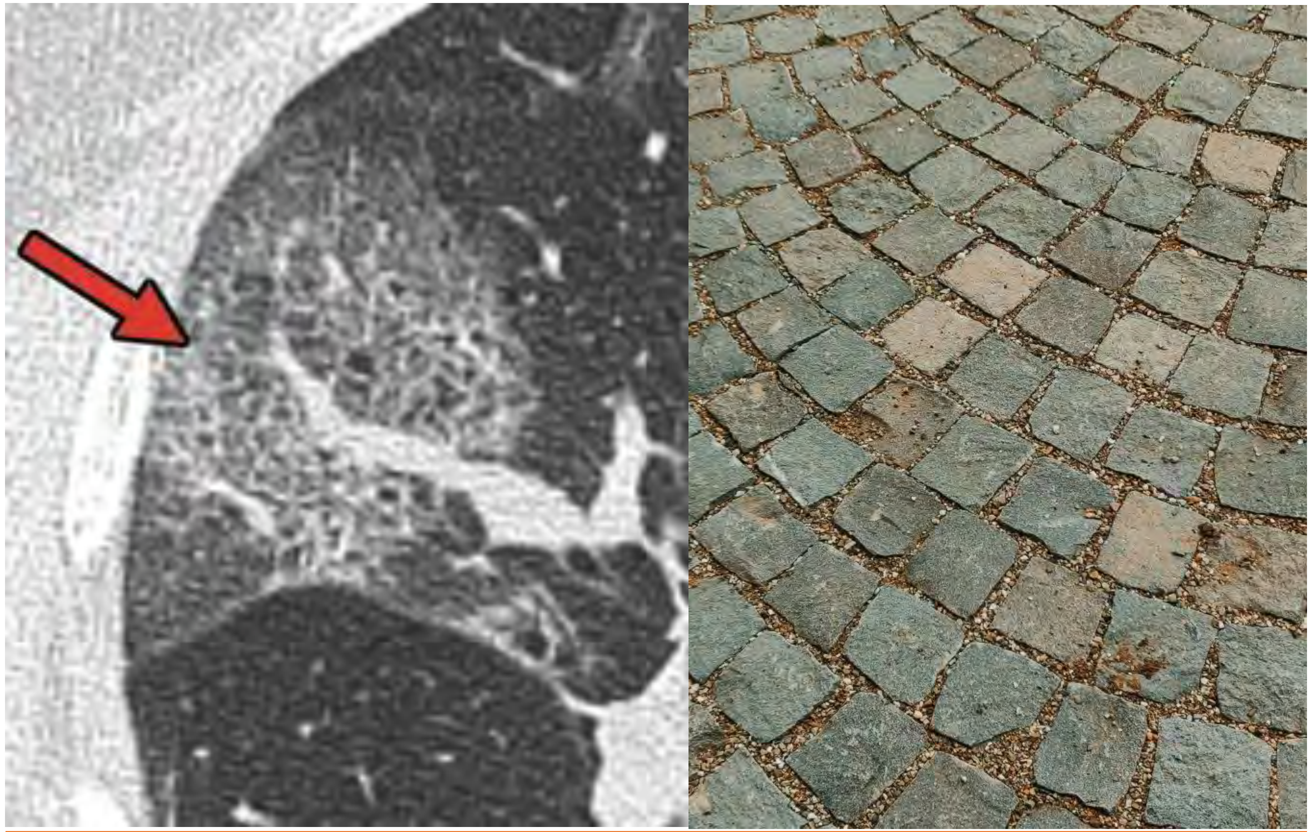
Subsequent Publications

CT Temporal Change

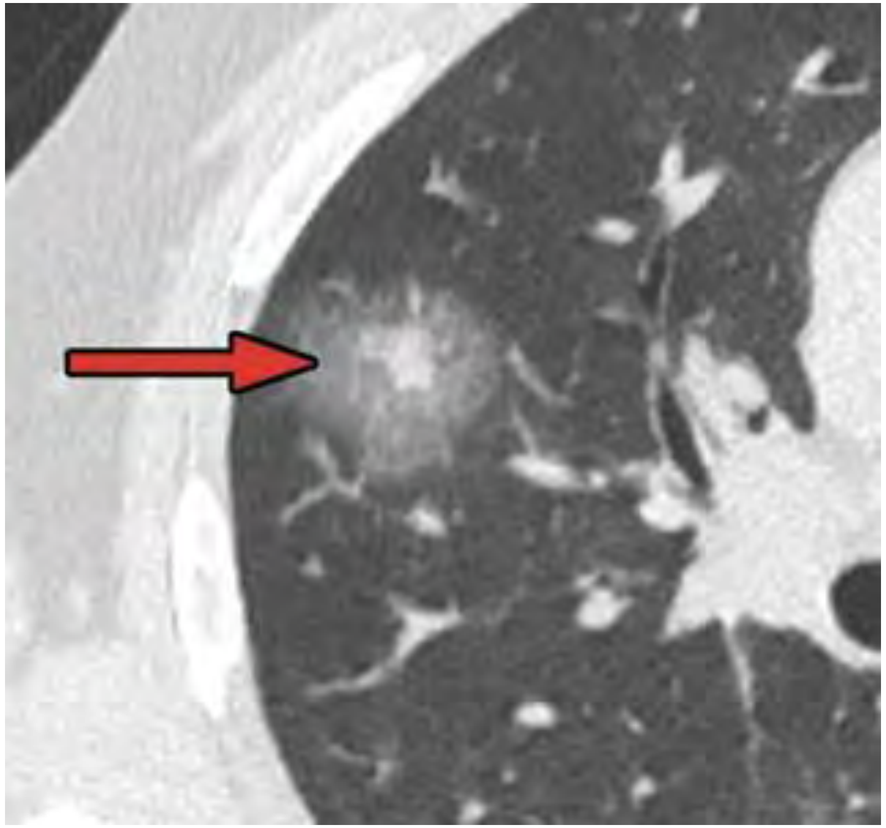


Agricola, et al. JACC Imaging 2020

Less Common Features



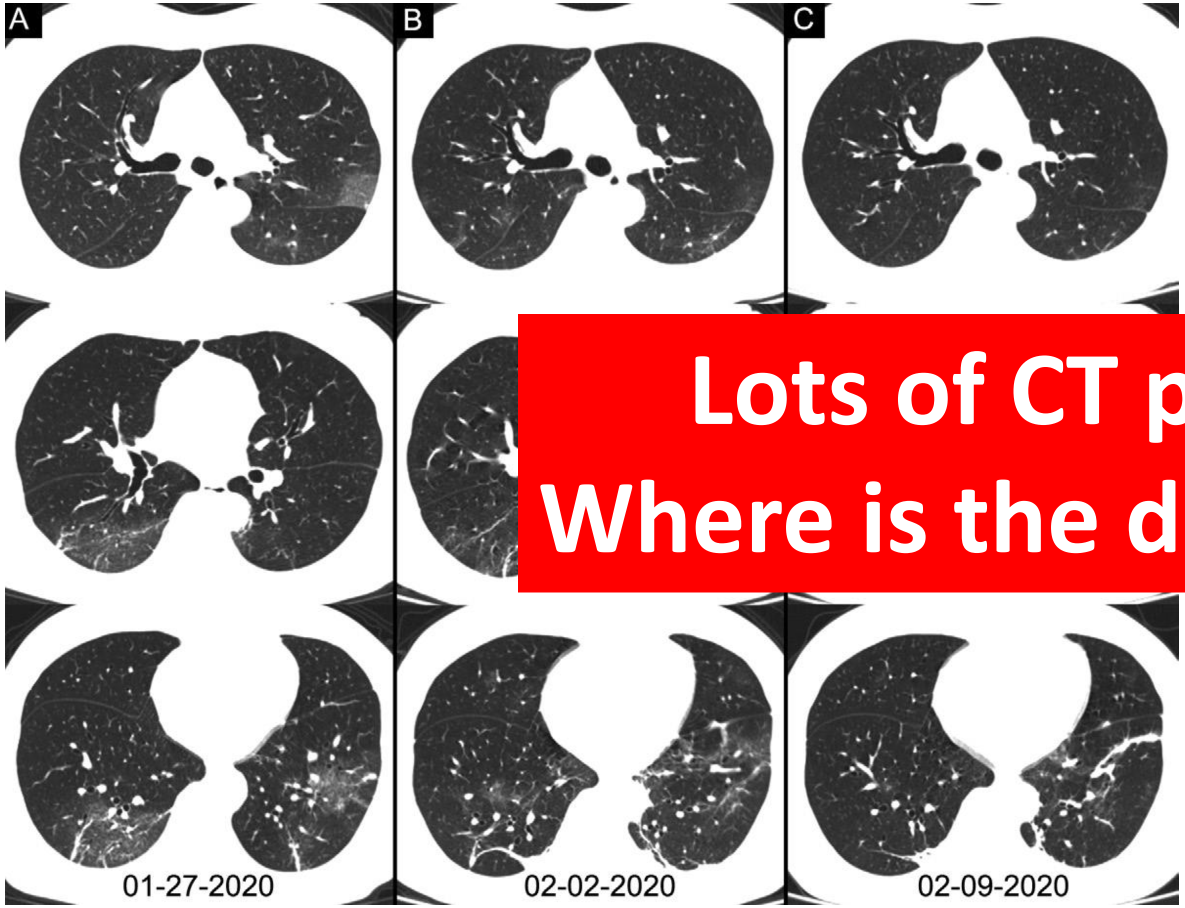
Crazy-Paving Pattern

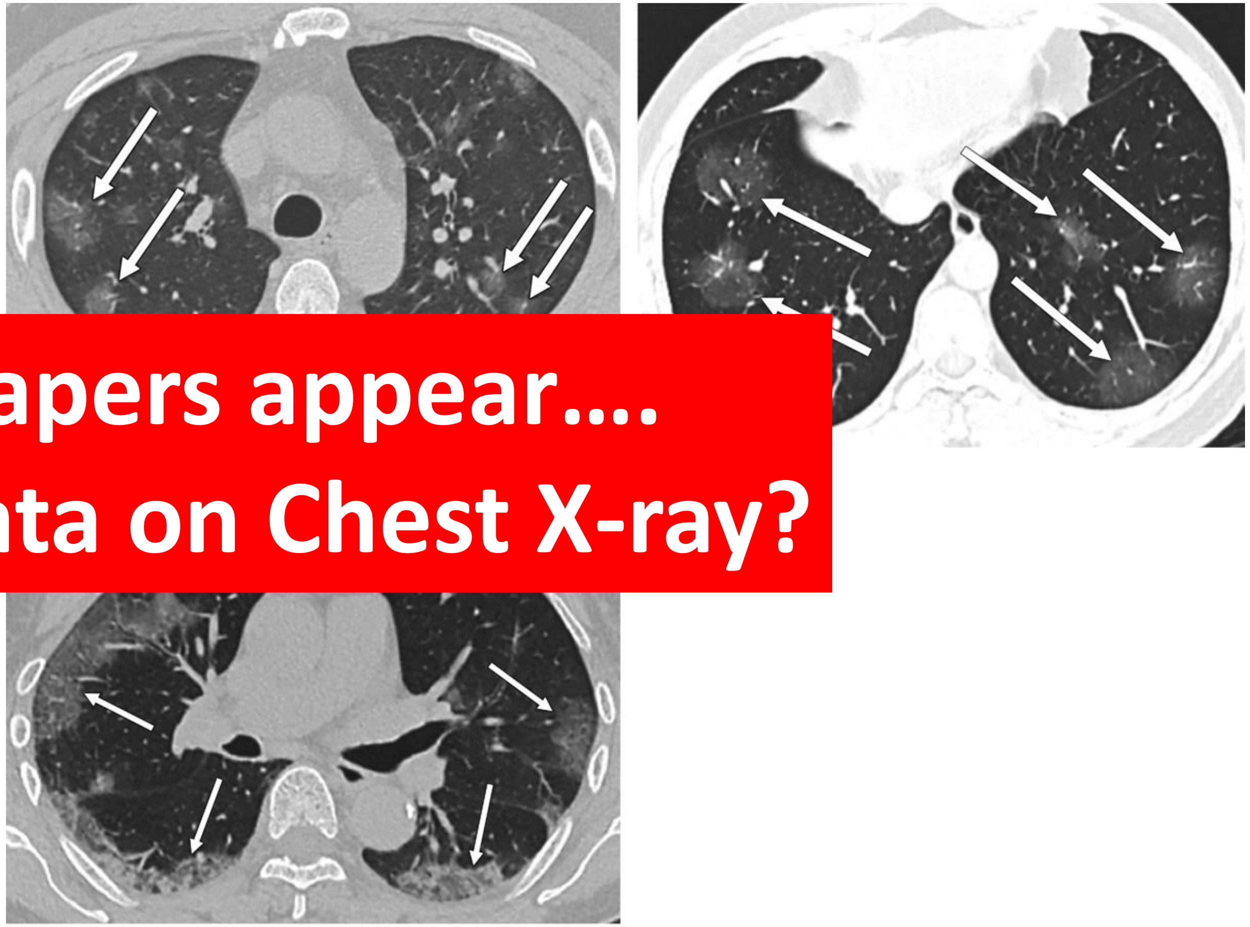


Halo Sign

Kwee & Kwee. Radiographics 2020

Confirmatory Publications





Lots of CT papers appear….
Where is the data on Chest X-ray?

c.

Ai et al. Radiology 2020

Bernheim et al. Radiology 2020

Chest X-rays

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ORIGINAL RESEARCH • THORACIC IMAGING

Radiology

Frequency and Distribution of Chest Radiographic Findings in Patients Positive for COVID-19

Ho Yuen Frank Wong, MBBS • Hiu Yin Sonia Lam, MBBS • Ambrose Ho-Tung Fong, BS • Siu Ting Leung, MBBS • Thomas Wing-Yan Chin, MBBS • Christine Shing Yen Lo, MBBS[1] • Macy Mei-Sze Lui, MBBS • Jonan Chun Yin Lee, MBBS • Keith Wan-Hang Chiu, MBBS • Tom Wai-Hin Chung, MBBS • Elaine Yuen Phin Lee, MBBS • Eric Yuk Fai Wan, PhD • Ivan Fan Ngai Hung, MBBS • Tina Poy Wing Lam, MBBS • Michael D. Kuo, MD • Ming-Yen Ng, MBBS

HYF Wong, et al. Radiology 2020

CXR Paper in Radiology

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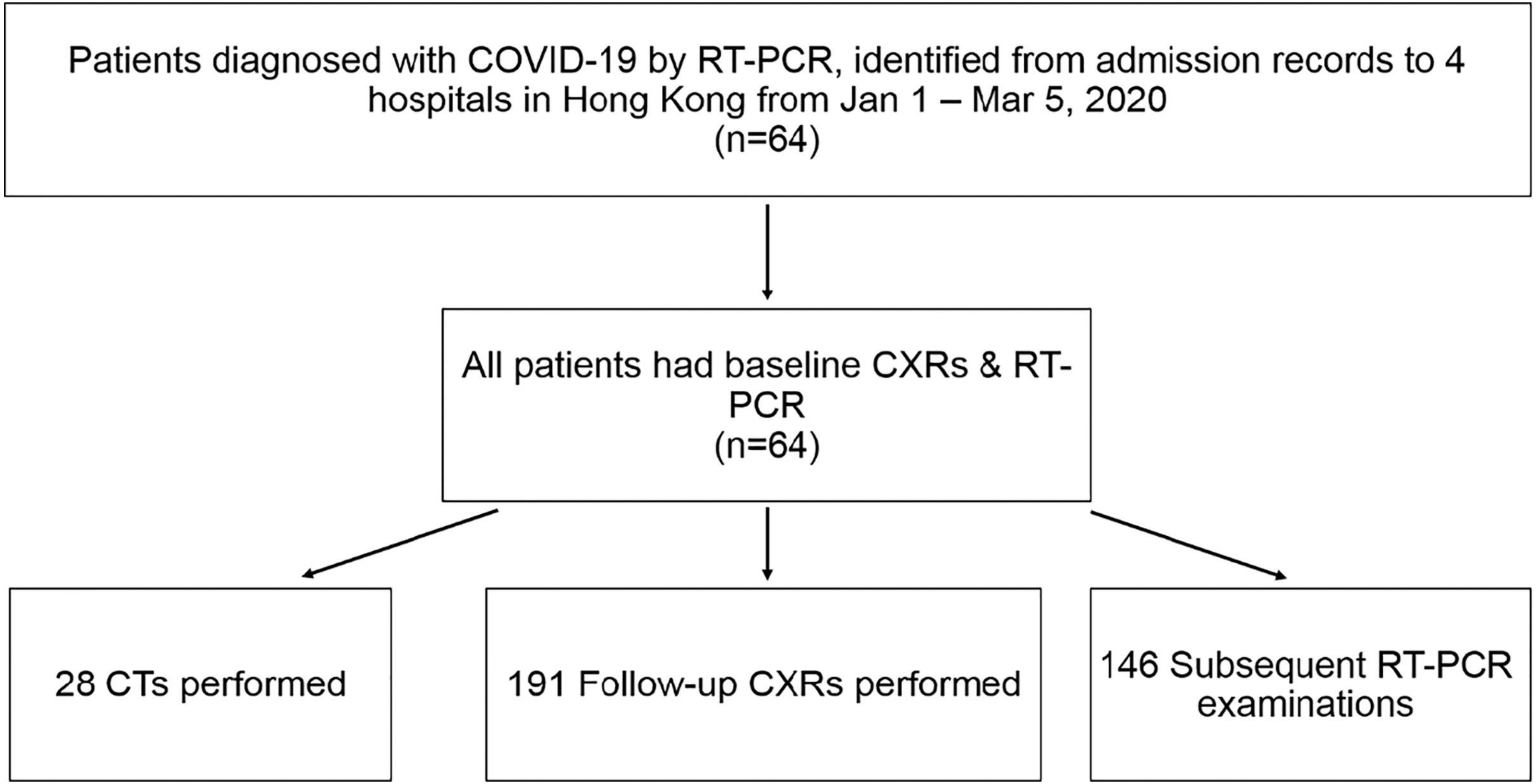

HYF Wong, et al. Radiology 2020

CXR Paper in Radiology

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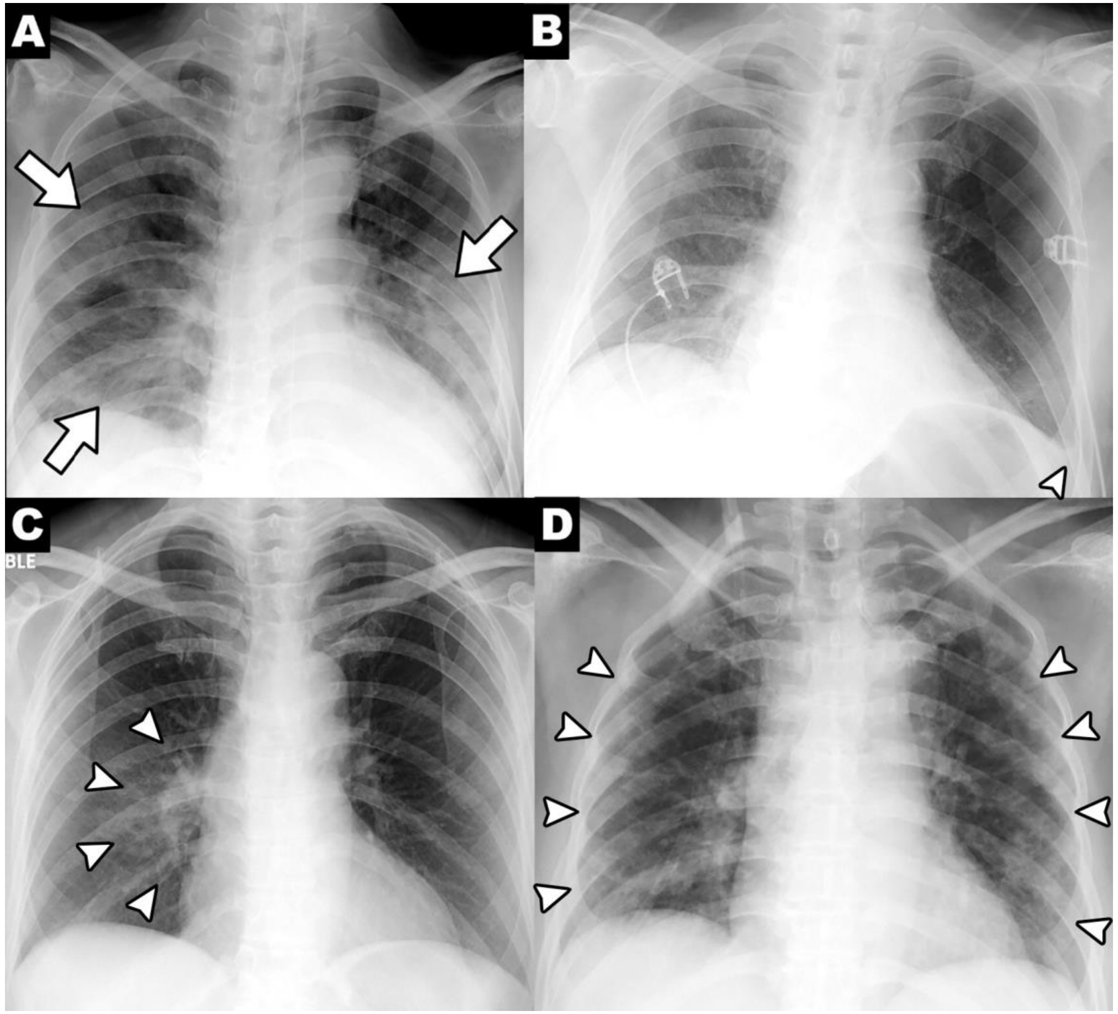

Table 2: Radiographic Findings at Chest Radiography

Characteristic	No. of Findings
No. of normal baseline chest radiographs	20 (31)
No. of abnormal baseline chest radiographs	44 (69)
No. of patients with normal baseline chest radiographs later becoming abnormal	7 (11)
Type of parenchymal opacity at baseline chest radiography	
Consolidation	30 (47)
Ground-glass opacities	21 (33)
Distribution at baseline chest radiography	
Peripheral predominant	26 (41)
Perihilar predominant	6 (9)
Neither peripheral nor perihilar	19 (30)
Right lung	10 (16)
Left lung	9 (14)
Bilateral lungs	32 (50)
Upper zone predominant	0 (0)
Lower zone predominant	32 (50)
No zonal predominance	19 (30)
Other features on baseline chest radiographs	
Pleural effusion	2 (3)
Pulmonary nodules	0 (0)

Note.—Data in parentheses are percentages; percentages were calculated on the basis of 64 patients.

HYF Wong, et al. Radiology 2020

CXR Paper in Radiology

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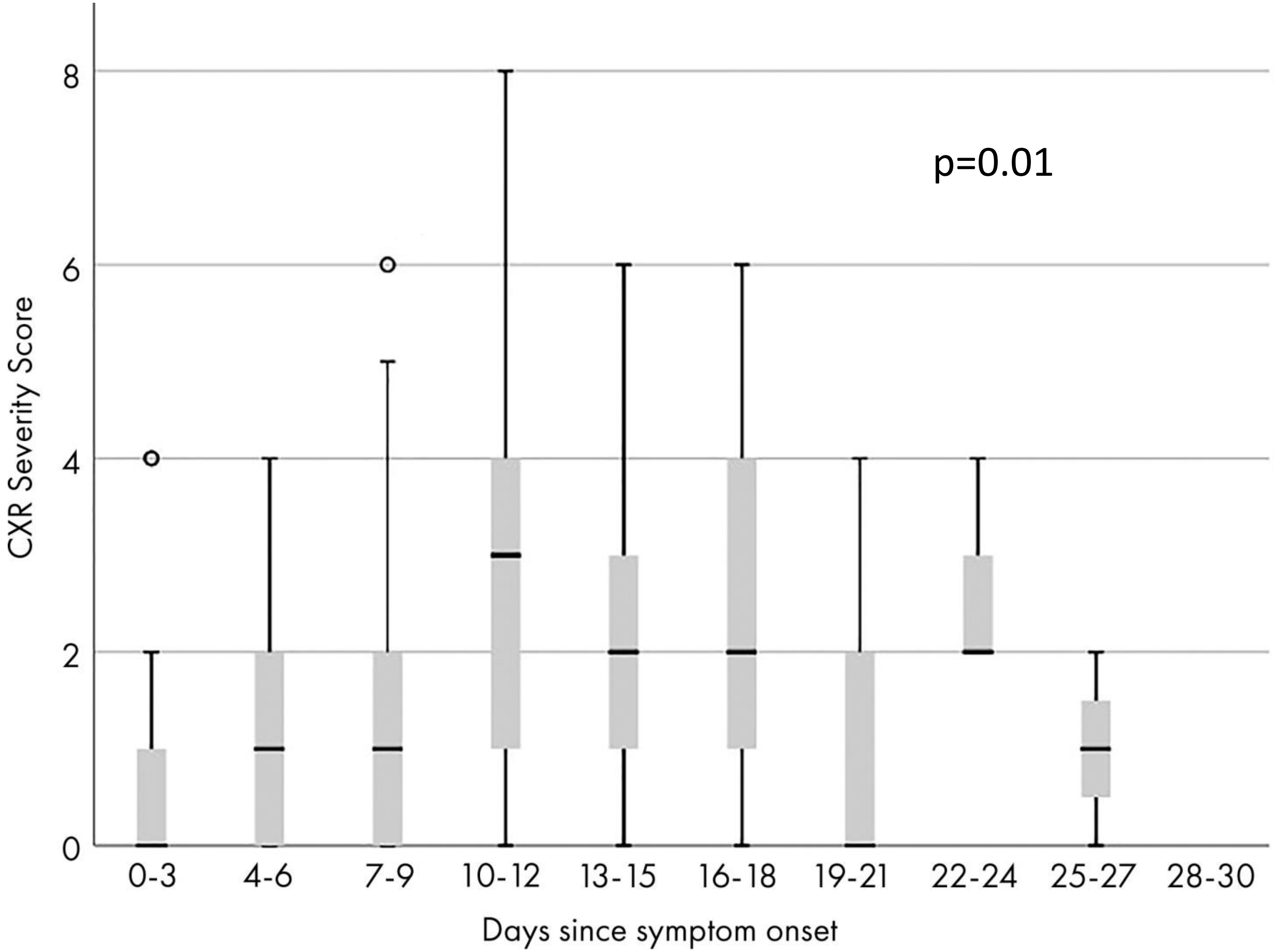

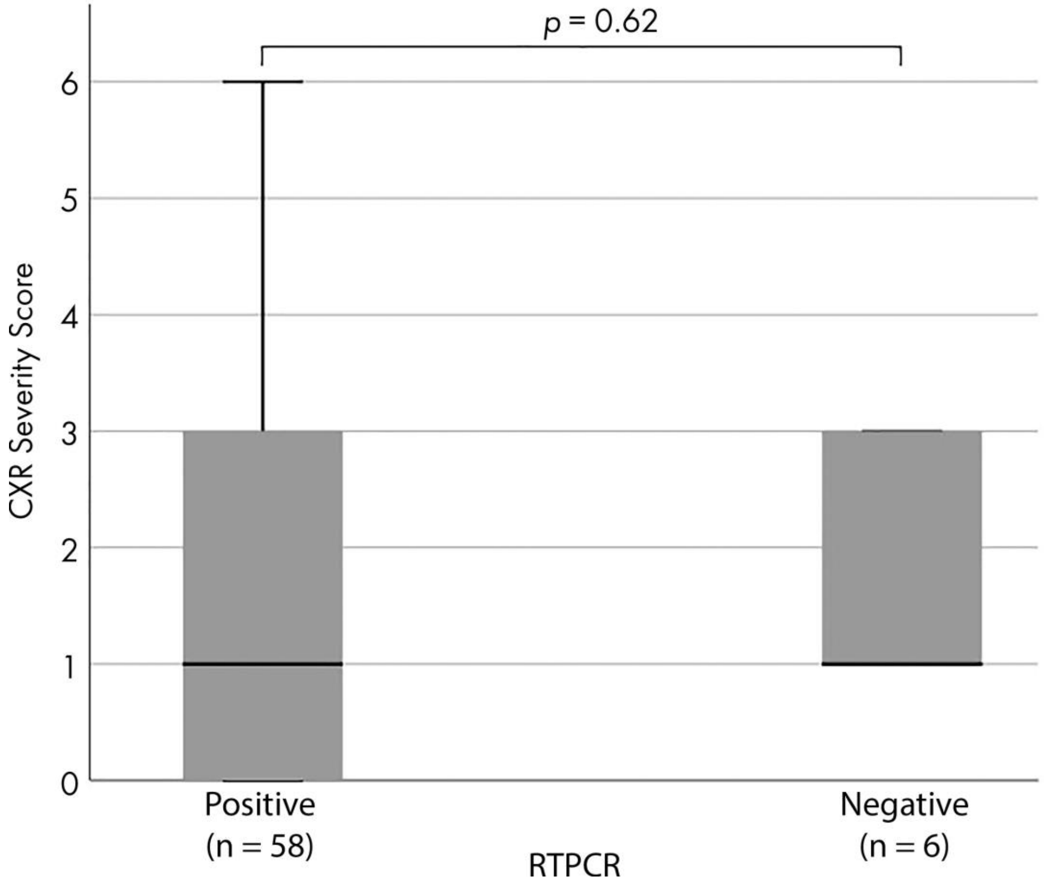

HYF Wong, et al. Radiology 2020

What is the Diagnostic Accuracy of CT?

COVID-19 Scoring System

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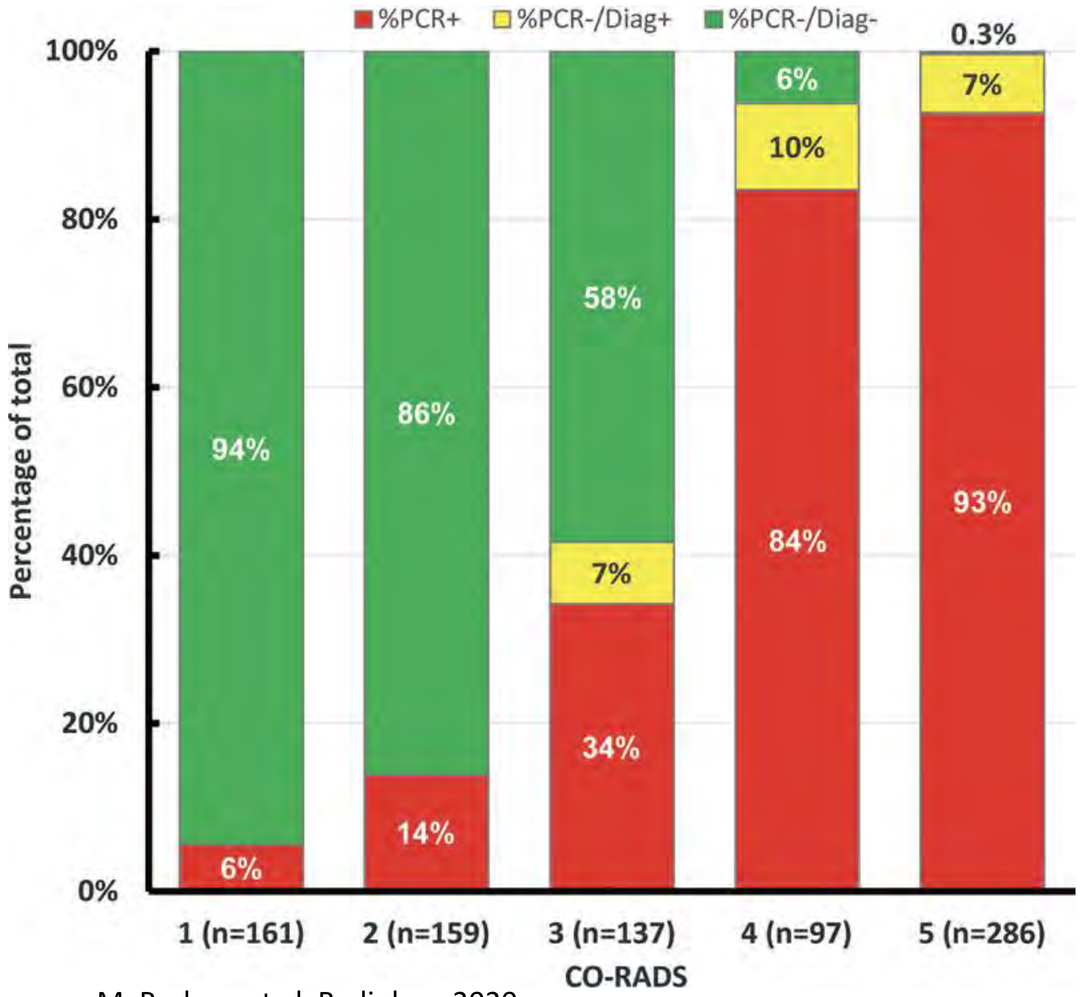
CO-RADS Category	Level of Suspicion for Pulmonary Involvement of COVID-19	Summary

M. Prokop, et al. Radiology 2020

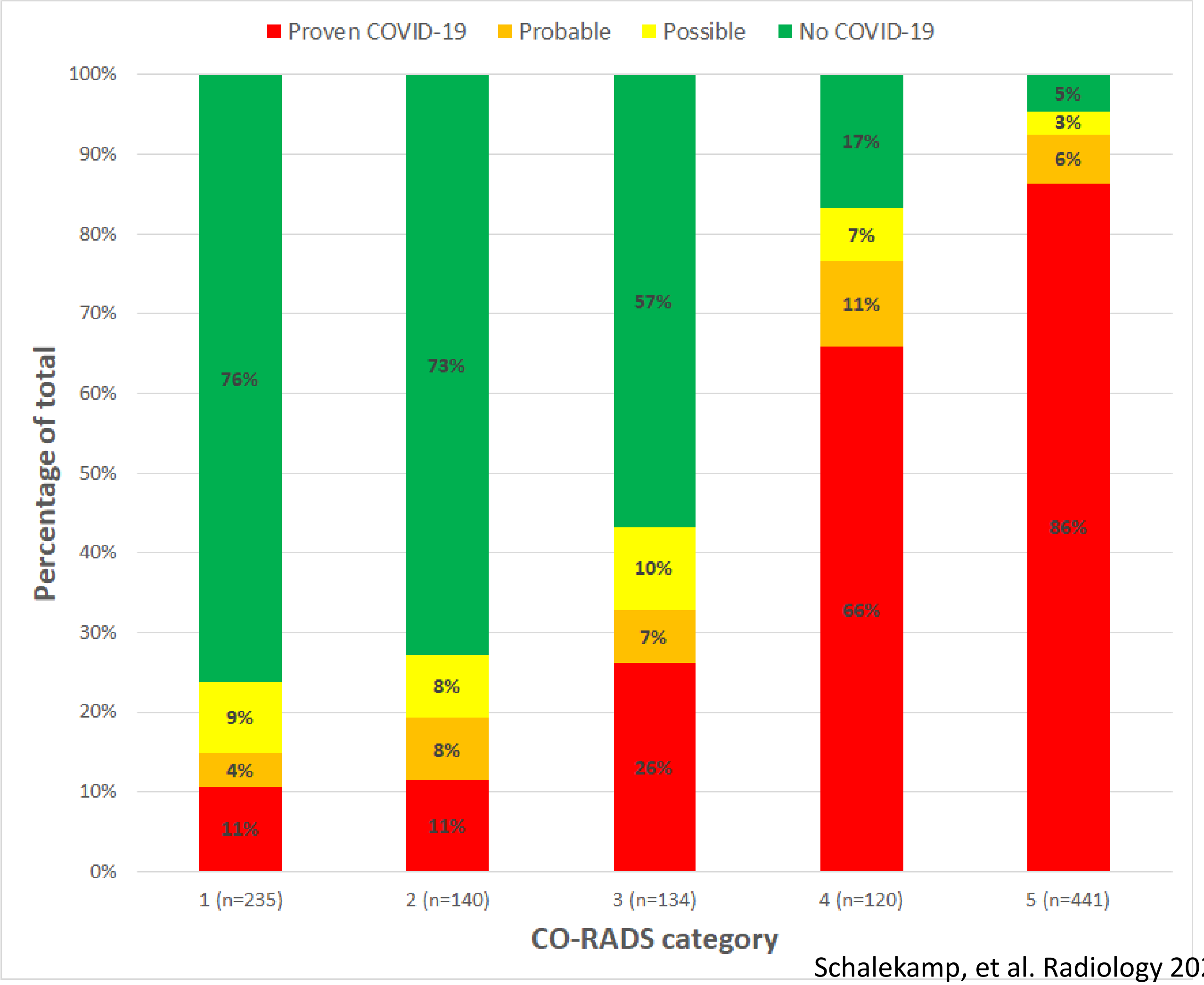
COVID-19 Reporting System

1st Study (n=105 CTs)



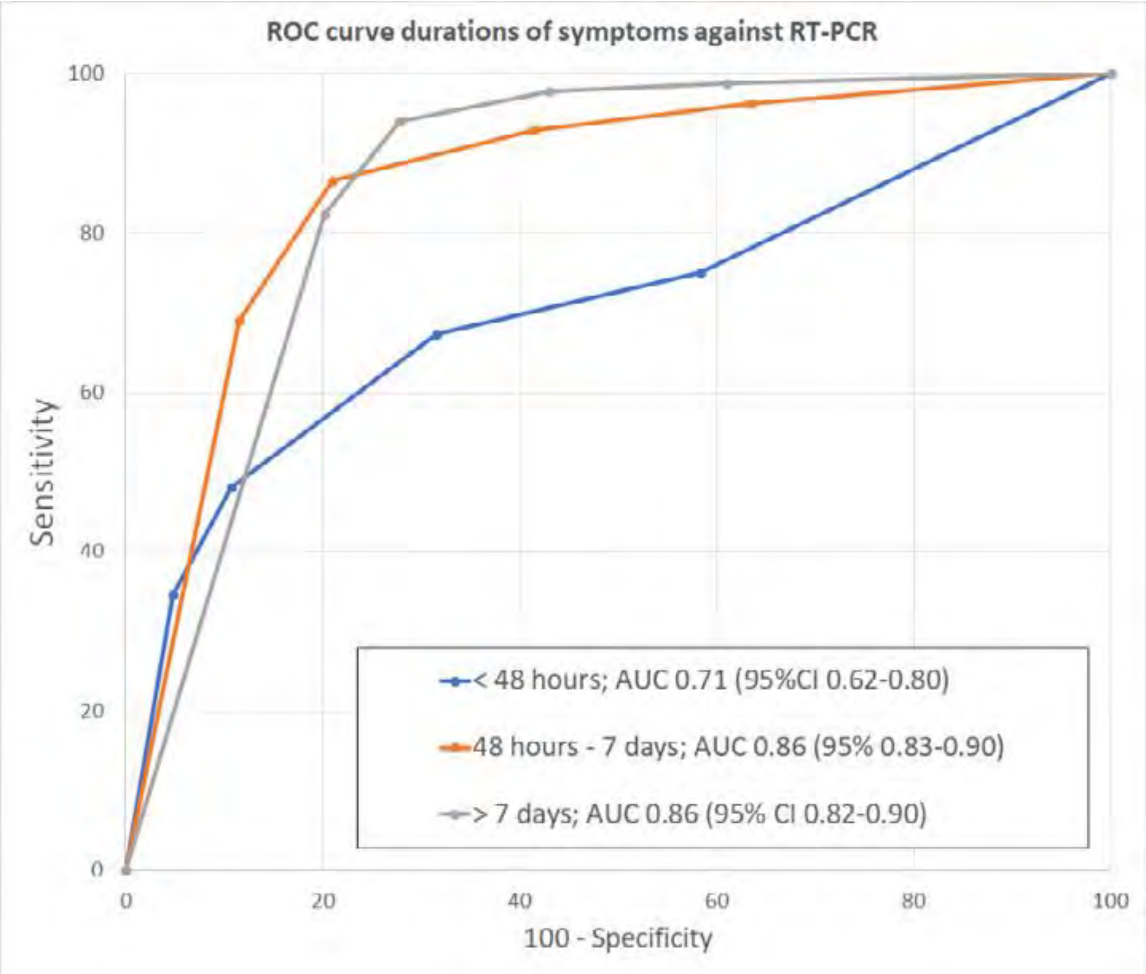
M. Prokop, et al. Radiology 2020

2nd Study (n=1070 CTs)



Schalekamp, et al. Radiology 2020

COVID-19 Reporting System



CT performed better with symptom duration of ≥48 hrs of symptoms

Schalekamp, et al. Radiology 2020

COVID-19 Reporting System

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Table 2: Imaging Classification and CT Features of COVID-19 Pneumonia

Imaging Classification	Rationale	CT Features
Typical appearance	Commonly reported imaging features of greater specificity for COVID-19 pneumonia	Peripheral, bilateral, ground-glass opacities with or without consolidation or visible intralobular lines ("crazy-paving" pattern) Multifocal ground-glass opacities of rounded morphology with or without consolidation or visible intralobular lines (crazy-paving pattern) Reverse halo sign or other findings of organizing pneumonia (seen later in the disease)
Indeterminate appearance	Nonspecific imaging features of COVID-19 pneumonia	Absence of typical features AND the presence of the following features: multifocal, diffuse, perihilar, or unilateral ground-glass opacity with or without consolidation lacking a specific distribution and that are nonrounded or nonperipheral Few small ground-glass opacities, with a nonrounded and nonperipheral distribution
Atypical appearance	Uncommonly or not reported features of COVID-19 pneumonia	Absence of typical or indeterminate features AND the presence of the following features: isolated lobar or segmental consolidation without ground-glass opacities; discrete small nodules (centrilobular, "tree-in-bud" appearance); lung cavitation; smooth interlobular septal thickening with pleural effusion
Negative for pneumonia	No features of pneumonia	No CT features to suggest pneumonia.

Source.—Adapted and reprinted under a CCBY 4.0 license from reference 51.

1. Kwee & Kwee. Radiographics 2020
2. S. Simpson, et al. Radiology Cardiothoracic Imaging 2020

Why do some centres prefer CXR or CT?

Using CXR or CT – Infection Control

- Cleaning of the scanners
- Room cannot be used for ~30 minutes (dependent on air-exchange rate)
- Impacts on regular CT lists
- Availability of scanners

Obtaining CXR - Portable

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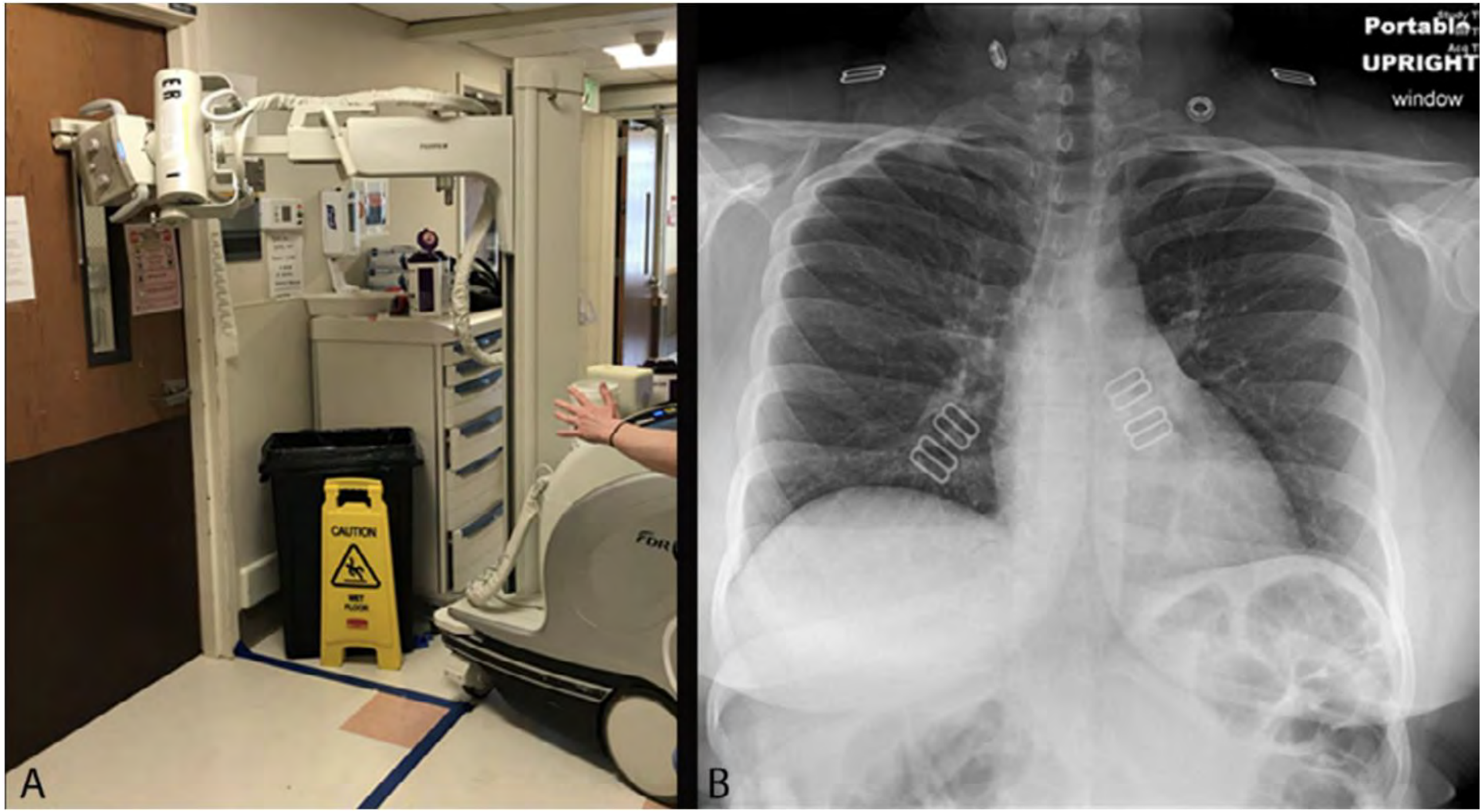

- Room cleaning not required
- CXR less sensitive than CT
- Less impact on radiology work-flow

M. Mossa-Basha, et al. RSNA COVID-19 Task Force: Best Practices for Radiology Departments during COVID-19. 2020

CTPA for Pulmonary Embolism

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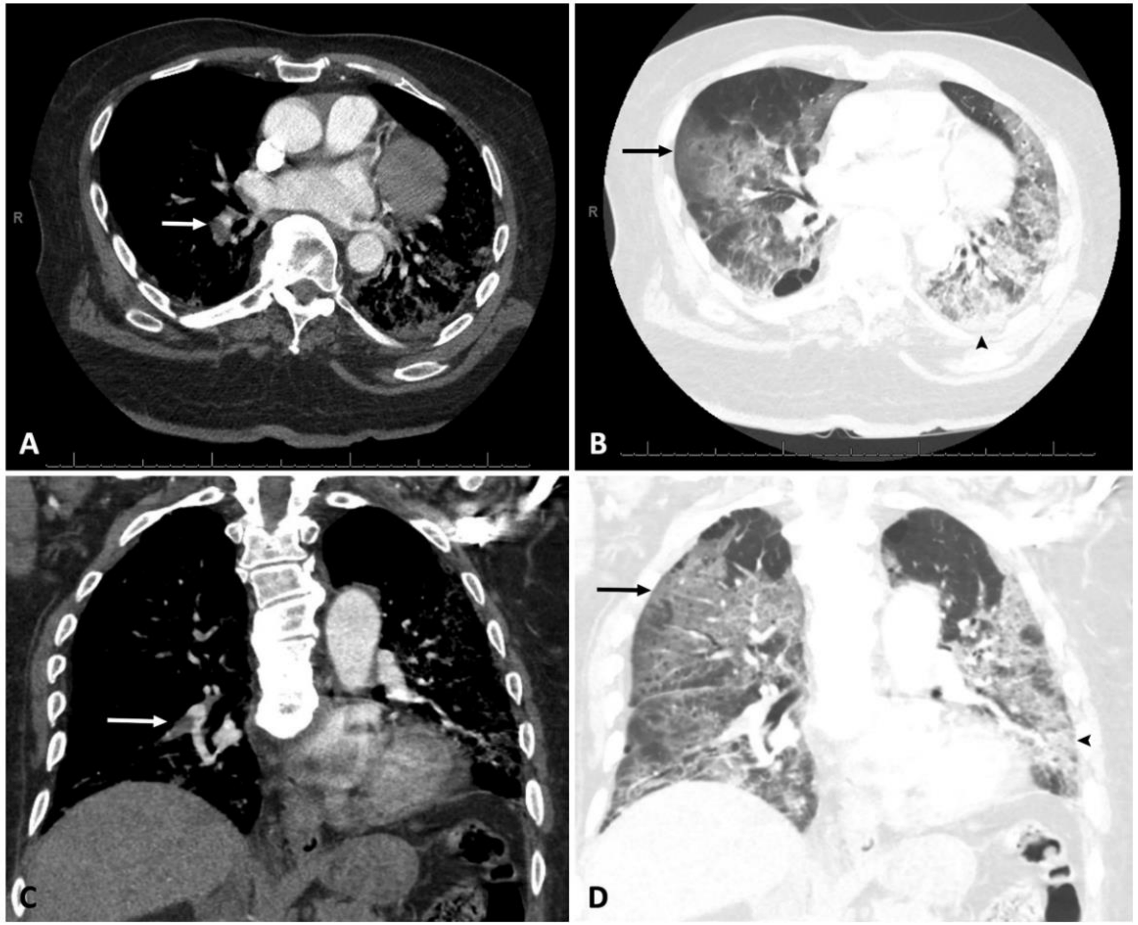
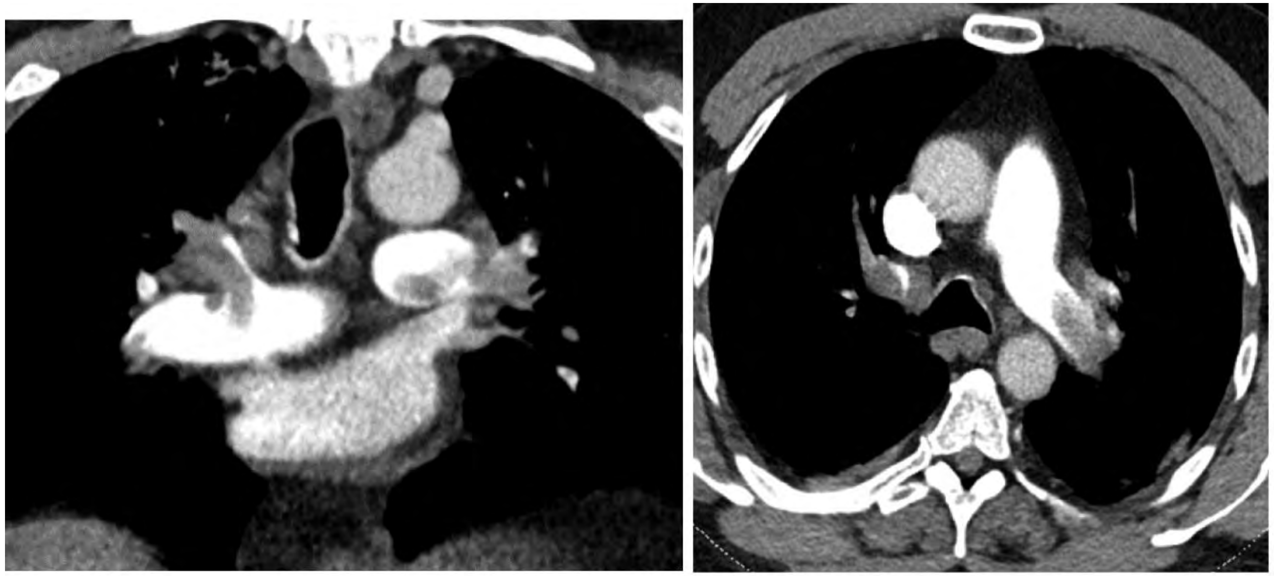


Figure 2: *A, B,* Axial and, *C, D,* coronal pulmonary CT angiography images in a 76-year-old African American man with body mass index of 37 kg/m² who required admission to medical intensive care unit for acute respiratory failure secondary to coronavirus disease 2019 confirmed with reverse transcriptase polymerase chain reaction. Pulmonary CT angiography was obtained 4 days after admission and demonstrates acute pulmonary embolism in right lower lobar pulmonary artery (white arrows), bilateral ground glass opacities (black arrows), and consolidation (arrowheads).



- 22%-37% of COVID-19 patients had PE
- Both studies showed that D-dimer was significant for differentiating patients with and without PE

1. Poyiadji et al. Radiology 2020; 2. Kaminetzky et al. Radiology: Cardiothoracic Imaging 2020

Role of CT Pre-Screening in Surgery

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Table 1 Summary of findings in studies using preoperative CT Chest screening in a surgical setting

Author	Month of Publication	No of patients undergoing Chest CT	Positive on CT	Positive on RT-PCR	Remarks
Callaway *et al*[3]	June	677	90(13·49%)	13/643(2·02%)	Sensitivity- 68·4%, Specificity- 88%, Disease prevalence- 2·95% Difficult to justify this additional examination.
Chetan *et al*[4]	June	439	32(7·28%)	7(1·59%)	Altered surgical management in 7% of the elective surgical cohort, but not in the acute abdominal emergency cohort requiring surgery.
Hernigou *et al*[5]	July	298	16(5·36%)	20/227(8·81%)	Chest CT scan is no longer useful outside the pandemic period Most accurate diagnostic test for COVID-19 pneumonia in patients who needed surgery in emergency Useful in patients who had a previous symptomatic infection with recovery and may have pulmonary sequels
Huybens *et al*[6]	July	374	18(4·81%)	3(0·80%)	CT chest has no added value in a low prevalence population.
Ikehara *et al*[7]	July	21	2(9·52%)	0	54% of asymptomatic patients have Pneumonic changes on CT, chest CT screening before procedural endoscopy may contribute to identify COVID-19 patients.
Shah *et al*[8]	July	625	105(16·8%)	1(0·16%)	Chest CT scanning did not provide valuable information in detecting asymptomatic cases of COVID-19 in low prevalence populations.

V. Agrawal, et al. British Journal of Surgery 2020

Issues withs CT Pre-Screening

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Delays Surgery

Safety of Radiology Staff

Increased Treatment Cost

Radiation Hazard

Decontamination of Scanner

Lung Ultrasound

Lung Ultrasound

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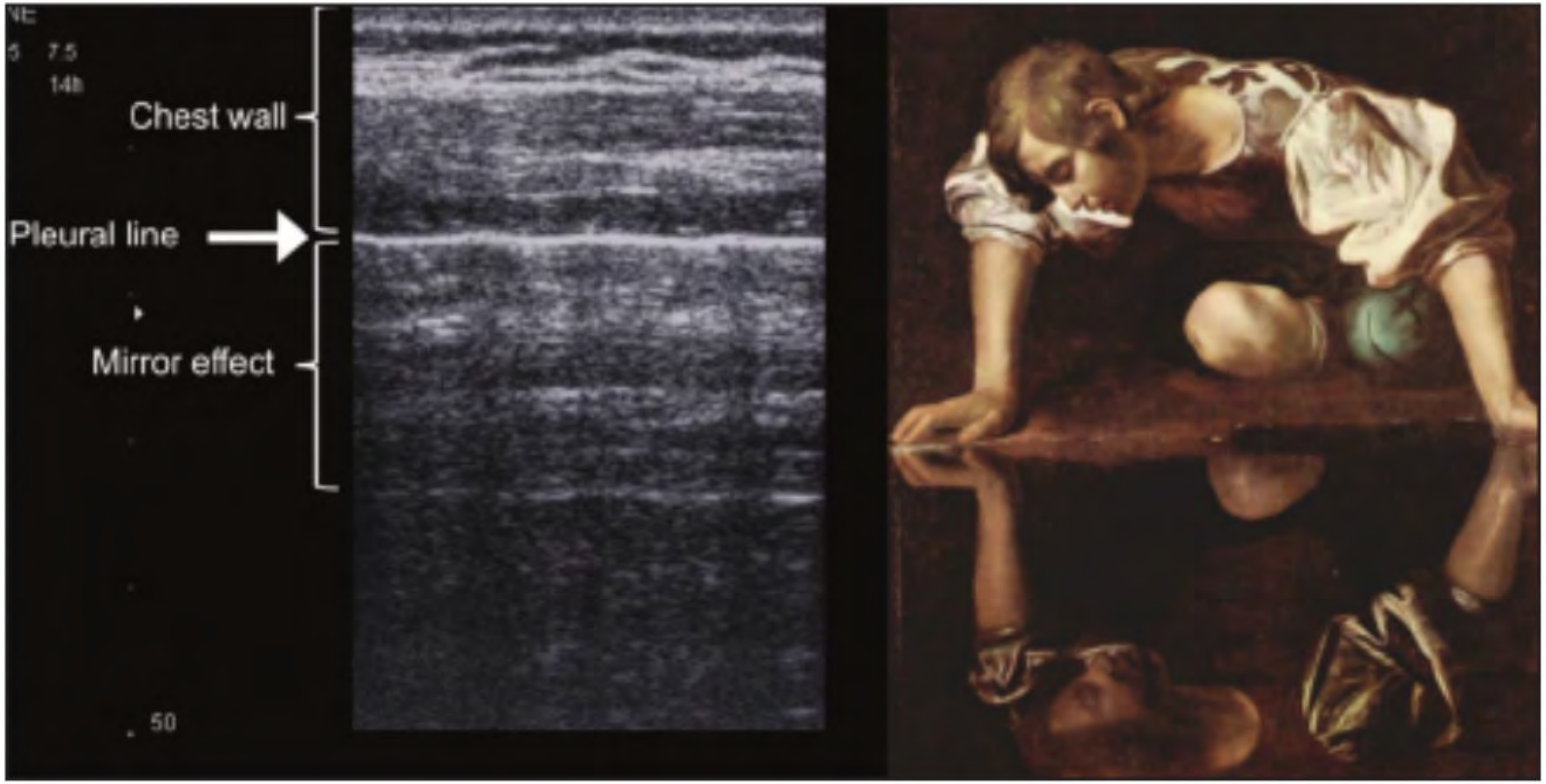

Normal Lung

G Volpicelli. J Ultrasound Med 2013

Lung Ultrasound

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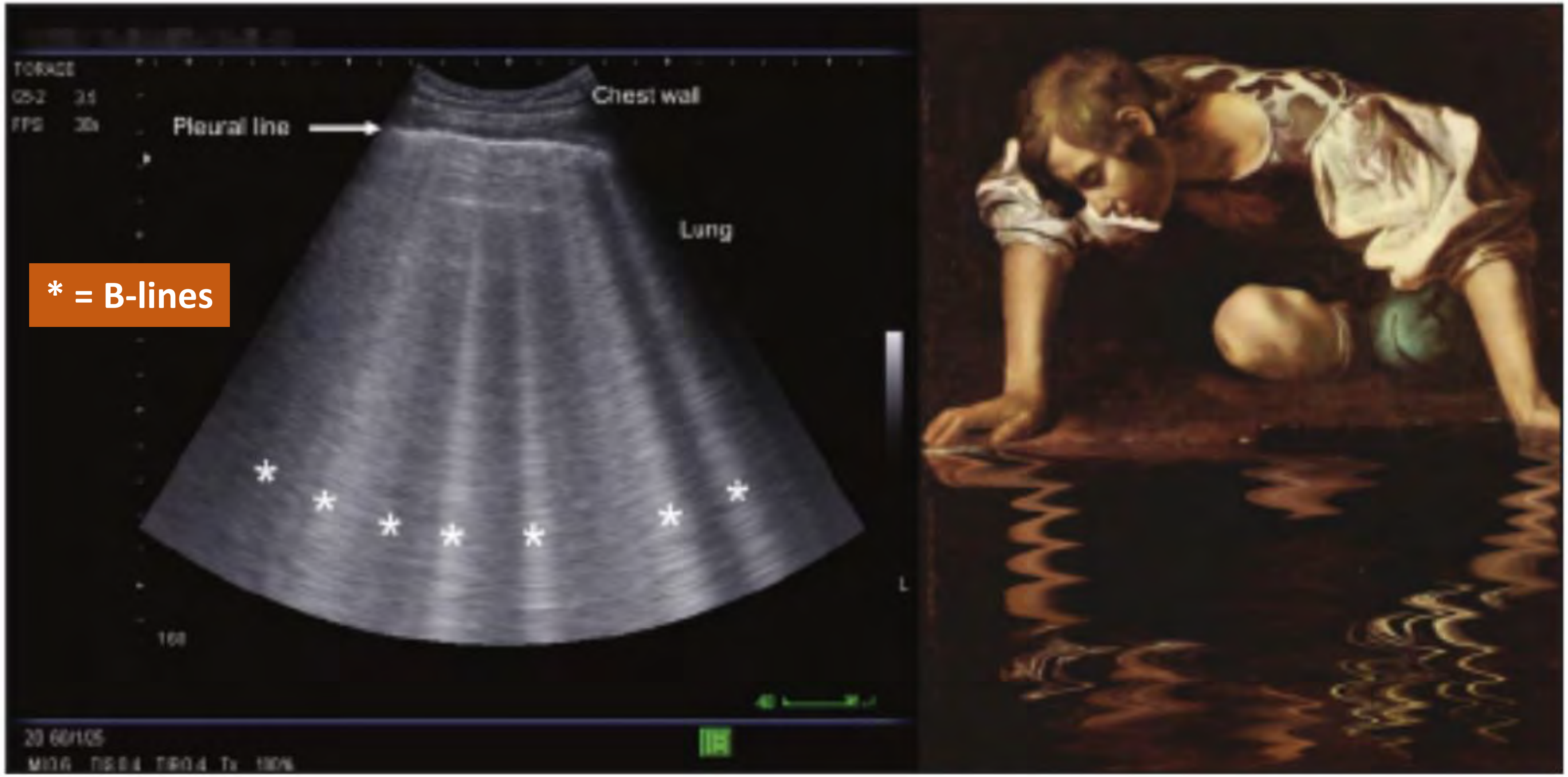

G Volpicelli. J Ultrasound Med 2013

Lung Ultrasound

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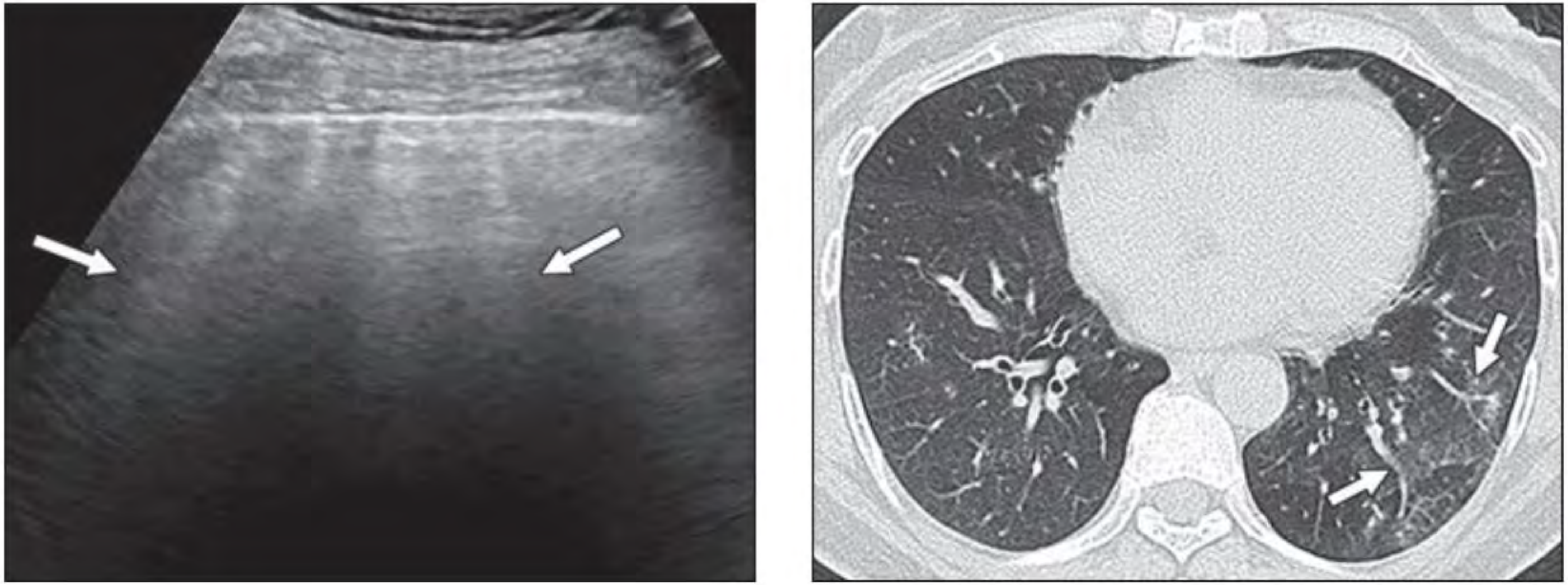

A B

Zhang et al. AJR 2020

Lung Ultrasound

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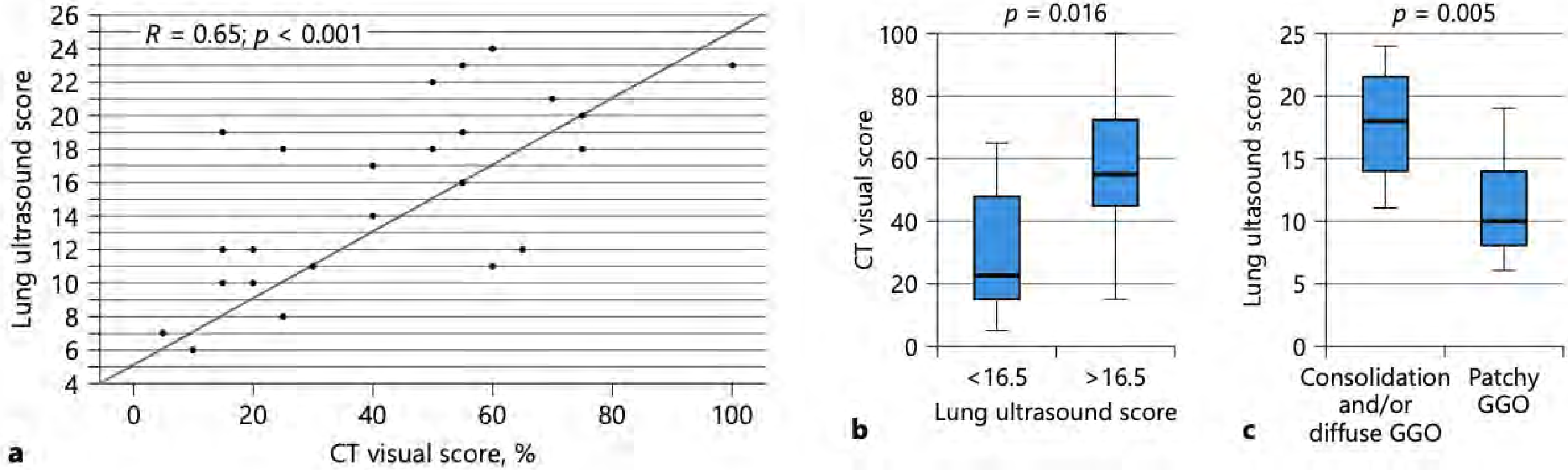
TABLE 1: Lung Ultrasound (US) Findings in Patients Classified by Duration of Symptoms

Lung US Finding	Early (*n* = 9)	Intermediate (*n* = 9)	Late (*n* = 10)	Total (*n* = 28)
A-lines[a]	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
B-lines	9 (100.0)	9 (100.0)	10 (100.0)	28 (100.00)
Thickened pleural line	1 (11.1)	6 (66.7)	10 (100.0)	17 (60.7)
Pulmonary consolidation	6 (66.7)	6 (66.7)	7 (70.0)	19 (67.9)
Pleural effusion	1 (11.1)	0 (0.0)	0 (0.0)	1 (3.6)

Note—The duration of symptoms from initial onset to lung US was classified as early (< 20 days), intermediate (20–30 days), or late (> 30 days). Data are reported as number (%) of patients.
[a]Only A-lines were visualized.

Zhang et al. AJR 2020

Lung Ultrasound



A. Nouvenne, et al. Respiration 2020

COVID-19: Cardiac Imaging

What's the excitement?

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FOX5 NEW YORK
News Weather Good Day Contests

PHYSICIAN'S WEE
Home Specialties Doctor's Voice Meeting Coverage Co

Heart Failure, Cardiac Injury May be Next in Covid-19

Jul 31, 2020

REUTERS | Reuters

New heart problems discovered post COVID-19; virus mutation may make vaccines more effective

Nancy Lapid
28 July 2020 · 5-min read

CNN

on the hear
the plot thickening'

By Jacqueline Howard, CNN
Updated 0045 GMT (0845 HKT) July 29, 2020

Newsweek

Business Tech & Science Culture Newsgeek Sports Health The Debate

NEWS

Most Recovered COVID-19 Patients Left With Heart Damage, Study Shows

BY KATHERINE FUNG ON 7/29/20 AT 5:23 PM EDT

CMR in COVID-19

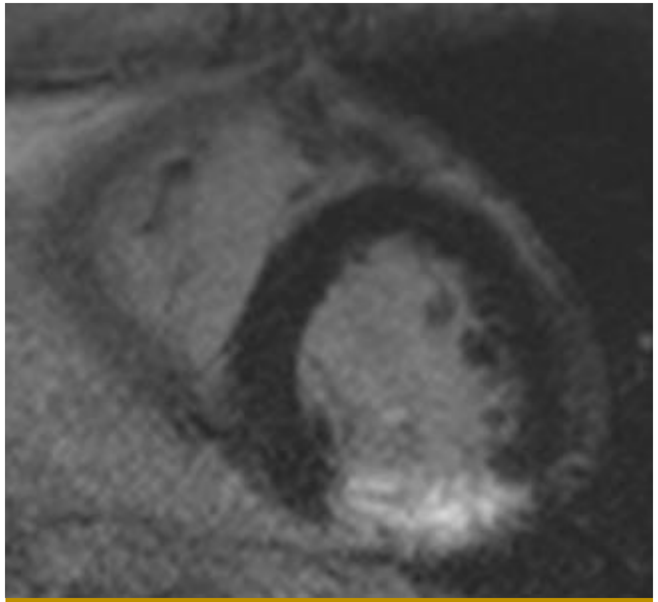
JAMA Cardiology | Original Investigation

Outcomes of Cardiovascular Magnetic Resonance Imaging in Patients Recently Recovered From Coronavirus Disease 2019 (COVID-19)

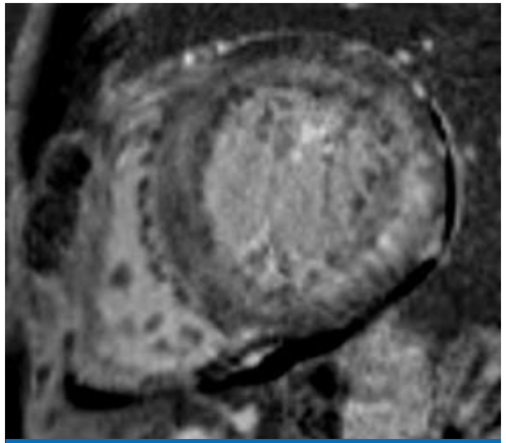
Valentina O. Puntmann, MD, PhD; M. Ludovica Carerj, MD; Imke Wieters, MD; Masia Fahim; Christophe Arendt, MD; Jedrzej Hoffmann, MD; Anastasia Shchendrygina, MD, PhD; Felicitas Escher, MD; Mariuca Vasa-Nicotera, MD; Andreas M. Zeiher, MD; Maria Vehreschild, MD; Eike Nagel, MD

tricular ejection fraction, higher left ventricle volume and mass, and raised native T1 and T2 measures. A total of 78 patients recently recovered from COVID-19 had abnormal CMR findings, including raised myocardial native T1 (n = 73),[21] raised myocardial native T2 (n = 60),[22] myocardial LGE (n = 32), and pericardial enhancement (n = 22) (Figure 1). A total of 12 pa-

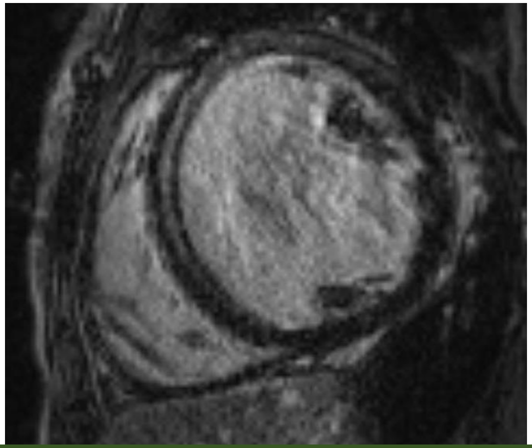
What is LGE?



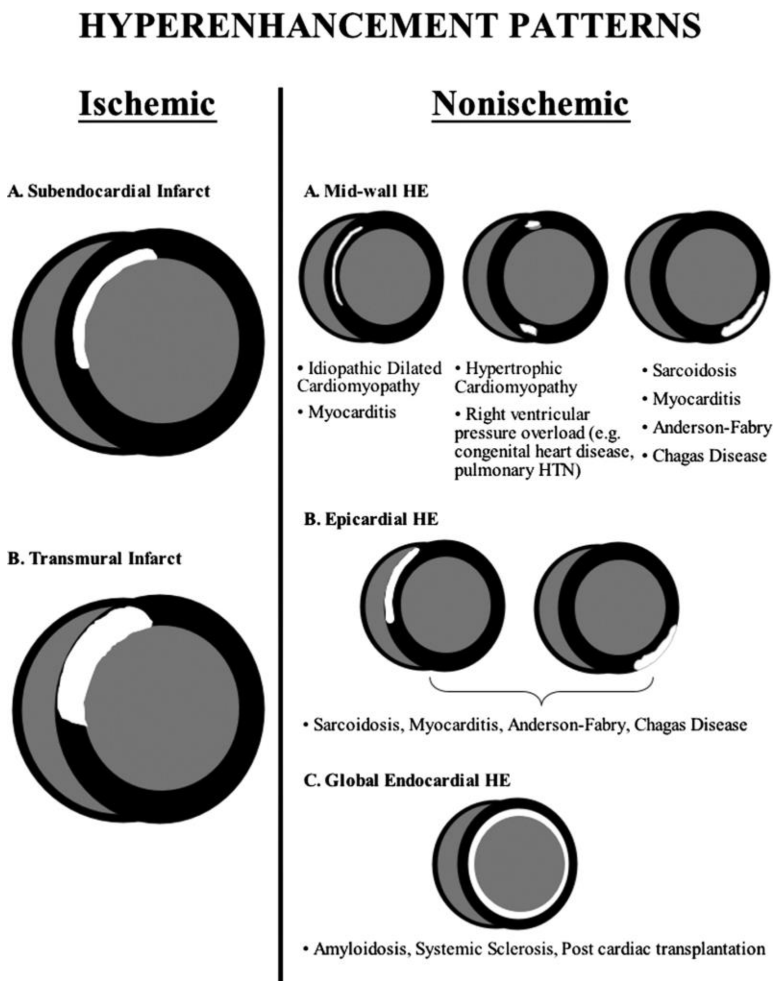
Infarct



Amyloidosis



Dilated Cardiomyopathy



Mahrholdt, H., et al. (2005). European Heart Journal

What is T1 and T2 Mapping?

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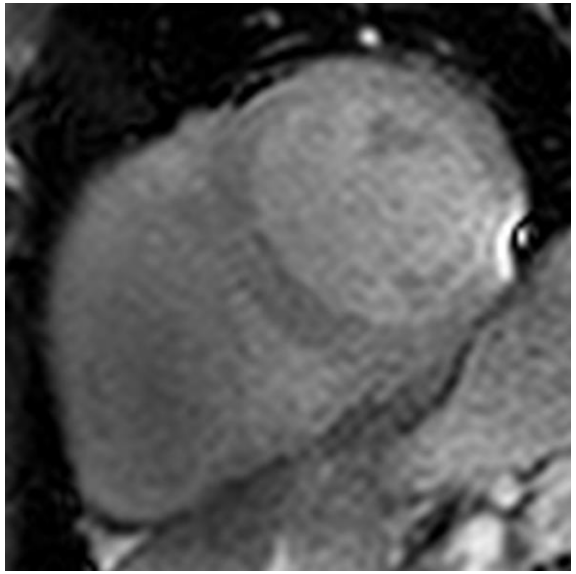
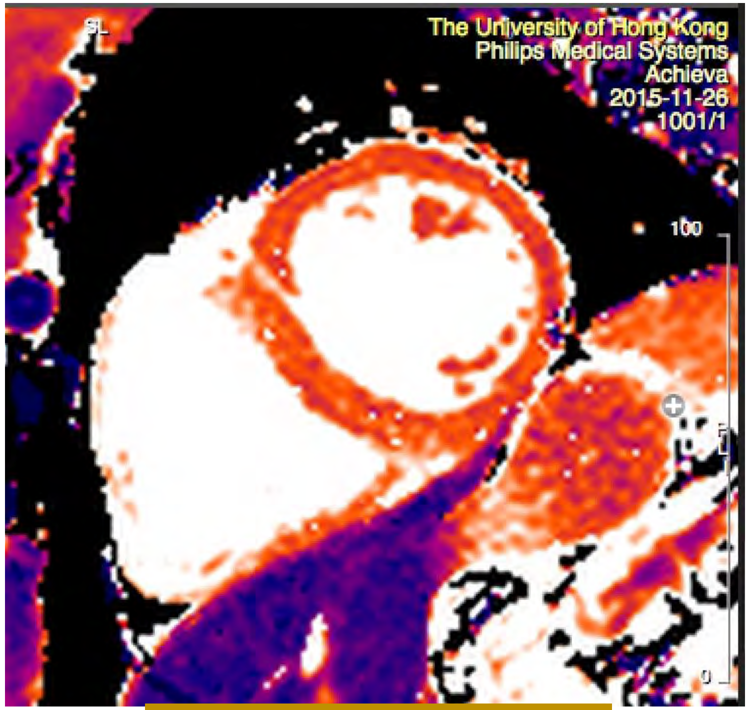


Multiple TI images acquired at different times



T1 Map

T1 Mapping

- Two types – native T1 and extracellular volume
- Native T1 quantifies tissue characteristics
- Does not rely on subjective interpretation
- Infers presence of **fibrosis, oedema and/ or infiltration**

T2 Mapping

- Quantifies T2 values and not subjective
- Measures **water/ oedema**

CMR in COVID-19

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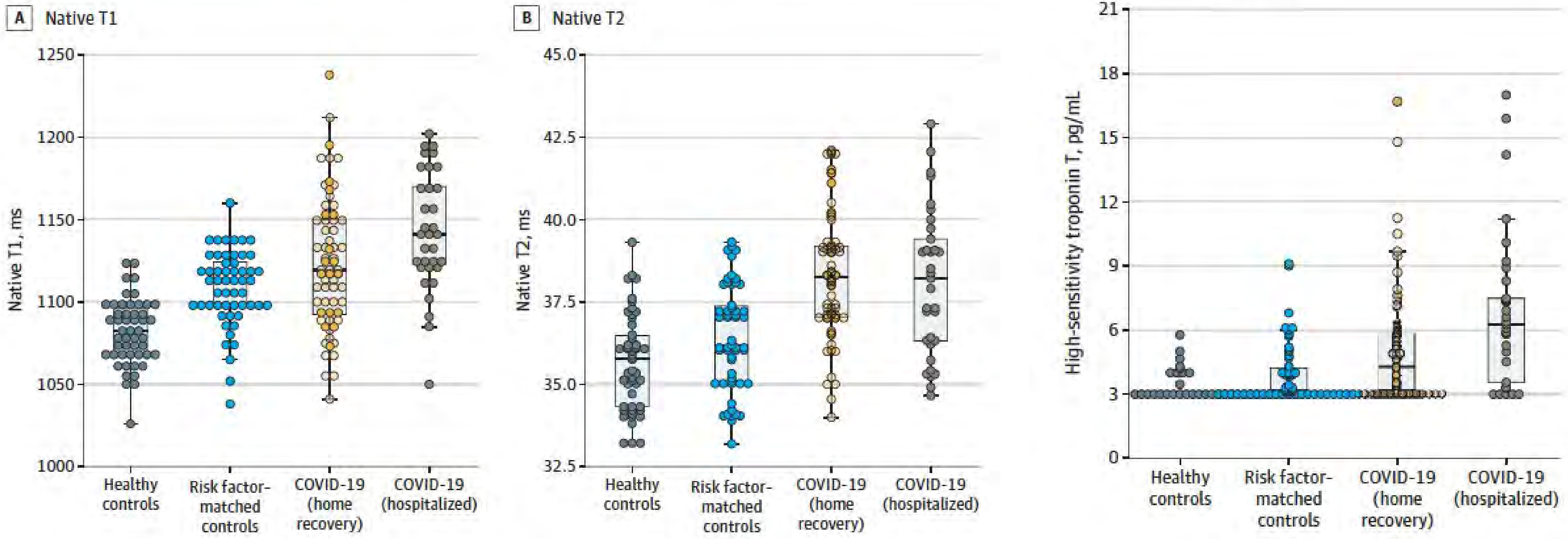
Figure 2. Scatterplots of Native T1, Native T2, and High-Sensitivity Troponin T Measures by Group



V Puntmann, et al. JAMA Cardiology 2020

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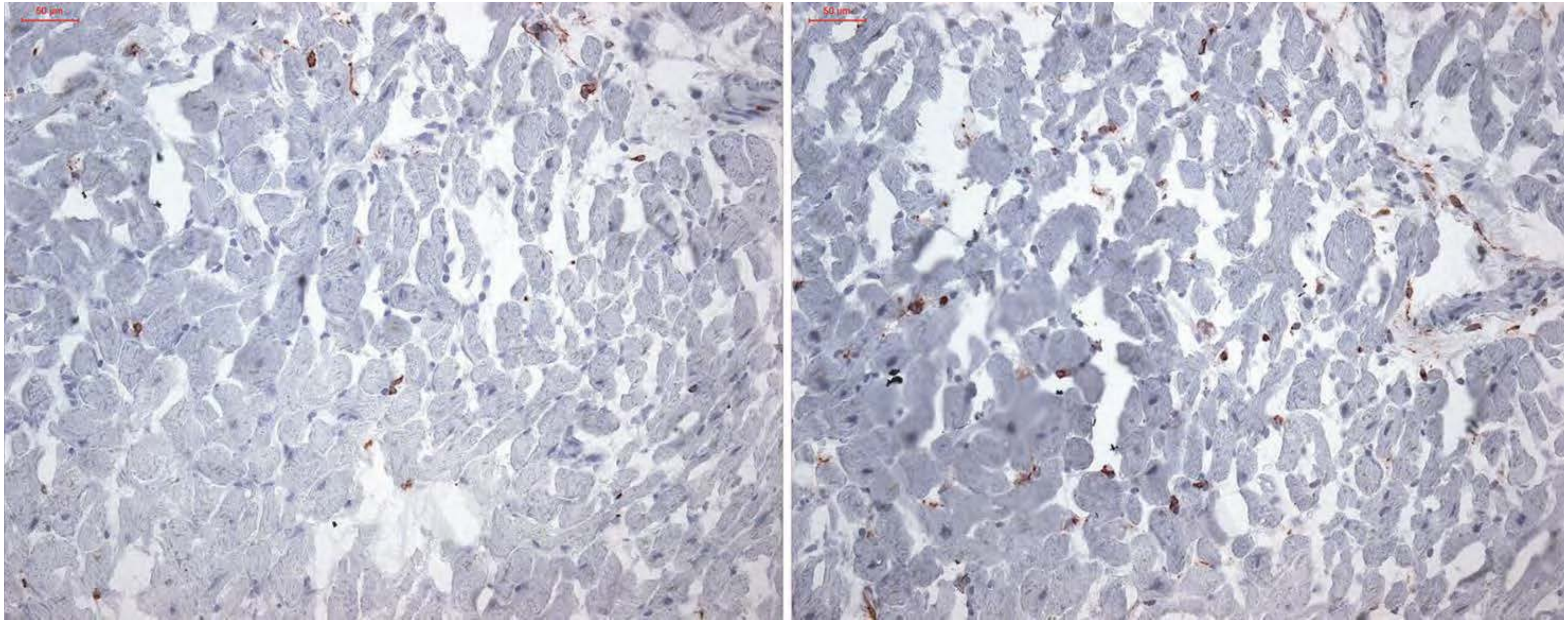

Intracellular oedema and acute lymphocytic infiltration was present

V Puntmann, et al. JAMA Cardiology 2020

Corrections

Comment & Response

FREE

August 25, 2020

Errors in Statistical Numbers and Data in Study of Cardiovascular Magnetic Resonance Imaging in Patients Recently Recovered From COVID-19

Eike Nagel, MD[1]; Valentina O. Puntmann, MD, PhD[1]

» Author Affiliations | Article Information

JAMA Cardiol. 2020;5(11):1307-1308. doi:10.1001/jamacardio.2020.4661

CMR in COVID-19 – 1st Paper

TABLE 2 Left and Right Ventricular Cardiac CMR Parameters of Patients Recovered From COVID-19 and Controls

	Conventional CMR Findings						
	Positive (n = 15)	Negative (n = 11)	Controls (n = 20)	Adjusted p Value†	Adjusted p Value‡	Adjusted p Value§	p Value*
Age (yrs)	39 (29-49)	37 (34-39)	40 (29-50)	0.83	0.99	0.69	0.78
Male	4 (27)	6 (55)	7 (35)	0.30	0.50	0.88	0.34
CMR parameters							
Left ventricle							
EF (%)	60.7 ± 6.4	64.3 ± 5.8	63.0 ± 8.9	0.30	0.65	0.86	0.40
EF<50%	1 (7)	0 (0)	0 (0)	NA	NA	NA	NA
EDV (ml)	71.6 (61.4-86.4)	78.2 (64.0-92.1)	86.1 (70.8-92.8)	0.59	0.30	0.91	0.31
ESV (ml)	28.7 ± 8.6	28.2 ± 7.9	30.3 ± 10.3	0.98	0.89	0.81	0.80
SV (ml)	43.5 ± 8.0	49.9 ± 8.7	50.2 ± 12.1	0.16	0.13	>0.99	0.10
CO (l/min)	3.0 (2.6-3.7)	3.7 (3.5-4.5)	3.5 (2.8-4.3)	0.05	0.88	0.32	0.05
Myo mass (g)	57.1 ± 12.4	69.1 ± 17.2	63.9 ± 14.7	0.15	0.31	0.68	0.14
EDV/BSA (ml/m^2)	43.9 ± 10.7	44.1 ± 6.7	47.3 ± 10.1	>0.99	>0.99	0.93	0.49
ESV/BSA (ml/m^2)	17.5 ± 5.6	15.9 ± 4.1	18.0 ± 6.8	0.68	0.96	0.52	0.58
SV/BSA (ml/m^2)	26.4 ± 6.2	28.2 ± 4.0	29.3 ± 5.5	0.64	0.34	0.81	0.29
CI (l/min/m^2)	1.9 ± 0.5	2.3 ± 0.4	2.0 ± 0.5	0.15	0.84	0.30	0.19
Myo mass/BSA (g/m^2)	34.3 ± 7.1	38.7 ± 6.6	37.4 ± 7.1	0.26	0.41	0.87	0.24
Global T1 (ms)	1,271 (1,243-1,298)	1,237 (1,216-1,262)	1,224 (1,217-1,245)	**0.03**	**0.002**	>0.99	**0.002**
Global T2 (ms)	42.7 ± 3.1	38.1 ± 2.4	39.1 ± 3.1	**<0.001**	**0.005**	0.57	**<0.001**
Global ECV (%)	28.2 (24.8-36.2)	24.8 (23.1-25.4)	23.7 (22.2-25.2)	0.12	**0.001**	0.84	**0.002**

Huang, et al. JACC Imaging 2020

CMR & Athletes with COVID-19

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Table. Demographic Features and Echocardiographic and Cardiovascular Magnetic Resonance Parameters in Competitive Athletes Recovering From Coronavirus Disease 2019[a]

Athlete No.	Sex	Symptoms	Time CMR performed after positive test result, d	Echocardiography, mL/m²		CMR, %		Native T1, ms	ECV, %	Maximal T2, ms, (AHA segments)	LGE (pattern/AHA segments)	CMR (updated Lake Louise Criteria)
				LVEDV	RVEDV	LVEF	RVEF					
1	Male	No	21	Not done	Not done	60	49	1034	21	51 (9)	Yes (RV insertion; 9)	Normal
2	Male	No	22	51	46	56	59	964	24	48 (9)	Yes (patchy; 6, 8)	Normal
3	Male	No	22	65	60	60	64	953	22	48 (10)	Yes (patchy, 5)	Normal
4	Male	No	15	65	48	59	54	905	20	48 (9)	Yes (linear; 8, 12)	Normal
5	Male	No	17	66	57	55	54	994	24	55 (9)	Yes (epicardial; 3, 9)	Myocarditis
6	Male	Yes	23	73	52	61	62	947	26	63 (3, 9)	Yes (patchy; 3, 9)	Myocarditis
7	Male	Yes	53	66	64	53	52	991	25	49 (7, 9)	Yes (linear, patchy; 8, 9, 12)	Normal
8	Male	No	20	76	36	56	53	963	17	51 (10)	No	Normal
9	Male	Yes	18	60	71	56	52	964	24	52 (7)	Yes (patchy; 3, 9)	Normal
10	Male	Yes	11	67	70	61	58	929	25	58 (8, 9)	Yes (patchy; 2, 3, 8, 9)	Myocarditis
11	Male	No	23	57	49	63	60	987	22	53 (7)	No	Normal
12	Male	Yes	28	72	59	50	53	966	28	53 (7, 8)	No	Normal
13	Male	No	28	81	52	33	53	925	25	53 (7, 8)	No	Normal
14	Male	No	11	46	41	65	54	989	24	53 (8)	No	Normal
15	Male	No	48	56	51	59	57	1003	25	53 (7)	Yes (RV insertion; 9)	Normal
16	Female	Yes	23	68	50	64	58	1001	26	52 (8)	No	Normal
17	Female	Yes	23	55	56	57	60	1030	28	48 (10)	No	Normal
18	Female	No	21	53	35	65	66	1008	25	48 (9)	No	Normal
19	Female	Yes	17	60	32	63	57	978	26	53 (8)	No	Normal
20	Female	No	31	62	51	58	59	1002	25	52 (8)	No	Normal
21	Female	Yes	31	52	40	60	60	946	28	53 (8)	No	Normal
22	Female	Yes	30	67	49	59	64	1000	27	52 (8)	Yes (linear; 12)	Normal
23	Female	Yes	30	58	57	57	55	964	26	53 (11)	No	Normal
24	Female	Yes	26	52	49	55	57	1010	30	53 (10)	No	Normal
25	Female	No	31	56	36	56	56	1027	28	50 (7)	No	Normal
26	Male	No	12	80	44	60	53	969	21	61 (8)	Yes (linear; 8, 9)	Myocarditis

Abbreviations: AHA, American Heart Association; CMR, cardiovascular magnetic resonance imaging; ECV, extracellular volume fraction; EDV, end-diastolic volume; EF, ejection fraction; LGE, late gadolinium enhancement; LV, left ventricular; RV, right ventricular.

[a] Symptoms refer to symptoms during short-term infection. Echo volumes were calculated by 3-dimensional method. Cardiovascular magnetic resonance imaging–derived left and right ventricular volumes and function were measured from contiguous short-axis cine images using semiautomated software for endocardial segmentation using endocardial and epicardial contours at end systole and end diastole per standard protocol. Cardiovascular magnetic resonance imaging–derived myocardial T1 and T2 mapping and ECV were done per standard guidelines. Mean (SD) native T1 less than 999 (31) milliseconds, native T2 of less than 53 milliseconds, and ECV of less than 29% were considered normal per institutional protocol based on phantom and human volunteer experiments. T2 and LGE were only considered significant if seen in 2 orthogonal planes.

JACC STATE-OF-THE-ART REVIEW

Cardiovascular Magnetic Resonance in Nonischemic Myocardial Inflammation

Expert Recommendations

Vanessa M. Ferreira, MD, DPhil,[a] Jeanette Schulz-Menger, MD,[b] Godtfred Holmvang, MD,[c] Christopher M. Kramer, MD,[d] Iacopo Carbone, MD,[e] Udo Sechtem, MD,[f] Ingrid Kindermann, MD,[g] Matthias Gutberlet, MD,[h] Leslie T. Cooper, MD,[i] Peter Liu, MD,[j] Matthias G. Friedrich, MD[k,l,m]

Rajpal, et al. JAMA Cardiology 2020

CMR in COVID-19

HKU Med LKS Faculty of Medicine Department of Diagnostic Radiology 香港大學放射診斷學系

JACC: Cardiovascular Imaging
August 2020
DOI: 10.1016/j.jcmg.2020.08.012

PDF Article

LETTERS TO THE EDITOR

Just Accepted

Recovered COVID-19 Patients Show Ongoing Subclinical Myocarditis as Revealed by Cardiac Magnetic Resonance Imaging

Ming-Yen Ng, Vanessa M. Ferreira, Siu Ting Leung, Jonan Chun Yin Lee, Ambrose Ho-Tung Fong, Raymond Wai To Liu, Johnny Wai Man Chan, Ka Lun Alan Wu, Kwok-Cheung Lung, Andrew M. Crean, Ivan Fan-Ngai Hung and Chung-Wah SIU

CMR in COVID-19

- Preliminary reports had indicated that a number of patients had elevated troponin during COVID-19 infection

- Study Aim:
  - To use CMR assess for evidence of myocardial involvement or ongoing myocarditis in patients who have recovered from COVID-19

- Inclusion Criteria:
  - Recovered COVID-19 patients with ↑ troponin or ECG changes during the acute illness.
- Exclusion Criteria:
  - Poor quality images which prevented ventricular function assessment or assessment of the LGE images.

- Images were assessed by 3 radiologists

MY Ng, et al. JACC Cardiovascular Imaging 2020

CMR in COVID-19

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Patients (n=16)	Symptoms at Follow-up	Reason for CMR Referral		Global Native T1 (ms)	Global Native T2 (ms)	LGE	Elevated Blood Biomarkers at Follow-up		
		ECG Changes	Troponin T Rise				Troponin	WBC	CRP
1	Nil	ST-elevation & sinus bradycardia	Yes	1183	40.7	Present†	Yes	No	No
2	Chest discomfort	1st degree AV block; Flatten T-wave I + v6	No	1258*	57.4**	Present	No	No	Yes
3	Nil	T-wave abnormalities	Yes	1220*	61.5**	Present	Yes	No	No
4	Nil	Inferior & anterior T wave abnormality	No	1257*	57.8**	Present	No	No	No
5	SOB & Cough	Anterior T wave abnormality	No	1212*	55**	Absent	No	No	No
6	Nil	Inferior/Lateral T-wave inversion	No	1149	76.3**	Absent	No	No	No
7	Nil	Anterolateral T wave abnormality	No	1259*	50.7	Absent	No	No	Yes
8	Cough	Anterior T-wave abnormality	No	1217*	52.7	Absent	No	No	Yes
9	Nil	Anterior T wave abnormality	No	1218*	49	Absent	No	Yes	No
10	SOB & Chest discomfort	Nil	Yes	1210*	49.8	Absent	No	No	Yes
11	Nil	New AF	Yes	1204	53.4	Absent	No	No	Yes
12	Nil	Anterior ST-elevation	Yes	1179	50	Absent	Yes	No	No
13	Nil	Sinus Bradycardia	Yes	1102	51.8	Absent	Yes	No	No
14	Nil	Anterior T wave abnormality	No	1207	52.6	Absent	No	No	No
15	SOB	Anterior T-wave inversion	No	1121	47.8	Absent	No	No	No
16	Nil	Nil	Yes	1110	51.4	Absent	No	No	No

AF = Atrial fibrillation; AV = Atrioventricular; CRP = C-reactive protein; LGE = Late gadolinium enhancement; SOB= Shortness of breath; Trop = Troponin; WBC = White blood cell count

*= Elevated native T1 (>1208 ms)
**= Elevated native T2 (>54.8 ms)
†= Patient with infarction likely due to previous NSTEMI

MY Ng, et al. JACC Cardiovascular Imaging 2020

CMR in COVID-19

- 69% (11 of 16) of recovered patients were asymptomatic
- 56% (9 of 16) had abnormal CMR findings
- In asymptomatic patients, 45% (5 of 11) had abnormal CMR findings
  - 27% (3 of 11) of asymptomatic patients had serological evidence of inflammation
- In symptomatic patients, 80% (4 of 5) had abnormal CMR findings
  - 75% (3 of 4) had corroborating serological evidence of ongoing inflammation.
- Overall, 6 of 16 (38%) patients had both imaging and serological evidence of myocardial inflammation

MY Ng, et al. JACC Cardiovascular Imaging 2020

CMR in COVID-19

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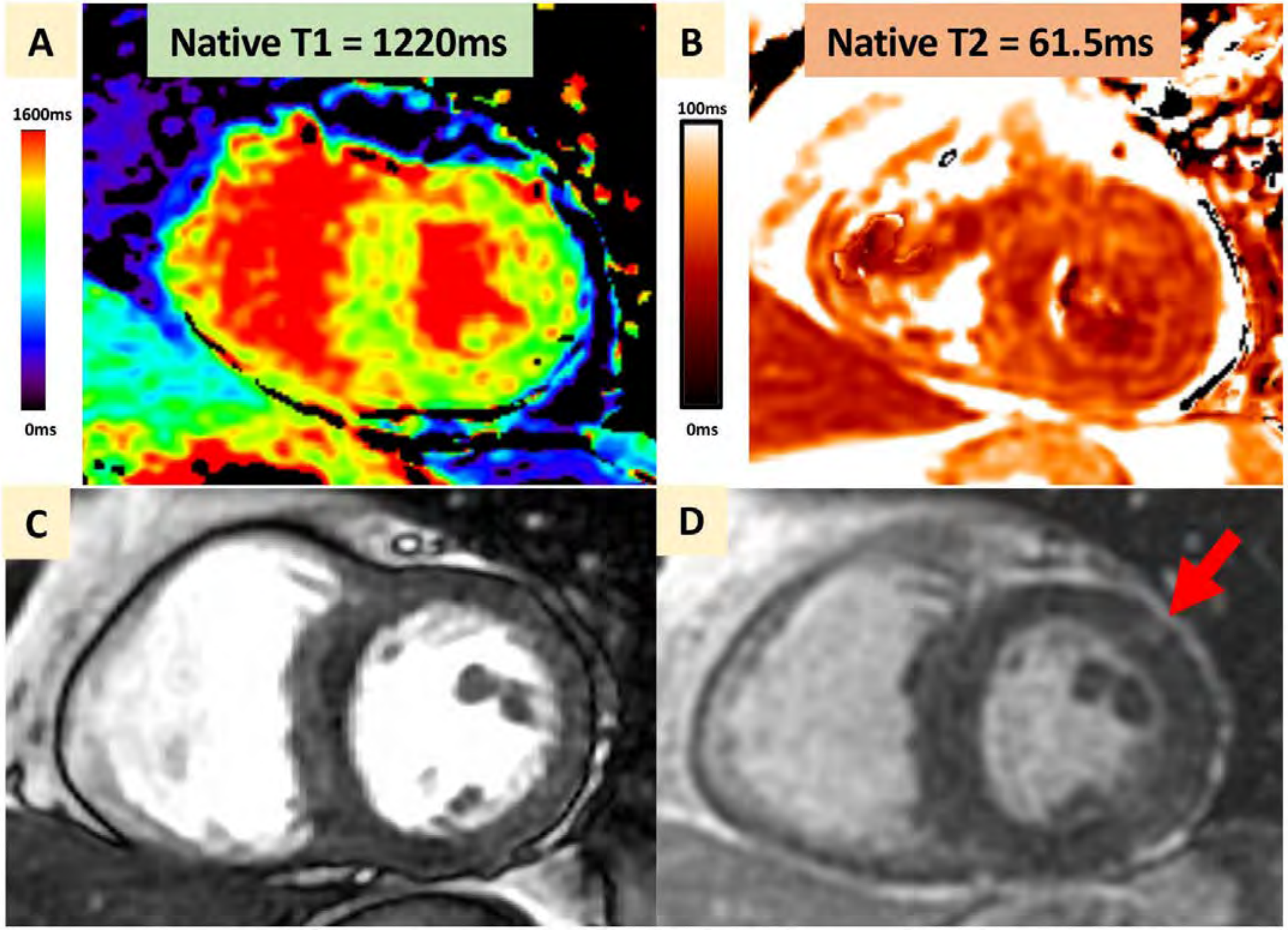

E

Cardiac Magnetic Resonance (CMR)	
LV End-Diastolic Volume Indexed (ml/m²)	79 (IQR: 70-84)
LV Ejection Fraction (%)	59 (IQR 56-65)
RV End-Diastolic Volume Indexed (ml/m²)	88 (IQR 76-94)¶
RV Ejection Fraction (%)	53 (IQR 48-57)
Global mid-ventricular native T1 (ms)	1209 (IQR 1164-1219)#
Global mid-ventricular native T2 (ms)	52 (IQR 50-56)##
High global native T1 only (>1208 ms) (n, % cases)	4 (25%)
High global native T2 only (>54.8 ms) (n, % cases)	1 (5%)
High native T1 and T2 (n, % cases)	4 (25%)

Notes:

IQR= Interquartile range; LV= Left ventricle; RV = Right ventricle

¶=One patient had borderline dilated right ventricle and dilated main pulmonary artery (37mm), with no initial suspicion of pulmonary embolus, and a VQ scan post-CMR was normal.

#p<0.02 when compared to 15 healthy volunteers with a mean T1 of 1158±25ms (2SD range 1109 - 1208 ms)

##p<0.01 when compared to 15 healthy volunteers with a mean T2 of 48.2±3.4ms (2SD range 41.5 - 54.8 ms)

MY Ng, et al. JACC Cardiovascular Imaging 2020

CMR & Children with MSIS

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4 patients, CMR done after intravenous immunoglobulin therapy

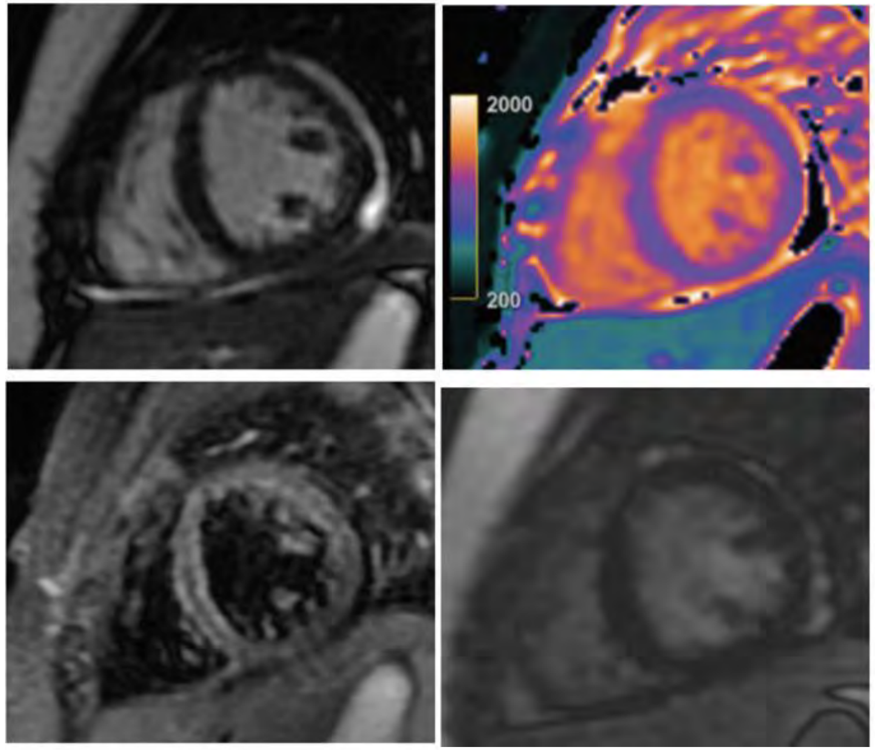

Table 2: Cardiac MRI Findings in Patients with Myocarditis Related to COVID-19 Infection

Finding	Reference Values	Patient 1	Patient 2	Patient 3	Patient 4
LV diameter (mm)	...	39	53	54	43
LV thickness (mm)	...	7.5	6.8	8.8	5.0
Dyskinesis or hypokinesis	...	No	No	No	No
LV EF (%)	...	68	51	56	52
LV EDV index (mL/m²)	...	51	93	74	83
LV ESV index (mL/m²)	...	16	45	32	40
Mass index (g/m²)	...	44	58	54	50
RV EF (%)	...	63	53	57	55
RV EDV index (mL/m²)	...	60	87	70	57
RVESV index (mL/m²)	...	22	41	30	26
Ratio T2 myocardium/muscle	<2	1.1	2.2	2.4	2.4
Myocardial T2 (msec)	46–50	47	N/A	N/A	62
Myocardial native T1 (msec)	950–1058	1050	1112	1124	1169
LGE present	...	NA	No	No	No
Pericardial effusion	...	No	Yes	Yes	Yes

Note.— COVID-19 = coronavirus disease 2019, EDV = end-diastolic volume, EF = ejection fraction, ESV = end-systolic volume, LGE = late gadolinium enhancement, LV = left ventricle, NA = not available, RV = right ventricle.

3 out of 4 patients had diffuse high T2 abnormalities and elevated native T1

Blondiaux, et al. Radiology 2020

CMR & Children with MSIS

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Contents lists available at ScienceDirect

Clinical Microbiology and Infection

ELSEVIER

journal homepage: www.clinicalmicrobiologyandinfection.com

Letter to the Editor

Cardiovascular magnetic resonance imaging in children with pediatric inflammatory multisystem syndrome temporally associated with SARS-CoV-2 and heart dysfunction

Luis M. Prieto [1, 2, 3, 4, *], Belén Toral [5], Ana LLorente [6], David Coca [7], Daniel Blázquez-Gamero [1, 2, 3, 4]

- All 5 children did **<u>not</u>** show any signs of myocardial oedema or LGE
- T1 & T2 mapping was **not** performed

SCMR Guidelines for COVID-19

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STUDY PROTOCOL Open Access

Society for Cardiovascular Magnetic Resonance (SCMR) recommended CMR protocols for scanning patients with active or convalescent phase COVID-19 infection

Sebastian Kelle[1,2*], Chiara Bucciarelli-Ducci[3], Robert M. Judd[4], Raymond Y. Kwong[5], Orlando Simonetti[6], Sven Plein[7], Francesca Raimondi[8], Jonathan W. Weinsaft[9], Timothy C. Wong[10] and James Carr[11]

Conclusion:

According to the **clinical indication**, standard or rapid protocols should be used for COVID-19 patients. Especially short and dedicated CMR examinations that focus on the **evaluation of cardiac morphology and function, as well as myocardial tissue characterization** are recommended.

Summary of CMR Data

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- CMR examination should be performed based on clinical need

- More research needs to be done to determine if the findings are significant
  - Long term follow-up
  - Comparison with CMR findings in other respiratory viral illnesses

Cardiac CT Use in COVID-19

SCCT Guidelines

ELSEVIER

Contents lists available at ScienceDirect

Journal of Cardiovascular Computed Tomography

journal homepage: www.JournalofCardiovascularCT.com

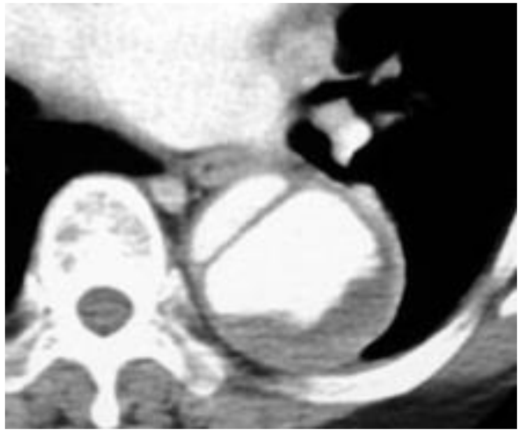
Review article

Use of cardiac CT amidst the COVID-19 pandemic and beyond: North American perspective

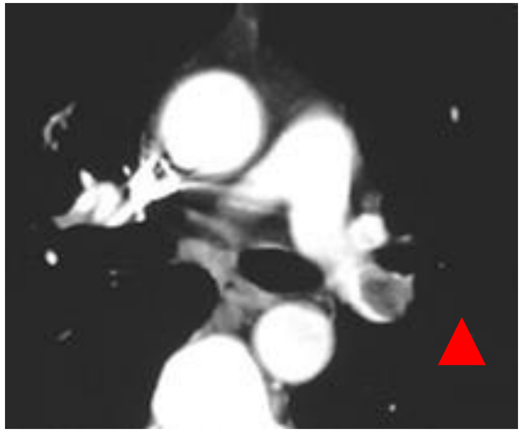
Vasvi Singh[a, b], Andrew D. Choi[c], Jonathon Leipsic[d], Ayaz Aghayev[a], James P. Earls[c], Philipp Blanke[d], Michael Steigner[a], Leslee J. Shaw Phd[e], Marcelo F. Di Carli[a, b], Todd C. Villines[f], Ron Blankstein[a, b, *]

Role of Cardiac CT – Chest Pain

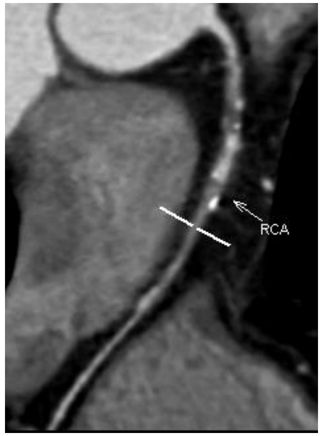
- Cardiac CT has been increasingly used for assessment of patients with acute chest pain rather than invasive catheter coronary angiography
- Triple rule-out CT scan…. became quintuple rule-out



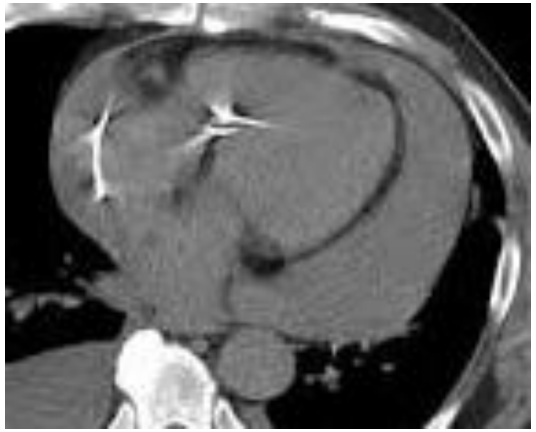
Aortic Dissection



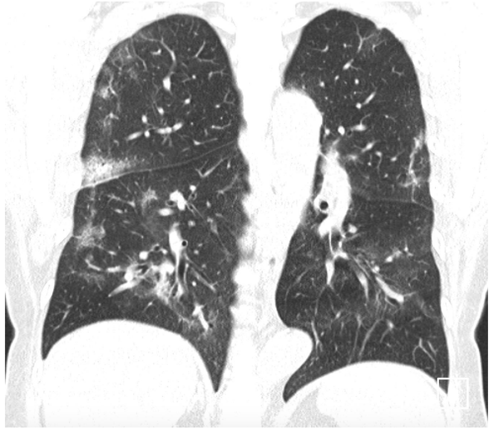
Pulmonary embolus



Coronary Disease



Pericardial effusion



COVID Pneumonia

SCAI Recommendations

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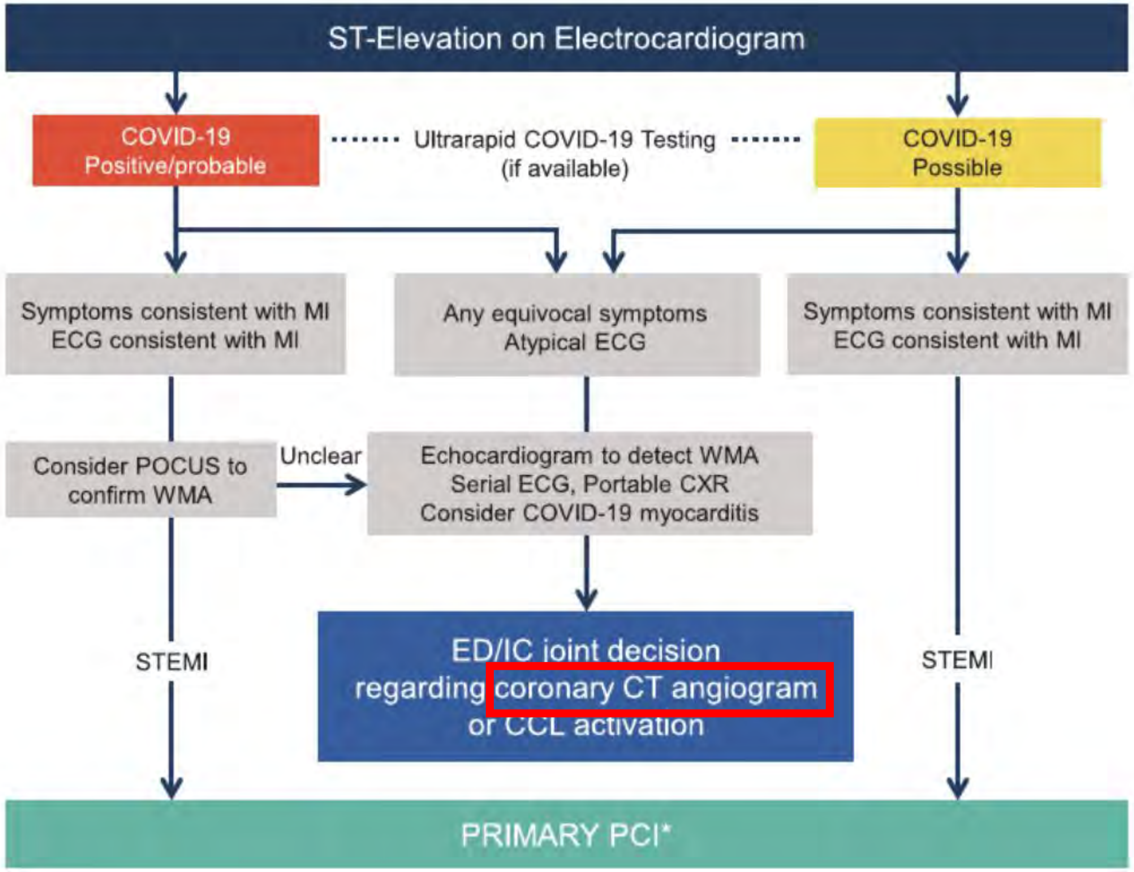
SCAI
Society for Cardiovascular Angiography & Interventions



Mahmud, et al. Catheter Cardiovasc Intervention 2020

Role of Cardiac CT – LA Appendage

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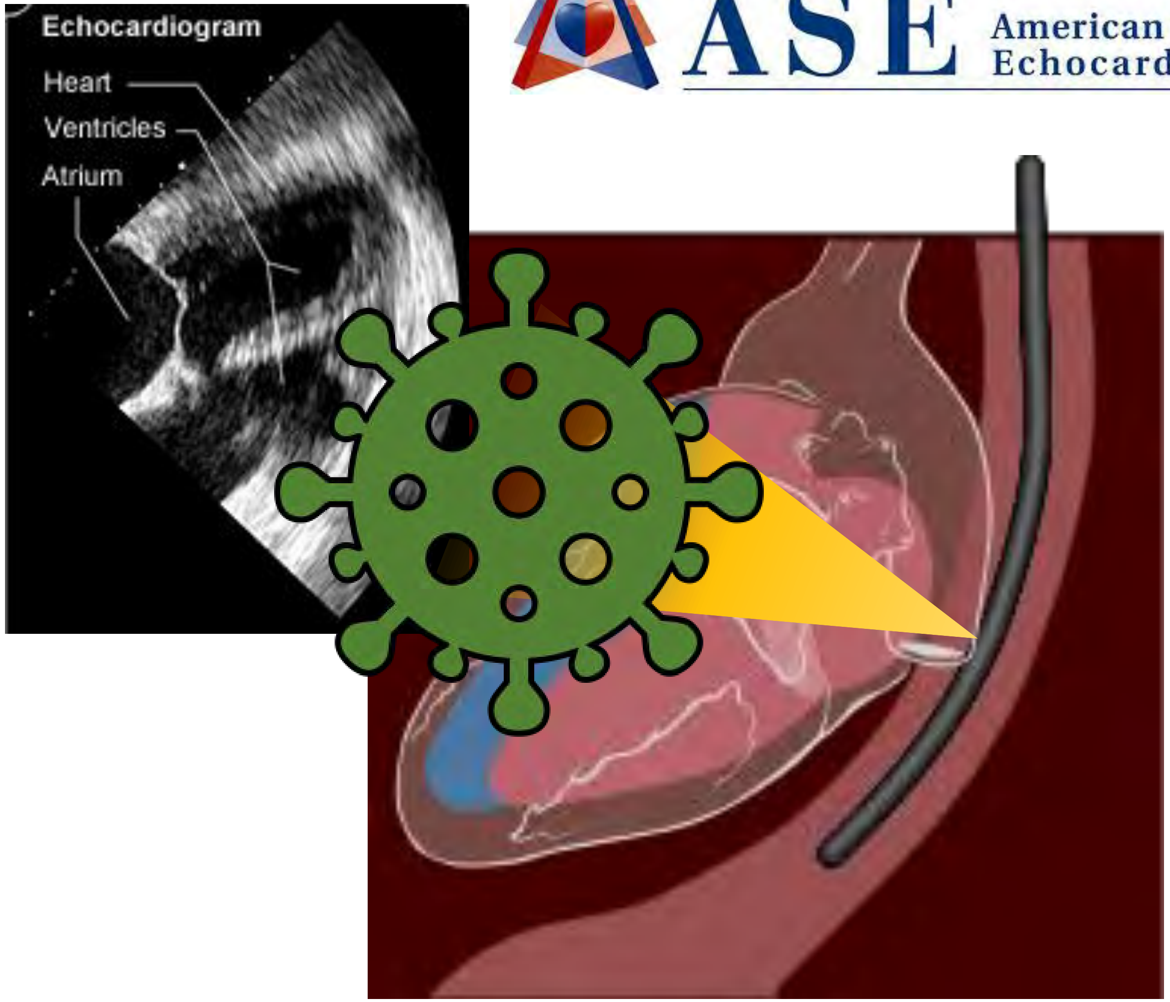
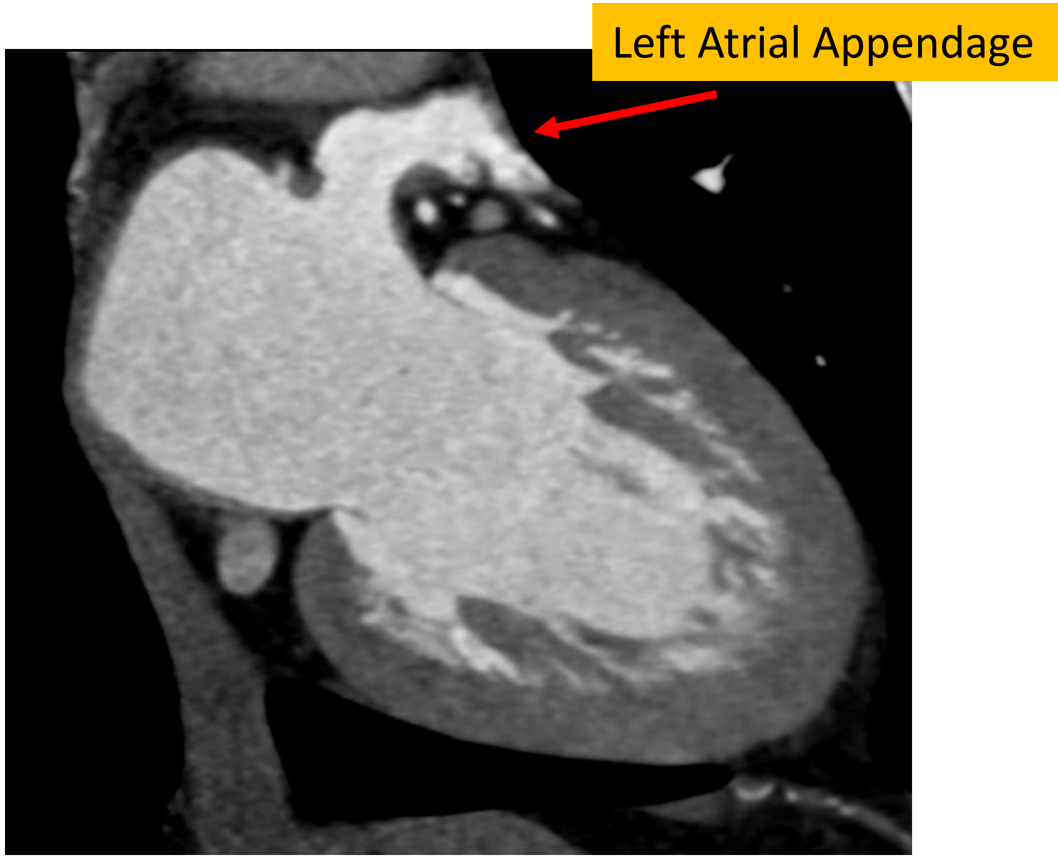
ASE American Society of Echocardiography





Kirkpatrick, et al. JASE 2020

Prediction Models

COVID-19 Prediction Model

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INTERNATIONAL JOURNAL OF INFECTIOUS DISEASES

INTERNATIONAL SOCIETY FOR INFECTIOUS DISEASES

FULL LENGTH ARTICLE | ARTICLES IN PRESS

PDF [2 MB]

Development and Validation of Risk Prediction Models for COVID-19 Positivity in a Hospital Setting

Ming-Yen Ng [1] • Eric Yuk Fai Wan [1] • Ho Yuen Frank Wong • ... Chak Sing Lau • Michael D. Kuo • Mary Sau-Man Ip • Show all authors • Show footnotes

Open Access • Published: September 15, 2020 • DOI: https://doi.org/10.1016/j.ijid.2020.09.022

COVID-19 Prediction Model

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- RT-PCR is the standard for confirming COVID-19 in patients

- Some countries did not have easy access to RT-PCR or results could not be provided rapidly

MY Ng, et al. International Journal of Infectious Diseases 2020

Lack of RT-PCR... and more!

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THE LANCET
Respiratory Medicine

CORRESPONDENCE | VOLUME 8, ISSUE 4, E22, APRIL 01, 2020

Adoption of COVID-19 triage strategies for low-income settings

Rodgers R Ayebare • Robert Flick • Solome Okware • Bongomin Bodo • Mohammed Lamorde

Published: March 11, 2020 • DOI: https://doi.org/10.1016/S2213-2600(20)30114-4

"This approach is simple and uses readily available technology. The most advanced tool required is a **thermometer**."

COVID-19 Prediction Model

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Department of Diagnostic Radiology
香港大學放射診斷學系

- **Study Aim:**
  - Develop two validated risk prediction models for COVID-19 positivity using readily available parameters in a general hospital setting
  - Develop nomograms and probabilities to allow clinical utilisation.

COVID-19 Prediction Model

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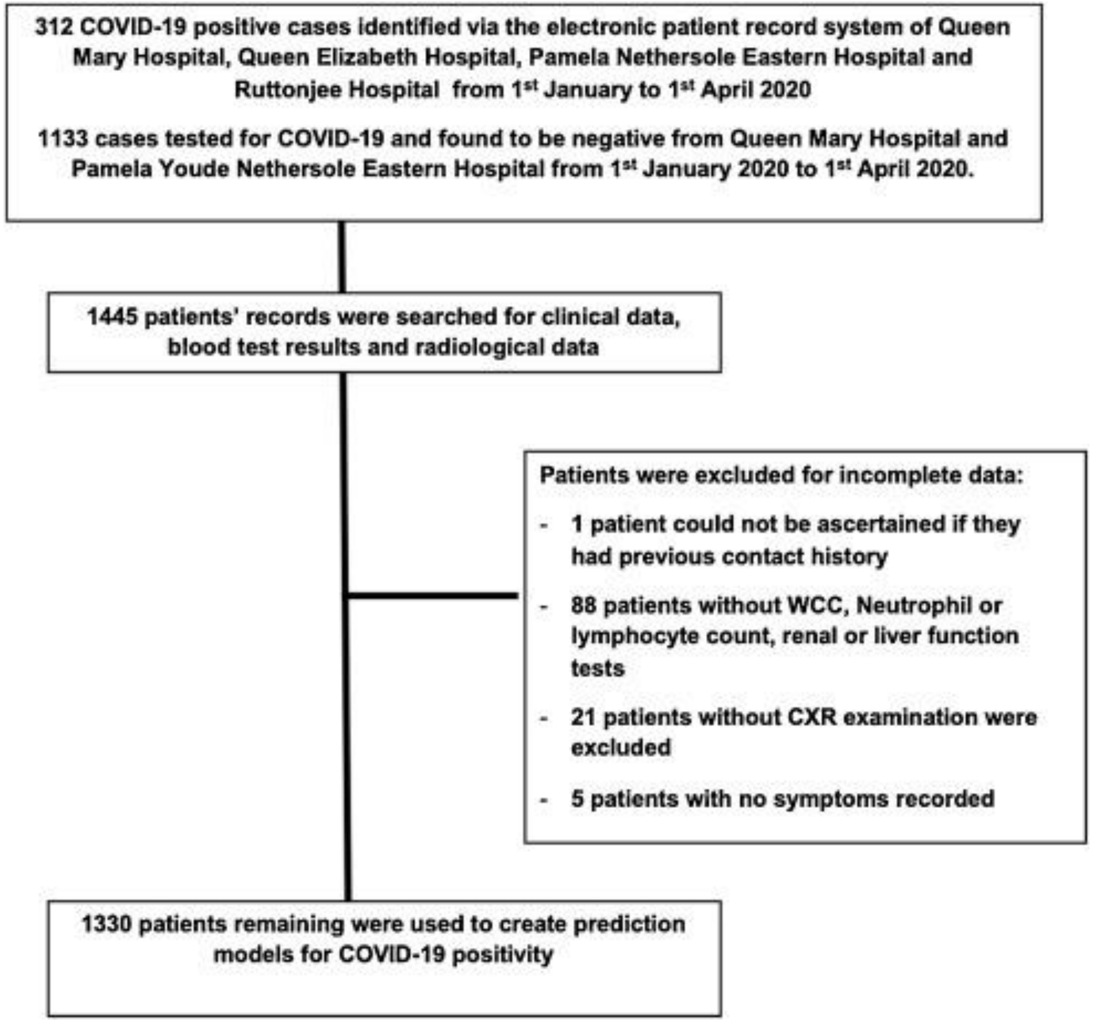

Obtained IRB approval across 4 HK hospitals

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CXR Assessment

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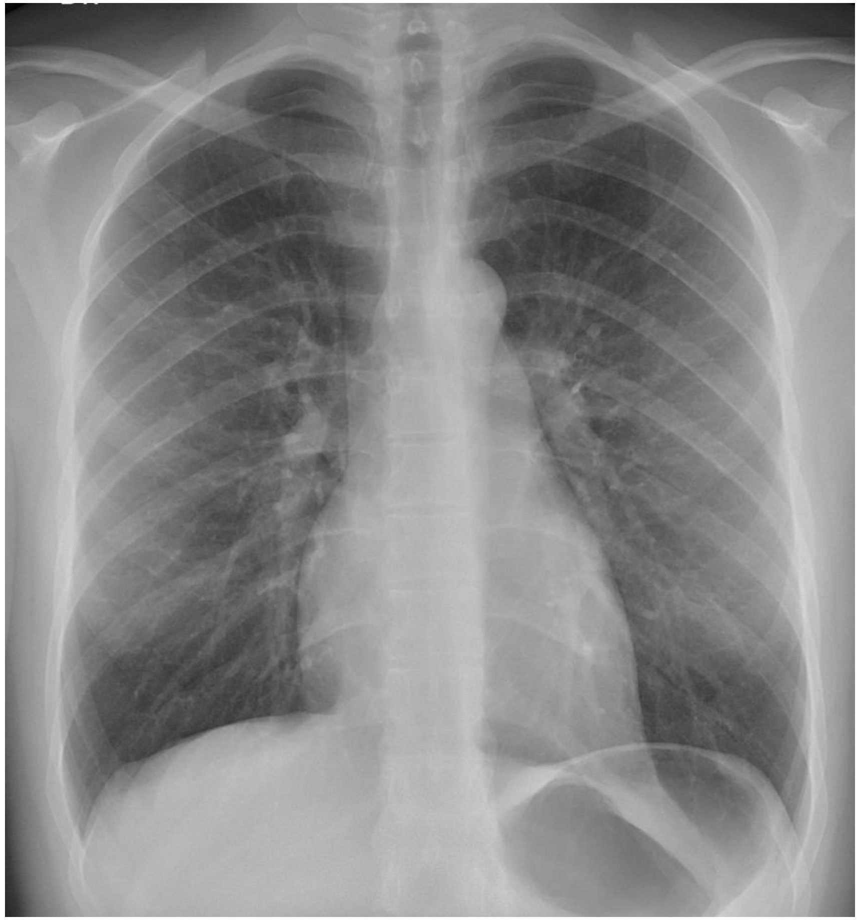
- Baseline CXR images were reviewed by radiologists blinded to patient's COVID-19 status.

- Binary assessment (present or absent) for:
  - Consolidation or ground glass opacity
  - Absence of pleural effusion



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COVID-19 Prediction Model

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Randomly split whole database 2:1

Model Development Database

N=893

COVID (n=212)

Validation Cohort

N=437

COVID (n=84)

- **Variables included in the models were:**
  - Sex
  - Age
  - Symptoms (ie. fever, cough, shortness of breath, vomiting and diarrhoea)
  - WCC
  - Neutrophil count
  - Lymphocyte count
  - Neutrophil: lymphocyte cell ratio
  - Albumin
  - Bilirubin
  - Alanine aminotransferase
  - Estimated glomerular filtration rate
  - CXR consolidation/ ground glass opacity (GGO)
  - CXR absence of pleural effusion
  - CXR combination of consolidation/GGO with absence of pleural effusion

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Calibration Plots

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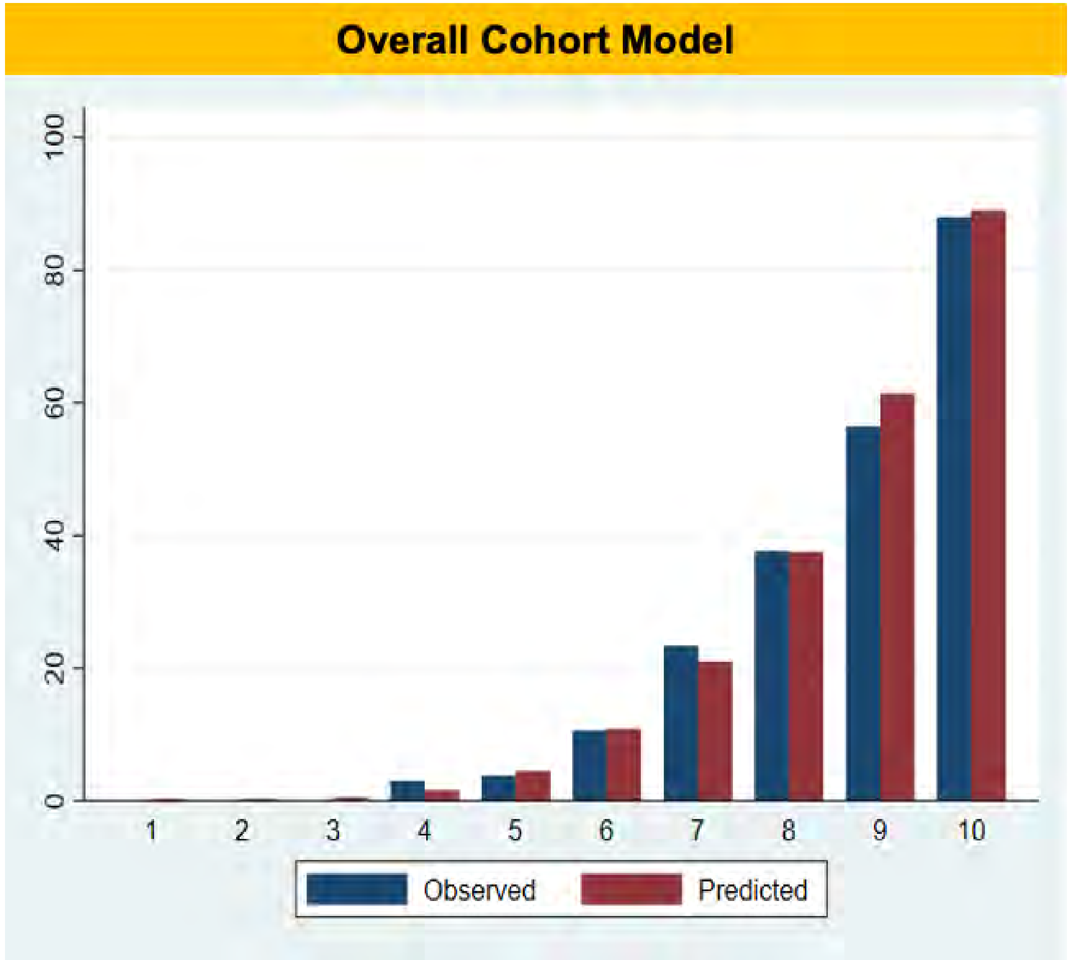

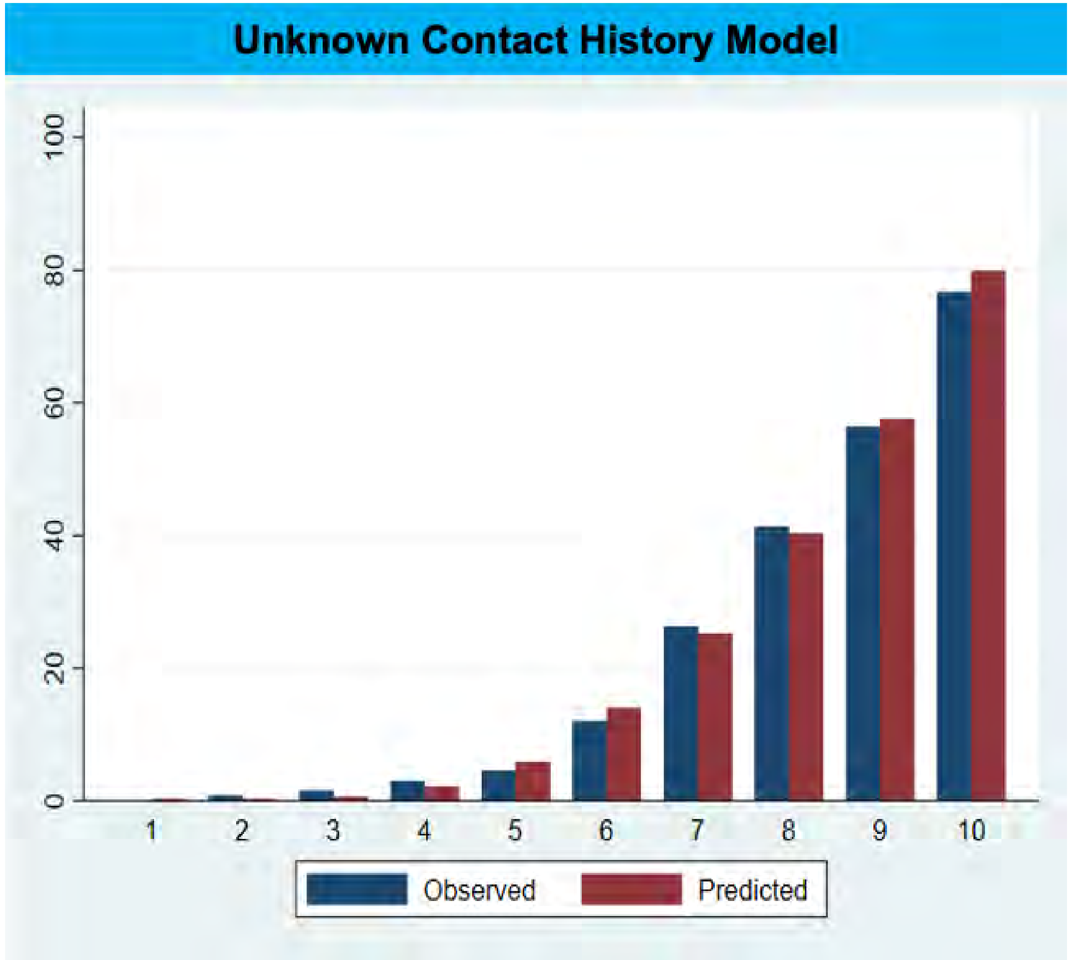

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COVID-19 Prediction Model

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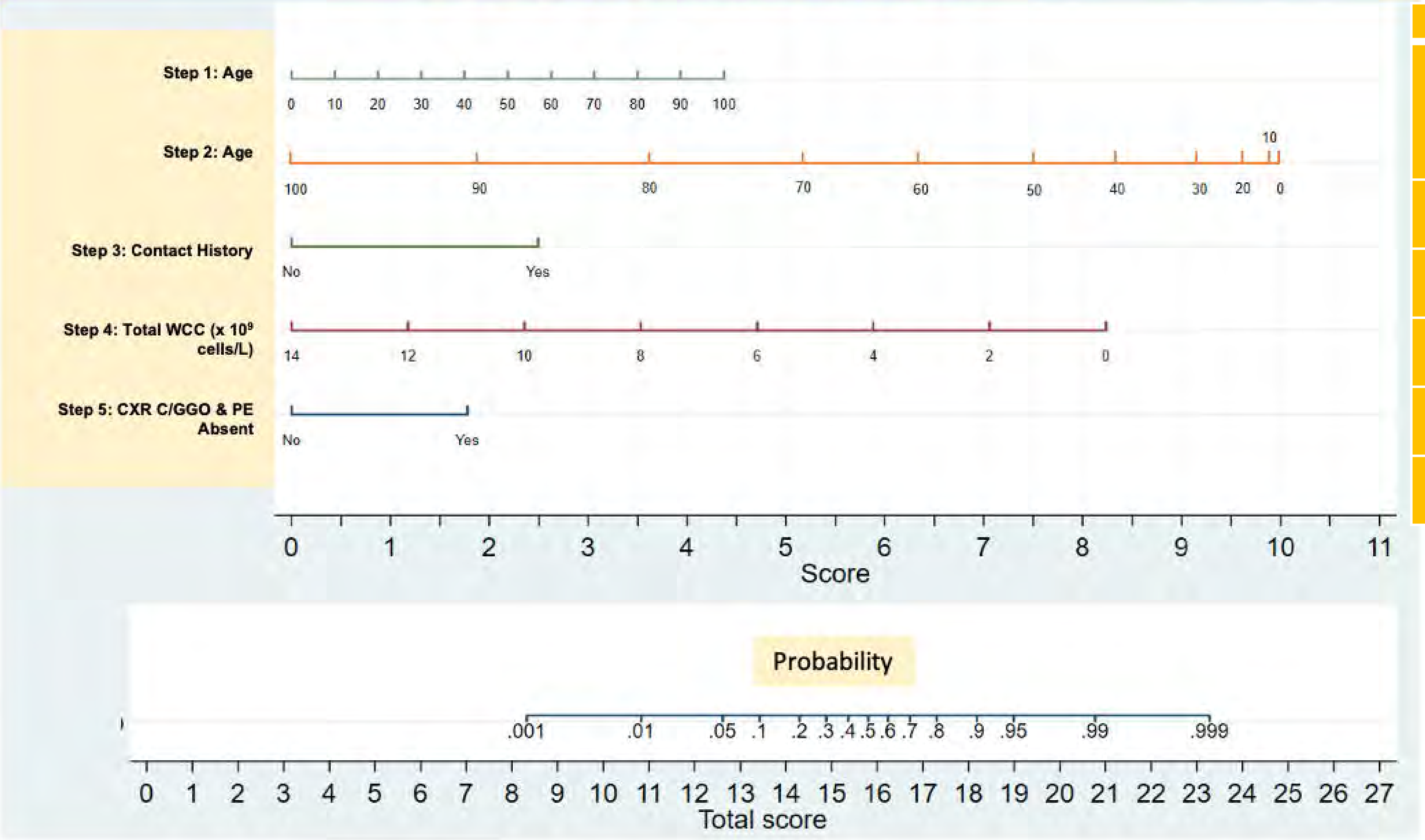
Overall Cohort Model



Overall Cohort Model – Validation Cohort				
Probability	**Sensitivity (95% CI)**	**Specificity (95% CI)**	**Positive predictive value (95% CI)**	**Negative predictive value (95% CI)**
0.1	91.7 (83.6,96.6)	69.4 (64.3,74.2)	41.6 (34.4,49.1)	97.2 (94.4,98.9)
0.18 (Optimal cut-off)	88.1 (79.2,94.1)	77.9 (73.2,82.1)	48.7 (40.5,56.9)	96.5 (93.6,98.3)
0.2	86.9 (77.8,93.3)	79.9 (75.3,83.9)	50.7 (42.2,59.1)	96.2 (93.4,98.1)
0.4	66.7 (55.5,76.6)	90.9 (87.4,93.7)	63.6 (52.7,73.6)	92.0 (88.6,94.6)
0.6	47.6 (36.6,58.8)	95.5 (92.7,97.4)	71.4 (57.8,82.7)	88.5 (84.8,91.5)

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COVID-19 Prediction Model

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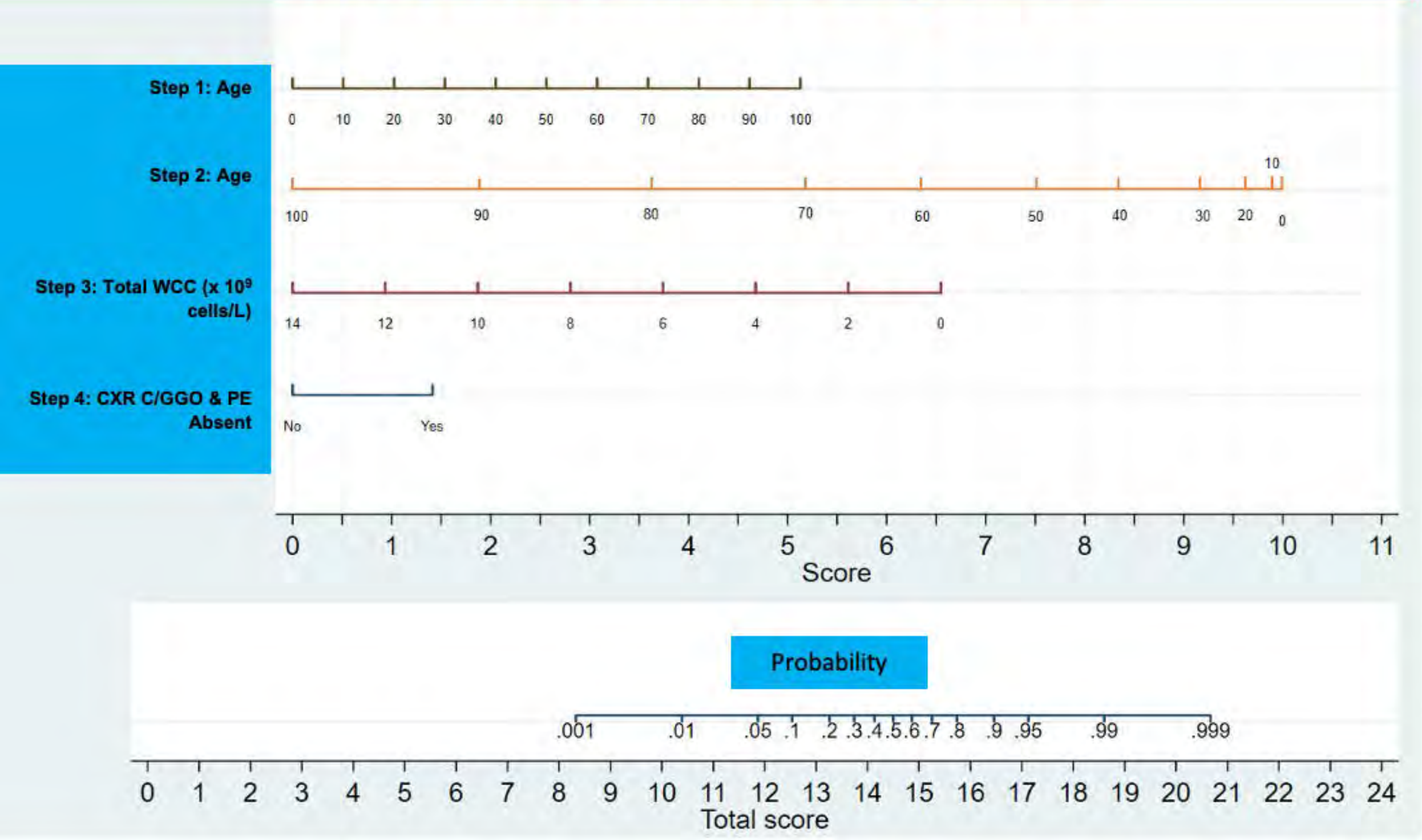
Unknown Contact History Model



Unknown Contact History Model – Validation Cohort				
Probability	Sensitivity (95% CI)	Specificity (95% CI)	Positive predictive value (95% CI)	Negative predictive value (95% CI)
0.1	90.5 (82.1,95.8)	65.2 (59.9,70.1)	38.2 (31.4,45.3)	96.6 (93.5,98.5)
0.18 (Optimal cut-off)	84.5 (75.0,91.5)	73.4 (68.4,77.9)	43.0 (35.4,51.0)	95.2 (92.0,97.4)
0.2	82.1 (72.3,89.6)	74.5 (69.6,79.0)	43.4 (35.6,51.5)	94.6 (91.3,96.9)
0.4	66.7 (55.5,76.6)	88.4 (84.6,91.5)	57.7 (47.3,67.7)	91.8 (88.3,94.5)
0.6	41.7 (31.0,52.9)	96.6 (94.1,98.2)	74.5 (59.7,86.1)	87.4 (83.7,90.6)

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Artificial Intelligence (AI) in COVID-19 Imaging

AI for Clinic Triage – AI Training

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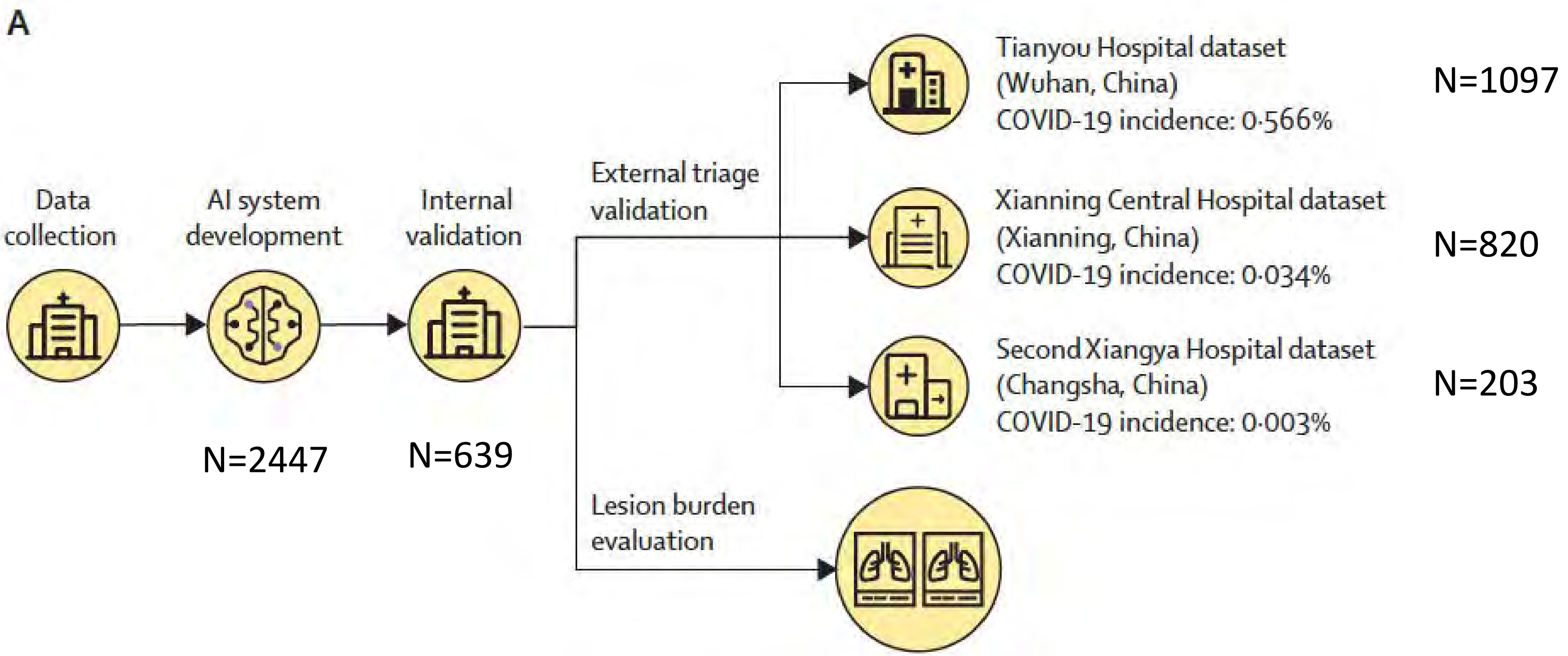
- AI was trained/ developed, internally and externally validated



Wang, et al. Lancet Digital Health. 2020

AI for Clinic Triage – AI Training

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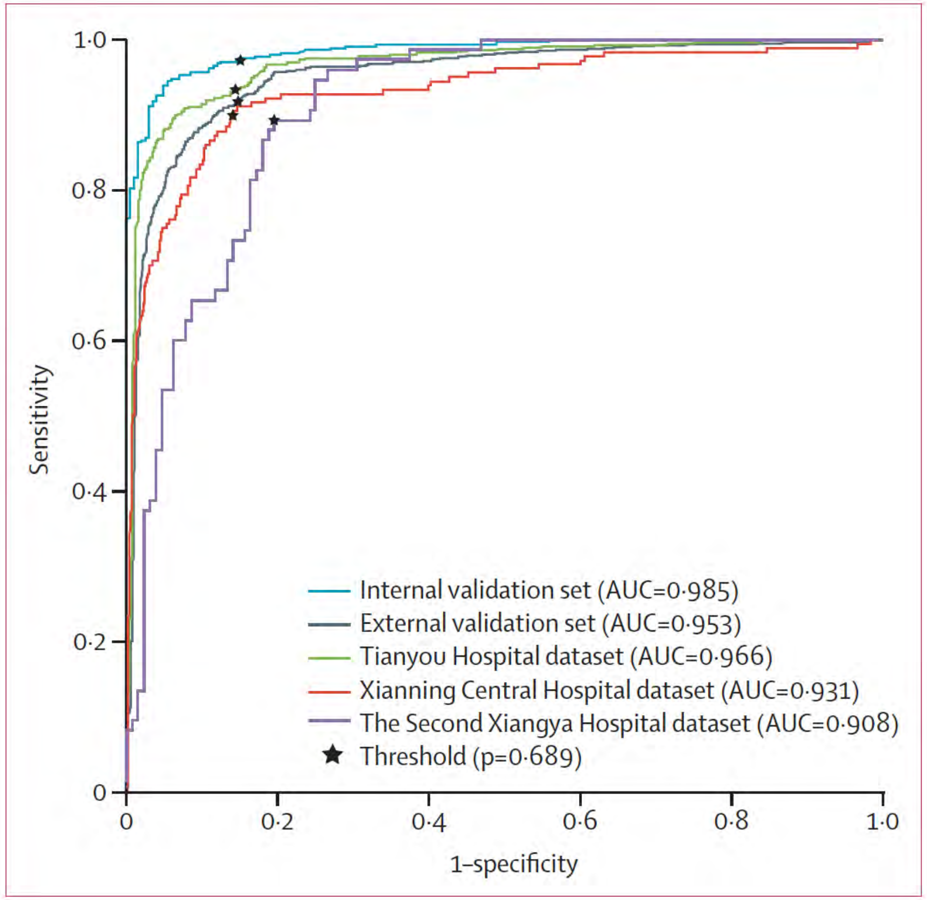
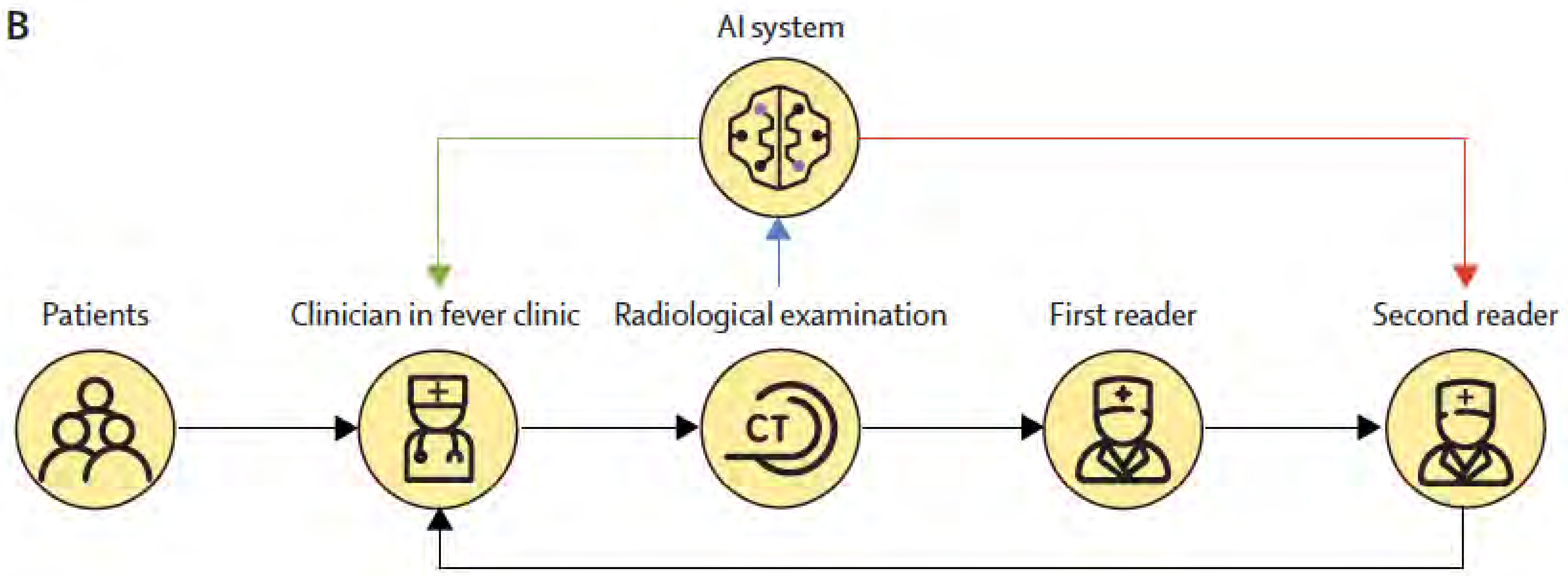


Wang, et al. Lancet Digital Health. 2020

AI for Clinic Triage



Wang, et al. Lancet Digital Health. 2020

Artificial Intelligence for COVID-19

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	External validation set	Tianyou Hospital dataset	Xianning Central Hospital dataset	The Second Xiangya Hospital dataset
True positive scans, n	698	511	129	58
Median draft report time (IQR), min*	16·21 (11·67–25·71)	14·50 (10·75–21·11)	24·75 (15·67–43·72)	25·73 (20·10–38·84)
Median report approval time (IQR), min*	23·06 (15·67–39·20)	19·23 (14·33–27·33)	47·37 (27·12–96·35)	198·77 (45·85–675·83)
Median AI triage time (IQR), min*	0·55 (0·43–0·63)	0·58 (0·45–0·64)	0·50 (0·42–0·58)	0·48 (0·44–0·53)
Median reduction in triage time under scan-to-second-reader triage workflow (IQR), min	15·73 (11·05–25·25)	14·03 (10·13–20·55)	24·31 (15·13–43·40)	25·24 (19·65–38·48)
p value†	<0·0001	<0·0001	<0·0001	<0·0001
t	257·42	243·09	114·59	69·32
Median reduction in triage time under scan-to-fever-clinician triage workflow (IQR), min	22·62 (15·12–38·63)	18·77 (13·88–26·73)	47·03 (26·53–95·83)	198·28 (45·31–675·26)
p value†	<0·0001	<0·0001	<0·0001	<0·0001
t	188·08	253·61	87·37	50·78

*Raw data did not follow a normal distribution. †Calculated by comparing the results with zero.

Table 3: Triage efficiency for the external validation set

Conclusion

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- Reviewed CXR, CT and ultrasound imaging features of COVID-19
- Explained CT scoring systems for confidence of diagnosing COVID-19
- CMR findings in COVID-19 and requirement for further research
- Role of cardiac CT in the COVID-19 era
- Predictive models for diagnosis
- Artificial intelligence assisting with image interpretation

Thank you for listening!

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