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Chest imaging findings in COVID-19 positive patients in an Australian tertiary hospital

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Short title: Imaging findings in COVID-19 – an Australian tertiary experience

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5 Article type : Radiology Original Article

6

7

8 **Title**

9 Chest imaging findings in COVID-19 positive patients in an Australian tertiary hospital

10

11 **Abstract**12 **Introduction:**

13 Coronavirus disease 2019 (COVID-19) has infected over 215 million individuals worldwide. .
14 Chest radiographs (CXR) and computed tomography (CT) have assisted with diagnosis and
15 assessment of COVID-19. Previous reports have described peripheral and lower zone
16 predominant opacities on chest radiographs. Whilst the most common patterns on CT are
17 bilateral, peripheral basal predominant ground glass opacities (1,2). This study describes the
18 imaging findings in an Australian tertiary hospital population.

19 **Methods:**

20 COVID-PCR positive patients who had chest imaging (CXR, CT and ventilation perfusion
21 (V/Q) scans) from January 2020 to August 2020 were included. Distribution, location and
22 pattern of involvement was recorded. Evaluation of the assessors was performed using
23 Fleiss Kappa calculations for review of radiographic findings and qualitative analysis of CT
24 findings.

25 **Results:**

26 A total of 681 scans (616 CXRs, 59 CTs, 6 V/Q) from 181 patients were reviewed. The most
27 common chest radiograph finding was bilateral lower lobe predominant diffuse opacification
28 and most common CT pattern being ground glass opacities. Of the CT imaging, 33 scans
29 were CT Pulmonary Angiograms of which 5 demonstrated acute pulmonary embolisms.

30 There was good inter-rater agreement between radiologists in assessment of imaging
31 appearances on CXR (kappa 0.29-0.73) and CT studies.

32 **Conclusion:**

33 A review of imaging in an Australian tertiary hospital demonstrates similar patterns of
34 COVID-19 infection on chest x-ray and CT imaging when compared to the international
35 population.

36

37 **Keywords**

38 COVID-19, Chest Imaging, Chest Radiograph, Chest CT, VQ

39

40 **Introduction**

41 Coronavirus disease 2019 (COVID-19) was first described in late 2019 where the first cluster
42 of cases was reported in Wuhan, Hubei Province, China (3). COVID-19 has since spread
43 globally and on March 11, 2020 the World Health Organisation (WHO) officially
44 characterised COVID-19 as a pandemic. As of 2nd September 2021 over 215 million
45 individuals have been infected worldwide resulting in significant mortality and morbidity. The
46 first case of COVID-19 in Australia was confirmed on the 25th January 2020, and by 2nd
47 September 2021 Australia has had more than 55,000 cases which have resulted in over
48 1000 deaths.

49 Chest radiographs (CXR) and computed tomography (CT) have frequently been utilised in
50 assistance with diagnosis and assessment of progression of disease. A multinational
51 consensus statement from the Fleischner society describes the role of chest imaging in the
52 management of COVID-19, recommending that imaging is not indicated in patients
53 suspected of having COVID-19 with mild clinical features, but is recommended for patients
54 at risk for disease progression and in those with worsening respiratory status(4). Imaging of
55 patients with COVID-19 infection has raised challenges in ensuring that studies are
56 performed appropriately whilst ensuring the safety of health personnel.

57 Whilst the CXR is low in sensitivity, it can be highly suggestive of COVID-19 in the correct
58 clinical setting when the radiographs exhibit characteristic COVID-19 findings(5). Typical
59 findings include a peripheral mid to lower zone lung distribution of opacification(1,5).

60 CT imaging is not recommended for screening or as a first line test to diagnose COVID-19
61 and should be used sparingly, for hospitalised, symptomatic patients with specific clinical

62 indications(6,7). The Royal Australian and New Zealand College of Radiologists (RANZCR)
63 recommendation for CT technique in the setting of COVID-19 is a volumetric CT of the entire
64 chest at end inspiration, with reconstruction of contiguous high-resolution (HR) images at
65 0.625mm to 1.5mm for assessment of the lungs. Studies have demonstrated that COVID-19
66 can cause microvascular injuries resulting in a procoagulant state(6). The role of computed
67 tomography pulmonary angiography (CTPA) is reserved for the detection of pulmonary
68 emboli in individuals who have clinical deterioration(8). Characteristic CT findings include
69 bilateral, peripheral and basal predominant ground glass opacities and consolidation(9).
70 Consolidation superimposed on ground glass opacity is found in a small number of cases,
71 predominantly in the elderly(8).

72 This study describes the imaging findings of 180 patients who presented to The Royal
73 Melbourne Hospital (an Australian tertiary hospital), evaluating the patterns demonstrated on
74 CXR, CT and ventilation perfusion (V/Q) scans.

75

76 **Methods**

77

78 The retrospective review was approved by the ethics committee through the quality
79 assurance pathway. COVID-PCR positive patients who had chest imaging (CXR, CT and
80 V/Q scans) from January 2020 to August 2020 were included. The imaging was evaluated
81 by a senior radiology registrar and four subspecialty chest radiologists including one dual
82 trained radiologist and nuclear medicine specialist. Imaging performed within 5 days prior to
83 the COVID-PCR positive test was also included to account for the potential lag time between
84 onset of infection and a COVID-PCR positive test.

85

86 A set of descriptors were developed for the purposes of labelling based on descriptors in the
87 current literature.

88

89 **Chest Radiograph Descriptors**

90

91 Chest radiograph descriptors were divided into zone involvement, distribution and findings.
92 The chest radiograph was divided into 6 zones, right upper, right middle, right lower, left
93 upper, left middle, and left lower (Fig. 1). This method of dividing the lungs into thirds is
94 commonly used in reporting and has been proposed for the reporting of COVID-19 chest
95 radiographs(10).

96

97 The distribution of the lung changes were also classified into three categories: peripheral,
98 central and diffuse (Fig. 2). Peripheral distribution was selected when only peripheral
99 opacities were present. Central distribution was selected when only central opacities were
100 present. A diffuse distribution was selected if there were opacities that either crossed both
101 regions or were both peripheral and central. Figure 3 demonstrates a chest radiograph with
102 a peripheral distribution.

103

104 Other findings recorded included the presence of pleural effusions or interstitial change.

105

106 **CT Descriptors**

107

108 CT characteristics were classified according to pattern, distribution, lobe involvement and
109 other findings. The CT descriptors were used for all chest CT imaging including pre and post
110 contrast CT chests such as pulmonary angiograms.

111

112 CT patterns reviewed were based on patterns described in the literature(2). Patterns that
113 were included were ground glass opacities, consolidation, ground glass with consolidation,
114 crazy paving pattern, reverse halo, interlobular septal thickening and air bronchograms.

115

116 Distribution on CT was divided into peripheral, central, peribronchovascular or diffuse.

117 Similar to the chest radiograph distribution, if more than one pattern was involved the diffuse
118 descriptor for distribution was selected. Lobar involvement was also recorded based on the
119 normal anatomical division of the right and left lung lobes (right upper, middle and lower and
120 left upper and lower). Each lobe involved in the CT was selected.

121

122 Other findings that were recorded included pleural effusions, lymphadenopathy, pulmonary
123 nodules, scarring and presence of pulmonary embolism on CT pulmonary angiograms.

124

125 **V/Q Scan Descriptors**

126

127 V/Q scans were analysed as either with findings or without findings. The V/Q scans recorded
128 in this study were either performed just prior to a positive COVID swab or after the acute
129 episode of COVID as follow up imaging.

130

131 **Evaluation of readers**

132

133 Between the 5 assessors, the senior radiology registrar reviewed all 661 studies. The
134 consultant radiologist each reviewed 20 studies, 20 of which was also reviewed by the
135 radiology registrar and 10 reviewed by another consultant radiologist. Fleiss kappa values
136 were calculated to assess inter-rater variability between all 5 assessors for chest radiograph
137 distribution (peripheral, central and diffuse) as well as for each of the 6 lung zones. A
138 qualitative assessment of the responses of the 5 assessors was performed with all
139 discrepancies reviewed.

140

141 **Results**

142 A total of 681 scans (616 Chest X-Rays, 59 CTs, 6 V/Q scans) from 181 patients were
143 reviewed. Of the 181 patients, there were 92 females and 89 males with a mean age of
144 61.99 (range 16-101).

145

146 **Chest Radiograph Findings**

147

148 103 (17%) of radiographs performed were normal with no findings. 3 chest radiographs were
149 considered not suitable for evaluation as they did not have the entire chest in view for
150 evaluation. The most commonly involved zones were the left lower zone (n = 441, 72%) and
151 right lower zone (n = 433, 70%). The least involved zone was the left upper zone (n = 112,
152 18%). The distribution in each lung zone is shown in Table 1. Findings in both lungs (n =
153 417, 67%) were demonstrated more often than unilateral findings (n = 239, 39%). The most
154 common pattern of distribution was a diffuse pattern (n = 351, 57%) followed by a peripheral
155 pattern (n = 146, 24%) with the least common pattern of distribution being central (n = 13,
156 2%). In the other findings evaluated, 3% had pleural effusions and 3% has interstitial
157 changes.

158

159 **CT Findings**

160

161 Of the 59 CTs, 9 were performed as follow up after the acute episode. 10 (17%) CTs
162 performed were normal. Of these normal CT studies, 2 were in follow up CT scans. 33 of the
163 scans were CT pulmonary angiograms, with 5 positive for pulmonary embolism. The most
164 common patterns demonstrated on CT imaging were ground glass opacity (n = 20, 45%)
165 and ground glass with consolidation (n = 20, 34%). The most common distribution
166 demonstrated on CT was peripheral (n=29, 49%) and peribronchovascular (n =16, 27%).
167 The most commonly involved lobe was the right lower lobe (n = 42, 71%) followed by the left
168 lower lobe (n= 41, 69%). Bilateral involvement (n=45, 76%) was more common than

169 unilateral involvement (n = 3, 6%). In the other findings evaluated, 4 demonstrated pleural
170 effusion (n=4, 7%), 2 cases demonstrated lymphadenopathy and 5 cases demonstrated
171 pulmonary nodules. Scarring was observed in 3 cases, 2 of which were in follow up CT
172 scans. An example CT demonstrating peripheral regions of consolidation, ground glass and
173 air bronchograms is shown in Figure 4.

174

175 **V/Q Scan Findings**

176

177 Of the 6 V/Q scans performed, 2 (33%) demonstrated findings and 4 (67%) were normal.
178 One V/Q scan was performed 7 days prior to the positive COVID test and 4 days prior to the
179 onset of symptoms to investigate a 6 month history of chest pain. The V/Q scan was
180 negative for pulmonary embolism with bronchopulmonary changes seen in the left apex on
181 both ventilation and perfusion images (Fig. 5). Although CT chest two days later
182 demonstrated no correlative changes, bilateral regions of opacification were subsequently
183 demonstrated on CXR 7 days after the V/Q scan. The other positive V/Q scan was
184 requested for follow up of pulmonary emboli demonstrated on CT pulmonary angiogram on
185 admission. This V/Q scan demonstrated mild heterogeneous tracer uptake in both lungs.

186

187 **Evaluation of readers**

188

189 Moderate agreement was demonstrated between the readers for assessment of distribution
190 on the chest radiograph (peripheral, central, diffuse) with a Fleiss Kappa value of 0.42 (p-
191 value < 0.05). The Fleiss Kappa values of the inter-rater agreement for the distribution of the
192 opacities in zones ranged from fair to substantial agreement with Fleiss kappa values
193 ranging from 0.29 - 0.73 (p-value < 0.05).

194

195 A qualitative assessment performed on the CTs read by all consultant radiologists
196 demonstrated consistency in labelling of the lobe involvement. There was a general
197 consensus for the presence of ground glass opacity, air bronchograms and ground glass
198 with consolidation.

199

200 **Discussion**

201 A review of imaging in an Australian tertiary hospital demonstrates similar trends on chest
202 radiographs with those described in the literature of international populations with
203 predominantly bilateral mid to lower zone regions of opacification(5,11). The population had
204 approximately 17% normal chest radiographs which is slightly lower than what has been

205 reported in other populations but comparable to those reported in hospitalised patients(1,12).
206 Another factor that would have contributed to a higher percentage of radiographs with
207 findings in this population would be that individuals who were hospitalised received a greater
208 number of radiographs when compared to those managed in the emergency department and
209 discharged for community treatment. Furthermore, this cohort demonstrated a greater
210 number of radiographs with a diffuse distribution of findings instead of a peripheral only
211 distribution which likely reflects the acuity of the patient population who present to hospital.
212 To our knowledge, this represents the largest series of imaging studies in COVID-19 patients
213 in Australia.

214 Litmanovich et. al proposed a suggested reporting language for the review of chest
215 radiograph findings of COVID-19 pneumonia (10). The authors proposed a reporting
216 language for grading the severity of lung disease using a modified version of a scoring
217 system used in quantifying the severity of acute respiratory distress syndrome. The authors
218 base their grading on the number of lung zones involved, dividing the lung into 6 zones,
219 similar to what was performed in this study. Mild disease is considered opacities in 1-2 lung
220 zones, moderate opacities in 3-4 lung zones and severe > 4 lung zones. This
221 standardisation in reporting is thought to be helpful in assessing progression over multiple
222 radiographs in a patient with COVID-19. Our study demonstrates that there is a fair to
223 substantial inter-rater agreement in the evaluation of opacities in zones which may indicate
224 that such a proposed reporting system may be useful in this clinical setting.

225 CT imaging findings described in this population were similar to the characteristics described
226 on CT of a systematic review performed on 919 patients with coronavirus disease with
227 predominantly bilateral and peripheral involvement demonstrated. A large proportion of CTs
228 in this study also demonstrated multilobar involvement, similar to that in the literature,
229 reflecting the severity of symptoms in patients who receive cross sectional imaging.

230
231 COVID-19 can cause microvascular injury and is associated with a procoagulant state
232 increasing the risk of thromboembolic disease (9,13). The role of CT pulmonary angiogram
233 in the setting of COVID-19 patients is in those who have deteriorated to the point where
234 pulmonary emboli need to be excluded (14). Greater than half of the CT chest scans
235 performed on COVID-19 positive patients were CT pulmonary angiograms with 5 positive for
236 pulmonary emboli demonstrating that the symptoms of PE may mimic or overlap with those
237 of COVID-19 infection.

238

239 Although V/Q imaging does play a role in the diagnosis of thromboembolic disease
240 especially in those with impaired renal function, the use of ventilation images in COVID-19
241 positive patients is discouraged due to its potential risk of spread of infection (15). All V/Q
242 imaging included in this study was either performed after a negative COVID-19 swab during
243 an acute episode, or prior to a subsequent positive COVID-19 swab, without clinical
244 suspicion of the diagnosis at time of study.

245

246 **Conclusion**

247 A review of imaging in an Australian tertiary hospital demonstrates similar trends on chest x-
248 ray and CT imaging when compared to the international population. A propensity for a
249 number of radiographs with diffuse findings may reflect the acuity of the patients who
250 present to the hospital.

251

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302

303 **Figure Legends**

304

305 **Figure 1:** The chest x-rays were distributed into 6 zones as illustrated

306

307 **Figure 2:** Descriptors for the distribution of opacity

308

309 **Figure 3:** Chest radiograph with a peripheral distribution

310

311 **Figure 4:** CT chest performed on a COVID-19 positive patient with regions of peripheral
 312 consolidation, ground glass opacity and air bronchograms which are lower lobe
 313 predominant

314

315 **Figure 5:** V/Q scan (A) in a patient which subsequently became COVID-19 positive and
 316 subsequently demonstrates bilateral regions of opacification on CXR 7 days later (B).

317

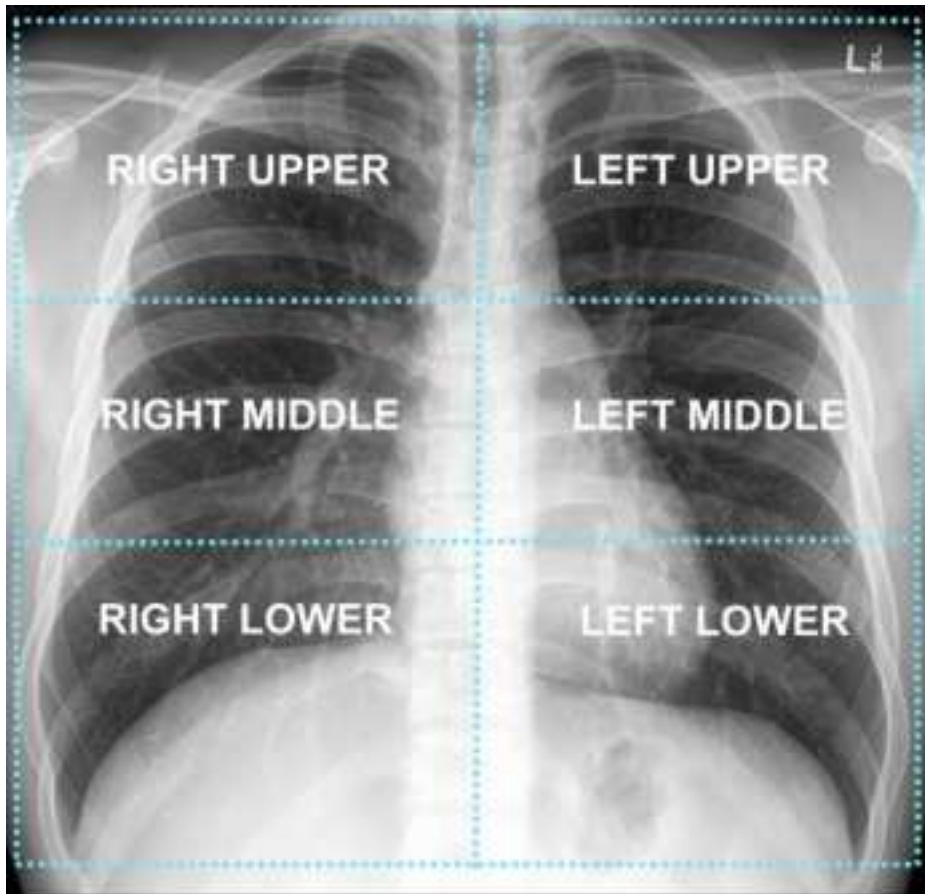
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319 **Tables**

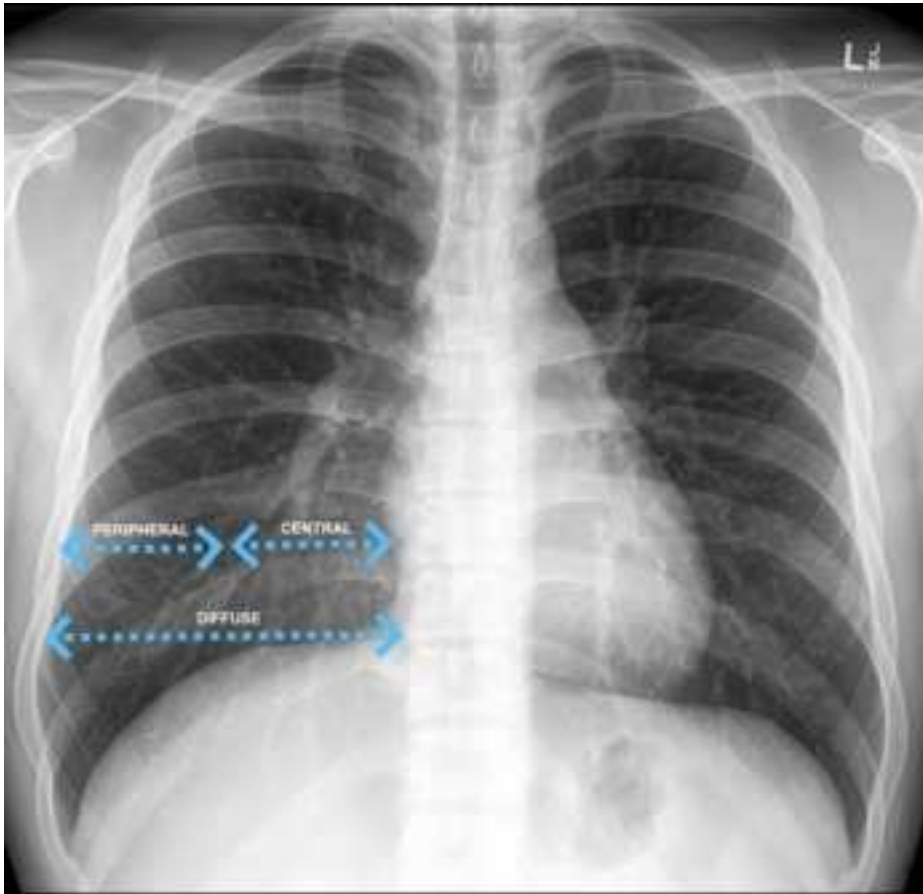
320 **Title:** Distribution of changes in each zone on chest radiograph

Zone	Number	Percent
Right upper	239	39%
Right middle	337	55%
Right lower	433	70%
Left upper	112	18%
Left middle	266	43%
Left lower	441	72%

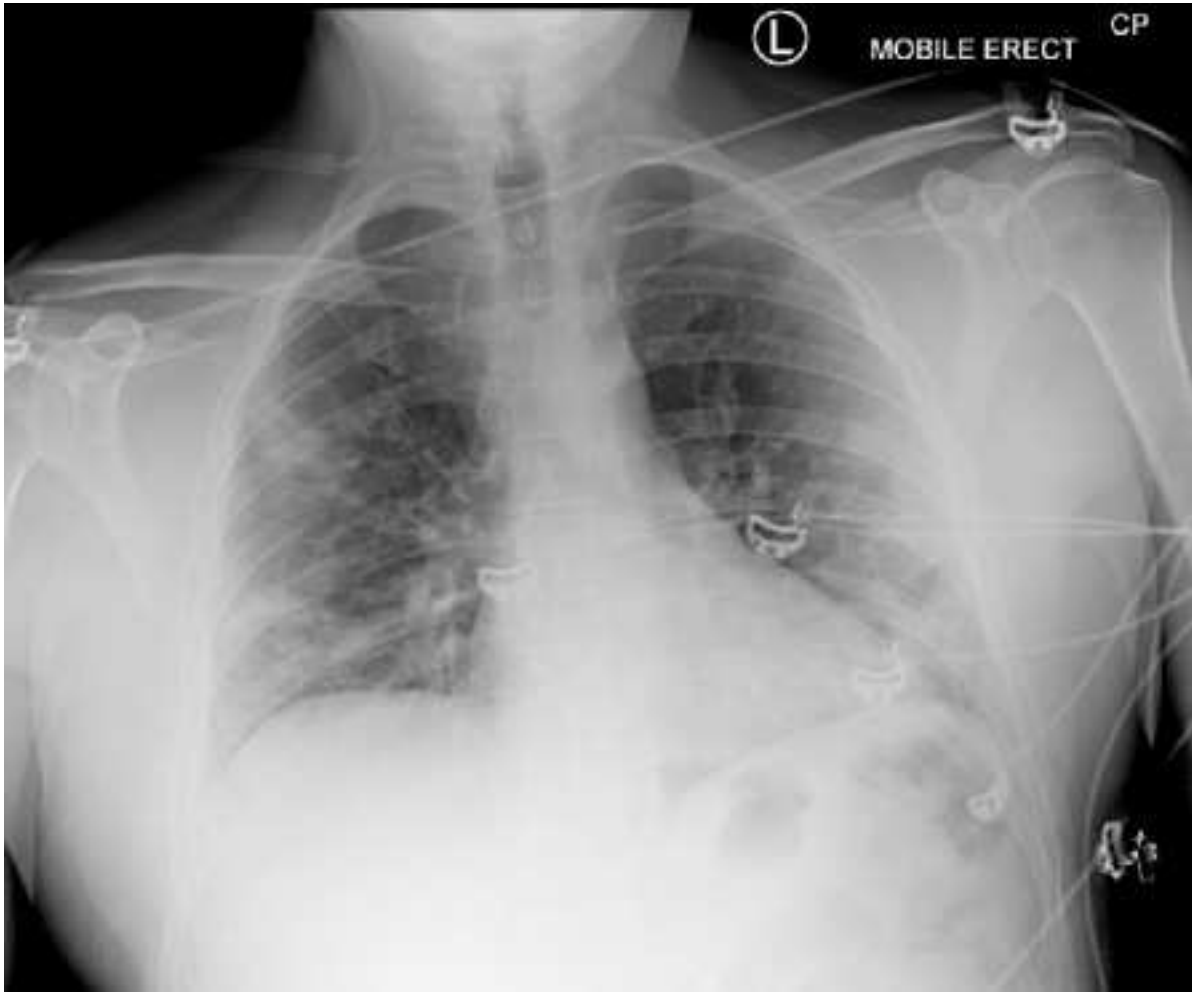
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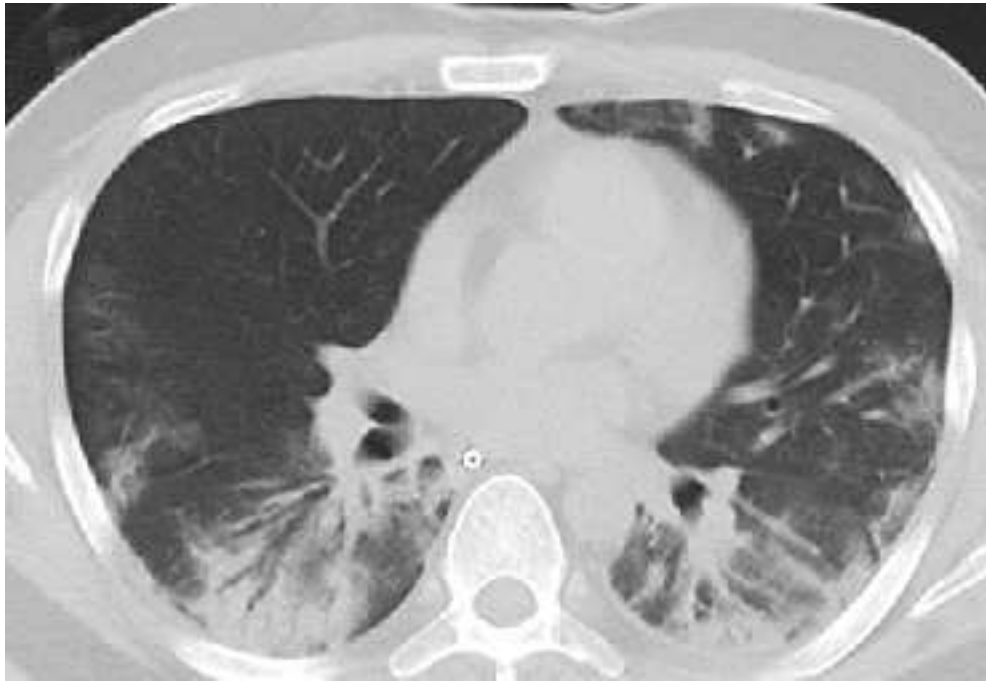
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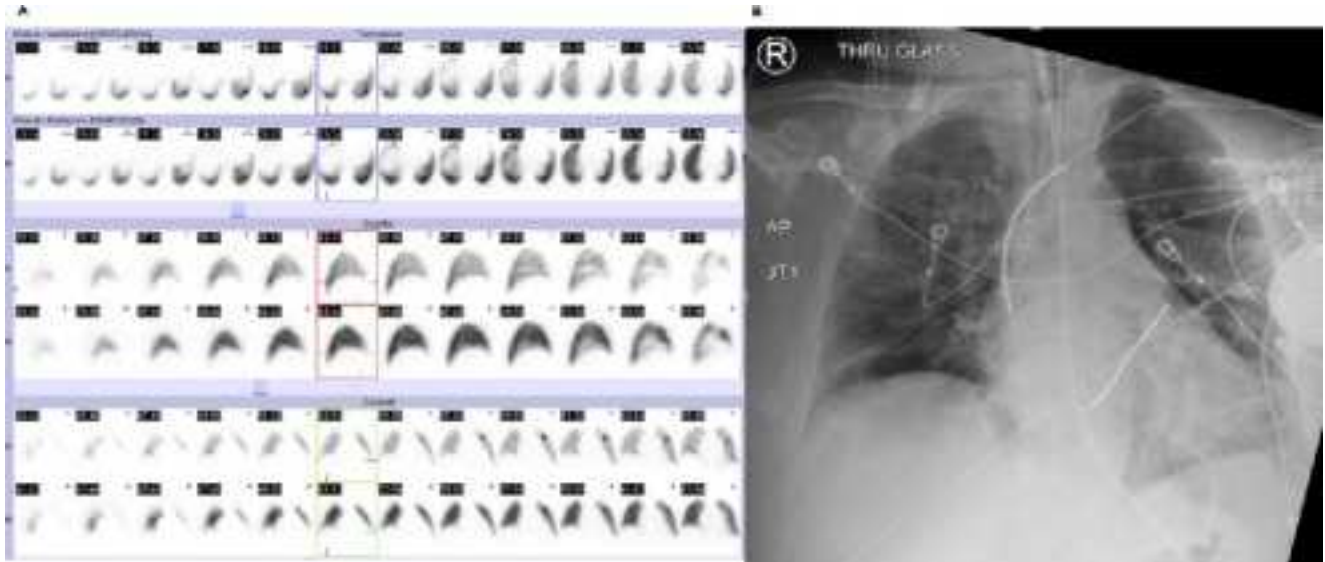
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