

Portable chest X-ray examination procedures for COVID-19-positive patients: performance time necessary for radiological technologists

COVID-19陽性患者のためのポータブル胸部X線検査の手順：診療放射線技師が検査に要する時間

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【Abstract】

Purpose: To measure time needed to conduct portable chest X-ray (CXR) examinations for in-patients with the coronavirus disease 2019 (COVID-19) and to compare that for non-COVID-19 patients.

Material and Methods: Portable CXR examinations were conducted on three COVID-19-positive in-patients from March 1, 2020 to May 14, 2020 for follow-up evaluation of pneumonia by four radiological technologists with work experience of 2 to 14 years. As controls, data of five in-patients who had follow-up examinations of pneumonia in the same ward (from October 22, 2017 to February 29, 2020) but without COVID-19 infection were investigated. Times taken before and after portable CXR examination, as well as for the entire examination, were recorded in each case, and the mean times were calculated.

Results: Five portable CXR examinations of COVID-19-positive in-patients were done, consisting of two times each for two patients and once for one patient. Mean preparation time before portable CXR examination was 15.8 minutes, mean time spent after portable CXR examination was 28.3 minutes, and mean total examination time was 44.1 minutes. Whereas, in contrast, in the five portable CXR examinations for non-COVID-19 patients, mean preparation time was 2.5 minutes, mean time after portable CXR examinations was 9.4 minutes, and mean total examination time was 11.9 minutes.

Conclusion: Time spent for portable CXR examinations of COVID-19-positive patients was 3.7-fold greater than that of non-COVID-19 patients, due to infection prevention measures particularly after portable CXR examinations.

【要旨】

目的：新型コロナウイルス感染症（COVID-19）入院患者のポータブル胸部X線検査（CXR）に要する検査時間を測定し、非感染者のCXRと比較する。

方法：CXRは、2020年3月1日から2020年5月14日までにCOVID-19入院患者3人に実施された。CXRの前後、および総検査時間を記録して平均時間を算出し、過去の同病棟の非感染者と比較した。

結果：COVID-19入院患者のCXRは合計5回実施された。CXR前の平均準備時間は15.8分、CXR後の平均所要時間は28.3分、平均総検査時間は44.1分であった。非感染者5回の平均は、それぞれCXR前2.5分、CXR後9.4分、総検査時間11.9分であった。

結論：COVID-19陽性入院患者のCXR検査時間は、CXR後の感染予防措置に多くの時間を要し、非感染者の3.7倍であった。

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1. Introduction

A novel coronavirus, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), was identified as the etiology for a cluster of pneumonia cases in Wuhan, a city in the Hubei Province of China¹⁾. It globally spread rapidly, and imaging features of patients with pneumonia induced by the coronavirus disease 2019 (COVID-19) were published^{2, 3)}.

Fang et al. reported that sensitivity of un-

enhanced computed tomography (CT) for detection of COVID-19 is higher than that of real-time polymerase chain reaction (RT-PCR) test particularly when results of RT-PCR tests are negative⁴⁾. Also, radiography screening images can be used as an alternative to PCR examination, as they exhibit a higher sensitivity in some cases; even portable chest X-ray (CXR) examinations are effective in detecting the presence of pneumonia as well as for use in follow-up examinations after treatment for pneumonia^{4,5)}. Portable CXR examinations may be more useful and practical than CT for patients who are difficult to move from bed or room, especially in epidemic disease cases such as COVID-19, due to a lower risk of spreading infection during an emergency referral, reducing the downtime for CT needed for other patients, and substantially reducing required numbers of personal protective equipment (PPE) per examination⁶⁻⁹⁾.

When conducting portable CXR examinations especially in patients with COVID-19, radiological technologists (RTs) must undertake adequate infectious prevention measures, including PPE, to avoid spreading infection within the hospital and a potential collapse of the medical care system^{10,11)}; therefore, infectious prevention measures for portable CXR examination are much more labor-intensive than for ordinary portable CXR situations. Zhao et al. reported their order of PPE fitting process

as “putting on the 1st surgical cap, the respirator, the 2nd surgical cap, isolation gowns, the 1st surgical gloves, the 1st shoe covers, the protective glasses, the disposable gowns, the 2nd surgical gloves, the 2nd shoe covers, the surgical mask, and then checking for tightness of the outfit”; they also reported the entire PPE fitting time to be about 30 minutes for an RT¹²⁾. To our knowledge, there have been no reports quantitatively examining time taken for the entire process of portable CXR examination of COVID-19-positive patients from registration of the examination to completion of the examination. Herein we report our procedures for portable CXR examination of in-patients at our institution, comparing those for COVID-19-positive and non-COVID-19 patients, to clarify the examination process and time necessitated for RTs.

2. Materials and Methods

2.1 Subjects:

Our subjects were three male in-patients with COVID-19-positive pneumonia (mean age: 64.3 years) who underwent follow-up examination using a portable CXR device from March 1, 2020 to May 14, 2020. Their symptoms ranged from mild to severe (Table 1). Portable CXR examination of the severe-symptom patient was done twice in supine position, and the other two patients were imaged twice

Table 1 Clinical information of COVID-19-positive pneumonia patients

Case I.D.	Age (years)	Sex	Positioning at CXR	Severity of symptoms*	Number of CXR examinations during hospitalization
A	52	M	Supine position	Severe	2
B	80	M	Sitting-up position	Moderate	2
C	61	M	Sitting-up position	Mild	1

*Note: Definition of COVID-19 severity was as follows:

Severe: Necessitated extracorporeal membrane oxygenation (ECMO) and mechanical ventilation (ECMO was used only at the beginning, then removed)

Moderate: Having SpO₂ ≤ 93%

Mild: Having only fever

and once, respectively, in a sitting-up position, for a total of 5 examinations. Control subjects were five in-patients with pneumonia without COVID-19 infection who underwent follow-up examinations using the same portable CXR unit in the same ward from August 1, 2019 to February 29, 2020 (Table 2). We excluded cases in which multiple sites were imaged for the same patient, or when multiple patients were imaged successively by the same RT. Our evaluation for the COVID-positive subjects and control subjects included portable CXR examinations by 9 RTs with working experience of from 2 to 17 years (mean 8.1 years) (Table 3). We measured time for each RT from their leaving the radiology department to returning to the department after completing a portable

CXR examination.

This study was approved by the ethics committee of our institution (Approval No. 2020-009).

2.2 Specification of PPE and Disinfection of equipment:

The PPE in our institution includes 1) eye protection (face shield), 2) a filtering facepiece respirator (N95), 3) a surgical cap, 4) gloves, and 5) a fluid-resistant gown. Surface wiping disinfection was not necessary for the flat panel detector (FPD), portable X-ray unit, and its peripheral equipment, as those were dedicated solely for infected patients' use in the ward.

Table 2 Clinical information of non-COVID-19 patients

Case I.D.	Age (years)	Sex	Positioning at CXR	Reasons for hospitalization
D	91	M	Supine	Pneumonia
E	84	F	Sitting-up	Radius fracture
F	50	M	Sitting-up	Pelvic fracture
G	84	M	Sitting-up	Cervical fracture
H	91	M	Sitting-up	Pneumonia

Abbreviations: M = male, F = female

Table 3 Radiological technologists conducted portable CXR examination

I.D. number of Radiological technologist	Sex	Experience as a technologist (years)
I	M	14
II	F	2
III	M	4
IV	F	3
V	M	8
VI	F	3
VII	M	14
VIII	F	8
IX	F	17

2.3 Scan parameters and protocols:

Portable CXR examinations (Portable X-ray unit: MobileArt Evolution, Shimadzu, Tokyo, Japan; FPD unit: CALNEO smart, Fujifilm Corp., Tokyo, Japan) were performed in the antero-posterior projection, and all were obtained by one RT using standard clinical acquisition parameters according to our institution's protocols. The layout map of the ward for infectious diseases is shown in Fig.1. Zoning was done in the ward for each COVID-19-positive patient, while the sites for wearing and removing the PPE and placement of the portable X-ray unit are fixed.

Examination procedures for COVID-19-positive patients are as follows:

- ①The RT registers reception of the patient using the Radiology Information Systems (RIS).
- ②The RT confirms the patient's body type and previous X-ray images on RIS or on electronic medical records.
- ③The RT moves from the radiology department to the infectious disease ward on the

3rd floor.

- ④The RT must put on specialized PPE at the specified location on the 3rd floor ("on" in Fig.1b) (Fig.2).
- ⑤The RT goes to the room where the portable X-ray unit is located ("Po" in Fig.1b).
- ⑥The RT goes to the ward with the portable X-ray unit where the patient is staying.
- ⑦The RT performs portable CXR examination.
- ⑧The RT transfers the image data to DICOM.
- ⑨The RT returns the portable X-ray unit to its usual location ("Po" in Fig.1b).
- ⑩The RT removes specialized PPE, and shoes must be disinfected at the specified location ("off" in Fig.1b) (Fig.3).
- ⑪The RT returns to the radiology department.
- ⑫The RT records the examination data on RIS.

RTs conducting imaging examinations for COVID-19-positive patients are required to record their own body temperature and health condition for two weeks after conducting a portable CXR examination of a suspected or

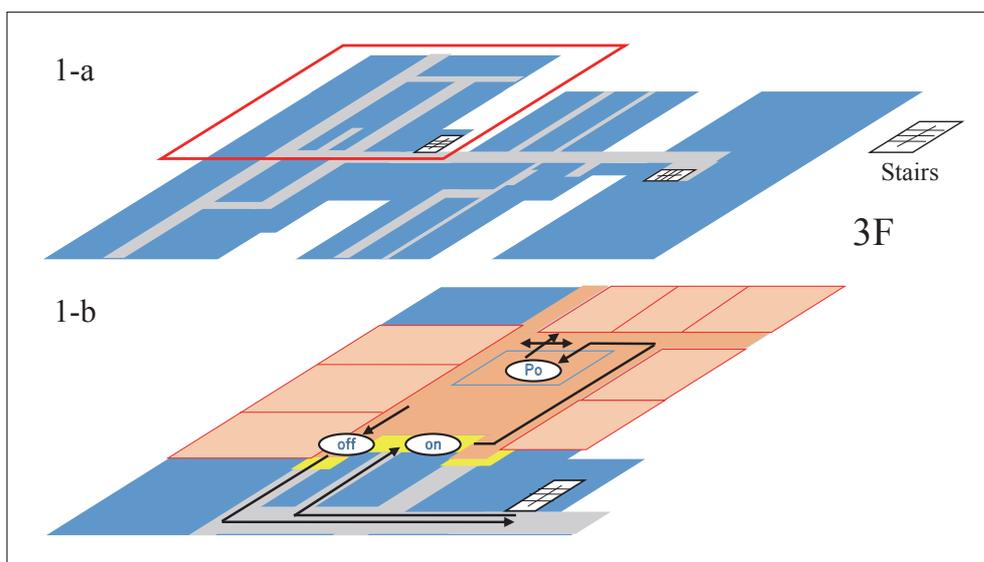


Fig.1 Locations of the specialized ward for infectious disease

1-a: Floor map of the third floor.

Radiological technologists move from the radiology department on the first floor to the infectious disease-specialized ward on the third floor (outlined in red) going up the stairs for CXR examination of COVID-19-positive patients.

1-b: Enlarged view of the infectious disease-specialized ward on the third floor (outlined in red in Fig.1a). Zoning is done for the infectious disease-specialized ward as shown in yellow (border portion), orange (ward floor hall), and pale orange (each ward room, outlined in red). Places are specified for the portable radiography unit (Po), putting PPE (on), and removing the PPE (off).

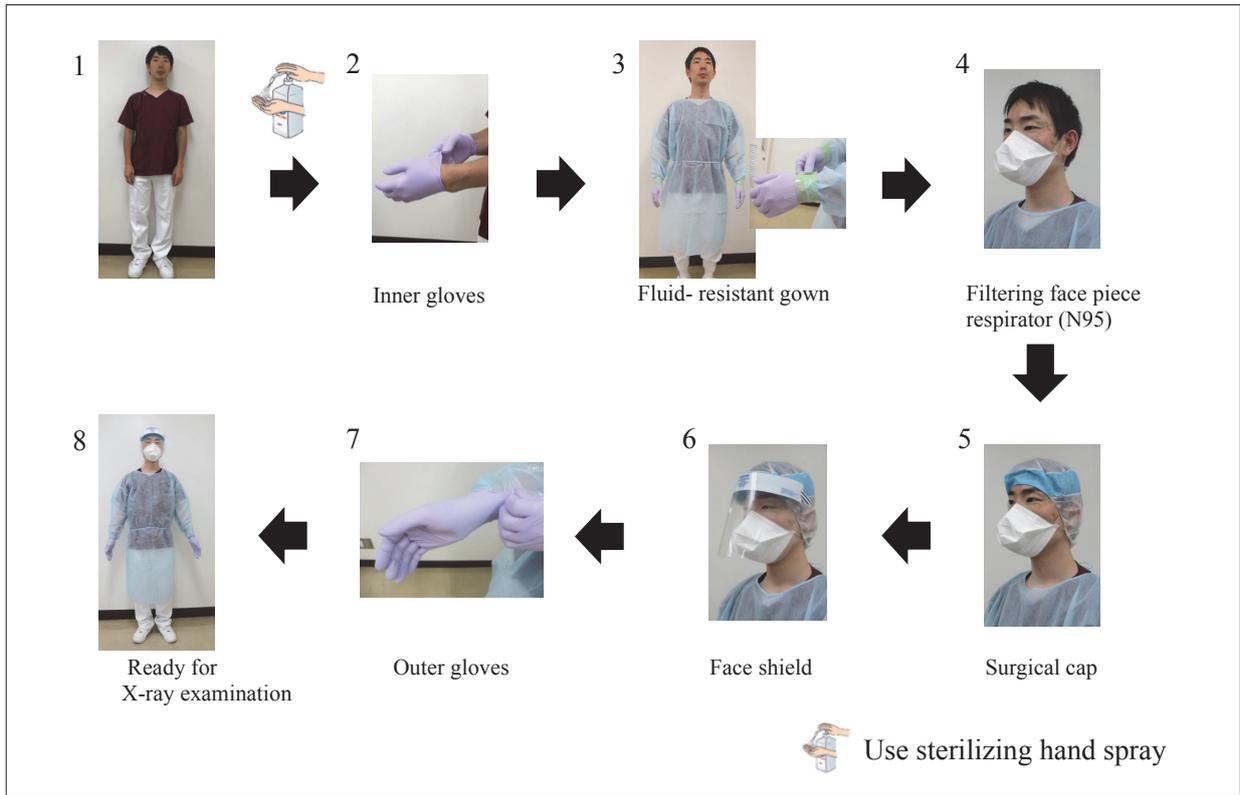


Fig.2 Process for wearing personal protective equipment (PPE)

PPE is put on starting with inner gloves, a fluid-resistant gown, a filtering facepiece respirator (N95), a surgical cap, a face shield, and outer gloves, in that order.

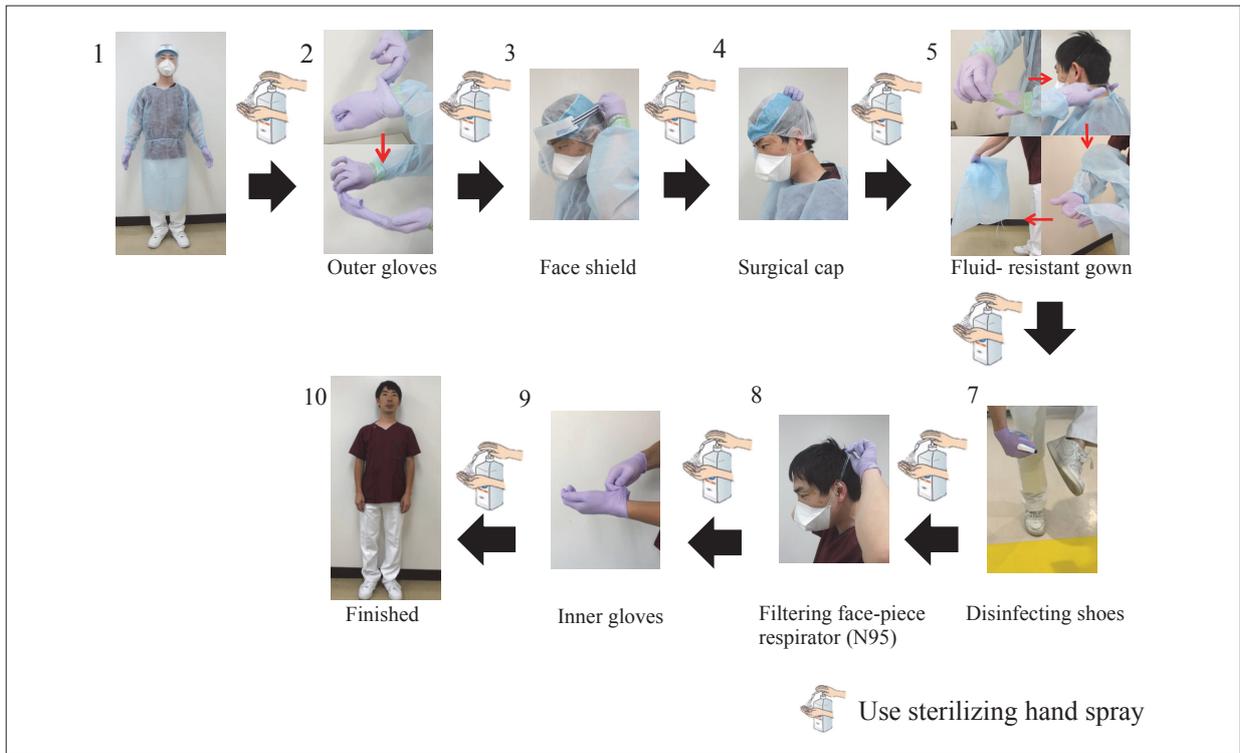


Fig.3 Process of removing personal protective equipment (PPE)

PPE is taken off starting with the outer gloves, the face shield, surgical cap, fluid-resistant gown; then, disinfecting of shoes, followed by removal of the filtering facepiece respirator (N95) and outer gloves, in that order. Radiological technologists should use sterilizing hand spray before each procedure step.

COVID-19-positive patient. The possible route of an intra-hospital-acquired COVID-19 infection is quickly checked and evaluated for our hospital staff.

2.4 Time calculation:

Figure 4 shows portable CXR examination procedures from reception to completion of portable CXR examinations. Among them, time at reception (①), time at transfer the image data (⑧), and time at recording the data to RIS (⑫) could be confirmed from the Digital Imaging and Communications in Medicine (DICOM) data. Accordingly, time spent for each procedure was calculated by the following formula (Fig.4):

Time spent from the preparation to onset of portable CXR examination (Preparation time) = ⑧-①.

Time spent after completion of portable CXR examination (Time after portable CXR) = ⑫-⑧.

Entire time from the reception to completion of portable CXR examination (Total examination time) = ⑫-①.

2.5 Statistical analysis:

Preparation time, time after portable CXR,

and total examination time were measured for each portable CXR examination, and all data were shown as mean.

3. Results

COVID-19-positive patients had a total of five portable CXR examinations, including two times for two patients and one time for one patient by RT ID No. I, II, II, and IV (Table 3). Mean preparation time was 15.8 minutes, mean time after portable CXR examination was 28.3 minutes, and mean total examination time was 44.1 minutes (Table 4).

By comparison, the five portable CXR examinations for five patients without COVID-19 infection were conducted by RT ID No. V to IV (Table 3). Mean preparation time was 2.5 minutes, mean time after portable CXR examination was 9.4 minutes, and mean total examination time was 11.9 minutes (Table 5).

As of May 31, 2020, the five RTs had no COVID-19 symptoms, had been tested as COVID-19-negative, and there had been no hospital-acquired COVID-19 infection cases in our institution.

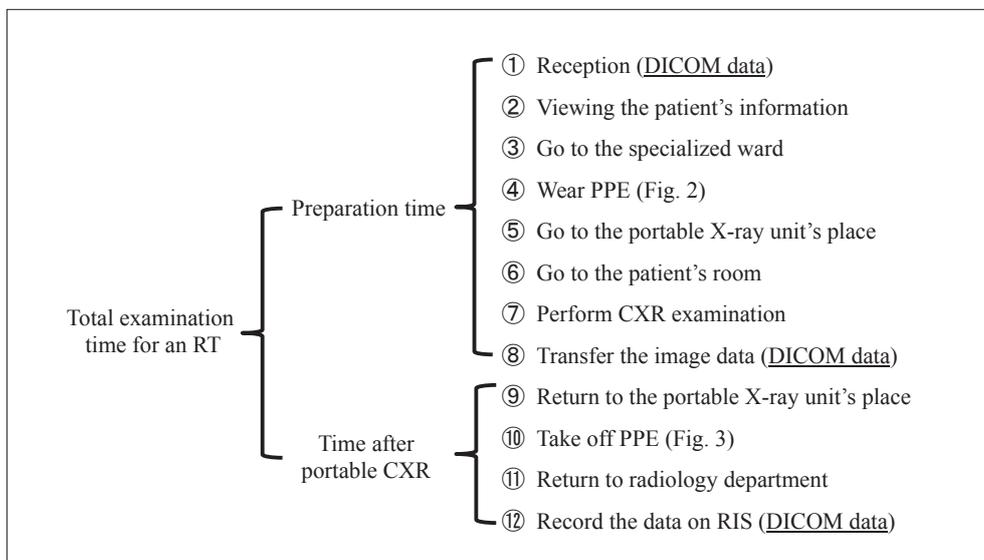


Fig.4 Portable CXR examination procedures

Note: ①, ⑧, and ⑫ were automatically recorded as DICOM data. Therefore, we could define ⑧-① =Preparation time, ⑫-⑧ =Time after CXR, and ⑫-① = Total examination time.

4. Discussion

In this study, mean total examination time for non-COVID-19 patients was 11.9 minutes and that for COVID-19-positive patients was 44.1 minutes, a 3.7-fold greater time for the COVID-19-positive cases. This is mainly attributable to time spent for prevention of infection (namely, putting on and taking off the specialized PPE). In COVID-19-positive cases, the mean time after portable CXR examination (28.3 minutes) was much longer than the mean preparation time (15.8 minutes) due to the need for carefully disinfecting the hands after removing each PPE item. Zhao et al. reported fitting time of PPE was about 30 minutes, probably due to a greater number of procedural steps than ours and their higher stage of infection prevention level¹²⁾.

SARS-CoV-2 remains detectable in aerosols for up to 3 hours, up to 24 hours on cardboard,

and up to 2-3 days on plastic and stainless steel¹³⁾. RTs are among the first-line health care workers who might be exposed to COVID-19; thus, sufficient preventive measures should be taken to avoid infection. There have been no COVID-19-infected RTs or other staff at our institution, indicating that the measures for COVID-19 prevention have been effective. Since the portable CXR unit used in our institution is dedicated solely for use in the infectious disease ward and zoning is done for patients within that ward, time spent disinfecting the portable CXR unit is substantially less, contributing to a shorter overall examination time while preventing hospital-acquired infection.

Our study has several limitations. The first limitation is the small number of our study subjects, insufficient for statistical verification of possible effects of the environmental factors. The second limitation is that performing time (⑥-⑦) was including in the preparation time

Table 4 Time spent regarding portable chest X-ray (CXR) examination in COVID-19-positive patients

Examination order number	Case ID	ID of Radiological technologist	Preparation time (minutes)	Time after CXR (minutes)	Total examination time (minutes)
1	A	I	11.0	32.1	43.1
2	A	II	18.2	25.3	43.5
3	B	III	17.8	27.0	44.8
4	C	III	13.0	31.7	44.7
5	B	IV	18.8	25.6	44.4
Mean			15.8	28.3	44.1

Table 5 Time spent regarding portable chest X-ray (CXR) examination in non-COVID-19 patients

Examination order number	Case ID	ID of Radiological technologist	Preparation time (minutes)	Time after CXR (minutes)	Total examination time (minutes)
6	D	V	4.0	8.7	12.7
7	E	VI	1.6	8.6	10.2
8	F	VII	3.5	9.5	13.0
9	G	VIII	1.2	8.8	10.0
10	H	IX	2.3	11.4	13.7
Mean			2.5	9.4	11.9

in our study, because time to perform portable CXR examination was not recorded as DICOM data. The X-ray examination time differs depending on the pathological condition of each patient. Portable CXR examination time for patients with very severe COVID-19 symptoms is considered to be longer than that for our study subjects. Therefore, further study including very severe symptom cases is necessary. The third limitation is the lack of inclusion of cases in which one RT conducted several portable CXR examinations sequentially, although one RT did perform two examinations in our study. An greater number of portable CXR examinations by each RT may subsequently reduce the entire examination time, due to more experience, skill, and improved technique at putting on and removing PPE. The fourth limitation is that the RTs were different for COVID-19-positive and non-COVID-19 patients; therefore, the time spent to conduct a portable CXR examination could not be easily compared for inter-operator variation. Further time measurement studies with the same RT members on COVID-19-positive and non-COVID-19 patients are necessary to eliminate such a bias.

5. Conclusion

From our findings on the entire procedure and time spent for each portable CXR examination for COVID-19-positive patients in our institution, a 3.7-fold increase in time was needed compared with that for non-COVID-19 patients due to infection prevention measures, particularly after a portable CXR examination, requiring a mean total of 44.1 minutes per case.

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Compliance with ethical standards

Conflict of interest: The authors declare that

they have no conflict of interest regarding the present study.

Ethical approval: The present study was approved by the ethics committee of our institution (Approval No. 2020-009).

Informed consent: Informed consent was obtained from all RTs included in the study.

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