

Review

Turkish Thoracic Society Experts Consensus Report: Recommendations for Pulmonary Function Tests During and After COVID 19 Pandemic

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Cite this article as: Gemicioğlu B, Börekçi Ş, Görek Dilektaşlı A, et al. Turkish Thoracic Society Experts Consensus Report: Recommendations for Pulmonary Function Tests During and After COVID 19 Pandemic. Turk Thorac J 2020; 21(3): 193-200.

Abstract

The recommendation of conducting pulmonary function tests (PFTs) from different societies during and after the coronavirus disease (COVID-19) pandemic was rated by the experts of the Turkish Thoracic Society (TTS) and presented as the TTS experts consensus report. Information about the topic has been provided.

Globally, as of mid-May 2020, there have been over 4.4 million confirmed cases of COVID-19. There are two main routes of transmission of COVID-19: respiratory droplets and contact transmission. PFTs are non-invasive tests that are commonly performed in routine assessment and follow-up of patients in the pulmonology units. However, PFTs may generate aerosols and require sharing common surfaces. With regard to the high prevalence of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in the community, PFTs should not be performed routinely in confirmed or suspected patients with COVID-19 during the pandemic. Because of the risk of human-to-human transmission of COVID-19, PFTs should be restricted to a small patient population with selected indications. Triage for COVID-19 should be performed prior to testing. Only essential PFTs such as spirometry, diffusion capacity of the lungs for carbon monoxide (DLCO), arterial blood gas analysis, or pulse oximetry should be performed in the selected cases. Tests should be scheduled to allow sufficient time for donning and doffing of the technical personnel with the full personal protective equipment (PPE) (gown, a filtering respirator mask, goggles or full-face shield, and disposable gloves), ventilation of the room, and application of post-test cleaning and disinfection procedures of the equipment and the testing room.

KEYWORDS: Coronavirus, pandemic, pulmonary function tests, triage

Received: 18.05.2020

Accepted: 25.05.2020

INTRODUCTION

Pulmonary function tests (PFTs) are aerosol-producing procedures and therefore, should not be routinely applied; even when applied, taking various precautions during and after the coronavirus disease (COVID-19) pandemic is necessary.

Various societies have published recommendations about PFTs during the COVID-19 pandemic [1-5]. These publications state that each country should adapt these recommendations [2, 4]. Some of them give information only for the pandemic period, but the European Respiratory Society (ERS) recommends separating the precautions during the pandemic, after the peak of the pandemic, and after the pandemic. According to the society, these levels of precautions are stated at 3 degrees of security [2]. These state that no routine test should be performed during the pandemic; if flu or COVID-19 symptoms are present again, PFTs should not be performed, and tests should be performed at least 30 days later. Similarly, the Thoracic Society of Australia and New Zealand emphasizes the decision that routine tests should not be performed during the pandemic [3]. The Association for Respiratory Technology & Physiology recommends the use of blood gas analysis or oximetry and performing spirometry when absolutely necessary and for selective cases [4]. The American Thoracic Society and the Turkish Thoracic Society (TTS), diagnostic and interventional methods assembly short recommendations paper have similar suggestions [1, 5].

In this recommendation paper, the first author developed 12 questions that were sent to 22 experts (6 authors and 16 other experts) around Turkey. All answers were received within 24 hours. All responses were rated as 0 (strongly disagree) or 10 (strongly agree), and the comments were considered to write this manuscript by the authors (Table 1).

The procedure of administering PFT requires maneuvers such as deep and forced expiration of the patient without a mask. This causes the distribution of droplets with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) to articles and persons around because of the high minute ventilation and air flow [2, 4, 5]. If necessary precautions are not

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taken, patients around or the next patient may be contaminated. The situation will be more critical if the patient coughs or sneezes during the procedure. A roadmap of various precautions that should be taken for the elimination of risk must be present.

As a conclusion, performing routine PFTs during the pandemic is not recommended. However, it is not clear how long this situation will last. There may be urgent cases such as transplantations, preoperative examinations, or legal urgencies that require PFTs. In this review, we provide information on the transmission of SARS-CoV-2, and detail precautions that should be taken to perform PFTs based on existing recommendations that have been published and expert opinions.

Transmission of SARS-CoV-2

The coronavirus that causes COVID-19 is a beta coronavirus in the same sub-genus as the severe acute respiratory syndrome (SARS) virus but in a different clade. The Coronavirus Study Group of the International Committee on Taxonomy of Viruses has proposed that this virus be designated as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The structure of the receptor-binding gene region of SARS-CoV-2 is very similar to that of the SARS coronavirus, and the virus has been shown to use the same receptor, the angiotensin-converting enzyme 2 (ACE-2), for cell entry [6].

Coronaviruses are minute (65-125 nm in diameter) encapsulated viruses with a crown-like appearance under an electron microscope due to the presence of spike glycoproteins on the envelope. Coronaviruses have large (26-32 kb) single-stranded, positive-sense RNA genomes. The viral particles contain four main structural proteins. These are the spike (S), membrane (M), envelope (E), and nucleocapsid (N) proteins.

Understanding the modes of transmission of an emerging infectious disease is a key factor in protecting both the public and healthcare workers. Generally, respiratory infections can

be transmitted through droplets of different sizes: When the droplet particles are 5-10 μm in diameter, they are referred to as respiratory droplets (droplet transmission), and when these are $<5 \mu\text{m}$ in diameter, they are referred to as droplet nuclei (airborne transmission). Droplets may also remain viable on surfaces, which serve as a source of transmission from the environment of an infected individual (contact transmission). There are two main routes of transmission of SARS-CoV-2: respiratory droplets and contact transmission. Respiratory droplets are generated when an infected person coughs or sneezes. Any person who is in close contact ($<1 \text{ m}$) with someone who has respiratory symptoms (sneezing, coughing) is at risk of being exposed to potentially infective respiratory droplets. The transmission may also occur through fomites in the immediate environment around the infected person, such as by contact with surfaces or with objects used by the infected person (e.g., stethoscope or thermometer) [7]. In an analysis of 75,465 COVID-19 cases in China, airborne transmission was not reported [8]. Airborne transmission is different from droplet transmission because it refers to the presence of microbes within droplet nuclei, which are generally considered to be particles $<5 \mu\text{m}$ in diameter; these can remain in the air for long periods and can be transmitted to others at distances $>1 \text{ m}$. In the context of COVID-19, the airborne transmission may be possible in specific circumstances and settings in which procedures or support treatments that generate aerosols are performed, i.e., endotracheal intubation, bronchoscopy, open suctioning, administration of nebulized treatment, manual ventilation before intubation, turning the patient to the prone position, disconnecting the patient from the ventilator, non-invasive positive-pressure ventilation, tracheostomy, and cardiopulmonary resuscitation [9]. A recent study suggested that experimentally produced aerosols containing SARS-CoV-2 virions remained infectious, with only a slight reduction in infectivity during a 3-hour period [10]. The published results were obtained from an experimental study in which aerosols were generated using a three-jet Collison nebulizer under controlled laboratory conditions that did not reflect normal human cough conditions, and the finding of SARS-CoV-2 in aerosol particles up to 3 hours did not reflect a clinical setting in which aerosol-producing procedures are performed because it was an experimentally induced procedure [10]. In a study conducted at MIT, the dynamics of exhalation (coughs and sneezes, for instance) were studied at the Fluid Dynamics of Disease Transmission Laboratory, and it was found that the exhalations produced gaseous clouds that could travel up to 27 feet (8.2 m) [11]. However, these were also experimentally obtained data, which did not change the dynamics of transmission in the clinical setting.

The stability of SARS-CoV-2 has been found to be similar to that of SARS-CoV-1 under experimental circumstances tested; these viruses probably arise from other factors, including high viral loads in the upper respiratory tract and the potential for persons infected with SARS-CoV-2 to shed and transmit the virus even while asymptomatic. SARS-CoV-2 has been found to be more stable on plastic and stainless steel than on copper and cardboard, being viable up to 72 hours. The longest viability of both viruses is on stainless steel and plastic; the estimated median half-life of SARS-CoV-2 is approximately 5.6 hours on stainless steel and 6.8 hours on plastic [12].

MAIN POINTS

- PFTs should not be routinely applied; taking various precautions during and after the COVID-19 pandemic is necessary.
- Triage of patients is necessary before PFTs.
- Because of the high contamination risk of COVID-19 among patients and pulmonary function laboratory staff, only essential tests such as spirometry, DLCO, arterial blood gas analysis or pulse oximetry should be performed during the pandemic period. Exercise testing (6-MWT, SWT, CPET, etc.), nebulization, bronchial challenge tests, and other aerosol-producing procedures should be postponed during the pandemic period.
- The staff performing the PFT should use full PPE, which consists of a long-sleeved disposable fluid-repellent gown, a filtering respirator mask (N95/FFP2/FFP3), goggles/full-face shield, and disposable gloves.
- Disinfection of surfaces with 0.1 to 0.5% sodium hypochlorite or 62-71% ethanol significantly reduces SARS-CoV-2 infectivity on surfaces within 1-minute of exposure.

Table 1. Recommendation questionnaire filled by the experts (0: strongly disagree, 10: strongly agree; results are represented as mean \pm SD [standard deviation]). Comments column reflects our actions regarding the experts opinions

	Recommendation	Comments	Rate 0-10 Mean \pm SD
1	Pulmonary function tests (PFT) are aerosol producing procedures, therefore it should not be routinely applied in COVID Pandemic period.	The details are in the text.	9.3 \pm 2.0
2	Pulmonary function tests should never be performed in COVID 19 newly diagnosed and untreated patient.	Not changed	9.6 \pm 1.2
3	Suspected patients for COVID 19 should be asked to isolate themselves until the nasopharyngeal brush result evaluated with PCR for SARS CoV2 is available	The comment is added.	9.5 \pm 1.5
4	If the patient is evaluated by the physician in terms of COVID presents any of the symptoms like fever cough or shortness of breath, advanced examinations, i.e. blood count, biochemistry, lung imaging, must be performed	The details are in the text.	9.6 \pm 1.1
5	PFT of the COVID 19 treated patient, can be applied at least 30 days past after his discharge from the hospital with negative PCR brush or at least 30 days past after he has finished complaining	The details are in the text.	8.8 \pm 1.8
6	Indication for pulmonary function tests should be restricted and recommended only in following conditions during COVID pandemic period: Lung or bone marrow transplantation Preoperative evaluation in urgent cases Monitorisation of immunosuppressive therapies Evaluation of disability and legal urgencies	We changed some indications and added some other comments.	8.5 \pm 2.5
7	Test reports of PFTs should be printed in another clean room in order to avoid contamination during COVID Pandemic period.	We changed the construction of the sentence.	7.7 \pm 3.0
8	It is not recommended to try testing more than twice against the risk of aerosolization during COVID pandemic period	We added some details.	8.1 \pm 2.7
9	Technician and patient should be positioned as their faces facing to the same side during the maneuvers.	We added some details.	7.5 \pm 3.9
10	For highest risk patients requiring testing, lung function test should be performed in a negative pressure room.	We changed this sentence.	9.4 \pm 1.6
11	As the respiratory function test maneuvers create a large amount of aerosol, the staff performing the procedure should use full PPE which consists of long-sleeved disposable fluid repellent gown, filtering respirator mask (N95 / FFP2 / FFP3), goggles/full face shield, and disposable gloves.	Not changed	9.8 \pm 0.6
12	All surfaces should be disinfection with 0.1 to 0.5% sodium hypochlorite (~corresponding to 1:10 dilution) or 62-71% ethanol significantly reduces coronavirus infectivity on surfaces within one-minute exposure time	The details are in the text.	8.9 \pm 2.0

COVID-19: coronavirus disease; PCR: polymerase chain reaction; PFT: pulmonary function test; SARS-CoV-2: severe acute respiratory syndrome coronavirus

SARS-CoV-2 has been detected in non-respiratory specimens, including stool, blood, ocular secretions, and semen, but the role of these sites in transmission is uncertain [7].

Triage

The procedures before PFTs will change depending on whether the patient has been treated for COVID-19 or not have COVID-19. However, we recommend that PFTs should never be performed in patients who are newly diagnosed with COVID-19 and untreated.

Triage of unknown COVID-19 patients

People who need PFT in both pandemic and post-pandemic periods must wear masks, and their fever should be measured just before the PFT. The PFT can be performed if the triage done by the physician or laboratory technician with relevant PPE is appropriate. Suspected patients should be asked to isolate themselves until the nasopharyngeal brush

results, evaluated with polymerase chain reaction (PCR) for SARS-CoV-2, are available [2]. If the risk of disease is high and the first test is negative, the results of the second test should be awaited. If the result is negative, it is recommended that the patient make an appointment with the laboratory after an average of 48 to 72 hours from the beginning [2]. If it has been more than a week since the negative PCR test, it is better to request a new PCR test. A positive patient is evaluated in an appropriate clinic for the treatment of COVID-19. The rules of PFTs are applied to patients who undergo COVID-19 treatment.

During the screening, the physician and/or the technician in the laboratory should ask the triage questions of the Ministry of Health of the Republic of Turkey, which are given in Appendix 1, and store one copy as a file or as a digital record. If it is done by the physician, he/she should deliver a copy to the patient for delivery to the laboratory.

This triage has two parts; if the patient evaluated by the physician for COVID-19 presents any of the symptoms such as fever, cough, or shortness of breath, advanced examinations and further tests, i.e., blood count, biochemistry, and lung imaging must be performed. If all the answers to all symptom questions are “no,” the physician must ask the patient if any of his or her relatives have been abroad in the past 14 days. The patient should also be questioned whether anyone nearby has had COVID-19 or any other respiratory disease in the past 14 days. Patients responding “yes” to any of the items in the questionnaire should be evaluated with specified tests for COVID-19 [13]. This form is presented in Appendix 1. However, our recommendation is to fill out the general form in Appendix 2.

Triage of patient who have been treated for COVID-19

PFTs in the COVID-19-treated patient should be conducted at least 30 days after his/her discharge from the hospital with a negative PCR test result or at least 30 days after he/she stops complaining of symptoms [2]. The patient should ask for PCR again in the application to the PFT laboratory, and after the brush PCR is obtained for SARS-CoV-2, the patient should be asked to isolate himself/herself until the results come out and arrive in the laboratory. With the assumption that the result will be negative, it is recommended that the patient make an appointment to the laboratory after an average of 48 to 72 hours from the beginning. If it has been more than a week since the last PCR test, it is better to request a new PCR test. PFT can be performed with all precautions if the new PCR test is negative.

Differential Diagnosis

The symptoms checked in the triage can also be seen in many diseases that require PFT. Therefore, if the medical examination is carried out by the technician, the chest disease physician should be asked to make an appointment in the case of a suspicious condition. For example, dyspnea and cough, which are also seen in a patient with uncontrolled asthma, may be due to an increase in asthma symptoms or due to COVID-19. If a decision cannot be reached with anamnesis, it is recommended that these cases be followed with peak flow meters in their homes, and the diagnosis can be performed from the treatment. While COVID-19 PCR and other examinations are performed, asthma treatments must be organized. The same will apply to diseases such as chronic obstructive pulmonary disease or interstitial lung disease.

Some findings may be general, such as fatigue, muscle pain, and some that belong to other systems. For example, nausea, vomiting, diarrhea, sore throat, skin findings, and conjunctivitis were also reported in patients with COVID-19 [14]. These should be questioned and directed to physicians in the relevant branch, and/or PCR and other examinations should be carried out to detect COVID-19.

General Triage

In patients who have applied to the outpatient pulmonary clinic, it is thought that it would be more appropriate to evaluate whether the patient has undergone treatment/testing for COVID-19 or to evaluate whether the patient has contracted COVID-19 but has not been diagnosed yet, with the

additions of these questions, including personal information and signed by both sides. The form prepared in this way is given in Appendix 2.

Organizational Measures

Because of the high contamination risk of COVID-19 among patients and pulmonary function laboratory staff, only essential tests such as spirometry, diffusion capacity of the lungs for carbon monoxide (DLCO), arterial blood gas analysis, or pulse oximetry should be performed during the pandemic period [15]. Therefore, indication for PFTs should be restricted and recommended only under the following conditions:

- Urgent lung or bone marrow transplantation
- Preoperative evaluation in urgent cases
- Evaluation of disability and legal urgencies

In addition, PFTs may be recommended if required for the diagnosis and/or treatment decision in patients being investigated for some important diseases (e.g., lung resection for malignancy, etc.).

Tests should be scheduled to allow sufficient time for the post-test disinfection of surfaces of the test equipment and the test room, ventilation of the room, and donning and doffing of PPE, as described in the ERS guidelines. These sanitizing procedures together with the PFT procedure will take approximately 60 minutes or minimum 30 minutes [2, 16].

Immunocompromised patients should be scheduled as the first patient of the day [17].

Waiting areas should be reorganized according to COVID-19 precaution rules. Patients should wear surgical masks while waiting and be seated 2 m apart. Patients should be alone, or only one person should attend, if necessary. Hand sanitizer should be provided in the waiting area [2-17].

The patient's temperature should be measured on arrival to the laboratory. PFT should be avoided in febrile patients [17, 18].

Triage for COVID-19 should be done prior to testing [2].

All patients should use hand gel before entering or leaving the test room [17].

Test rooms should be reorganized according to the disinfection rules. These rooms should be located in an area separate from other parts of the hospital and should be large enough to provide adequate space for the procedure. The test room should have windows so that natural air ventilation may be possible. Tests should be performed with windows open and doors shut. Furniture should be minimum, without carpet or curtains [19].

Test reports can be printed in another clean room to avoid contamination.

Pulmonary technicians should work in shifts.

Testing and Equipment

PFT laboratories should stop all routine tests during the pandemic, except mandatory tests until measures against COVID-19 are fully implemented in the laboratories [1, 2, 17].

When measures are obtained, test procedures should be limited to spirometry and DLCO, considering the safety of the staff and cross-contamination of the equipment. Other tests should only be performed if the risk has been adequately evaluated.

Bedside test is not recommended because of the risk of other individuals inhaling the droplets.

Exercise testing (6-min walk test [6-MWT], shuttle walking test [SWT], cardiopulmonary exercise testing [CPET], etc.), nebulization, bronchial challenge tests, and other aerosol-producing procedures should be postponed during the pandemic period [1, 2, 17, 20].

Patient Screening at the Entrance of the Laboratory

Technicians should be trained to screen patients by measuring the fever and using a triage questionnaire that will facilitate the identification of patients with signs and symptoms suggestive of COVID-19 infection [2]. If the screening is positive, technicians should contact the patient's physician, and the PFT appointment will be rescheduled for a later date. If the screening is negative, the patient will undergo PFT.

For patients with a negative triage questionnaire and with a negative COVID-19 test within 48 to 72 hours of the procedure, standard PFT laboratory procedures should be followed. PFT should not be performed if test results are positive for COVID-19 infection. Patients with COVID-19 must not be tested for a minimum of 30 days after infection [2].

Use of Equipment

Single-use consumables, e.g., nose clips and mouthpieces, are recommended for each patient. The use of disposable combined mouthpieces/sensors with additional disposable bacterial/viral filters (BVF) is recommended. BVFs combined with mouthpiece make cleaning the PFT equipment flow head much simpler, cost-effective, and compliant with the most stringent hygiene requirements within quality management systems [20].

During the Test

Spirometry requires a forced expiratory maneuver, which could spread droplets of the infected person who can be asymptomatic in that time.

Technicians should not demonstrate the test to the patients before testing. A short video or verbal description should be preferred to train the patient. It is not recommended to try testing more than twice because of the risk of aerosolization. It is important that the test be performed optimally.

The distance between the patient and the technician should be kept at a maximum (≈ 2 m) [3]. The technician and the patient should be positioned with their faces facing the same side during the maneuvers (not face to face).

The laboratory door should be kept closed, and windows open during the test [1]. There should be no individual in the room except the technician and the patient.

Technicians must avoid direct skin contact, which is a major source of infection [19, 20].

After the test is performed, the patient should leave the laboratory wearing a surgical mask [2].

Essentially during the COVID-19 pandemic, patients who require testing, the lung function test should be performed in a negative pressure room. If there is no negatively pressurized laboratory in the center, testing patients in their own rooms with adequate ventilation and maximal PPE should be considered [17, 21].

Protection of Pulmonary Function Laboratory Staff

The precautions for the safety of healthcare workers in the PFT laboratory have priority during the COVID-19 pandemic [1-3, 15, 22]. This process begins with the training of the technicians about the necessary precautions and the use of PPE. As part of precautions, PFTs should not be performed without providing the necessary training and equipment. It is recommended to pay attention to the following points to protect the staff of the PFT laboratory:

- Because the PFT maneuvers create a large number of aerosols, the staff performing the procedure should use full PPE, which consists of a long-sleeved disposable fluid-repellent gown, a filtering respirator mask (N95/FFP2/FFP3), goggles/full-face shield, and disposable gloves. There should be a separate clean area inside the PFT laboratory for donning the PPE. After the procedure, there should be another separate area for doffing the contaminated PPE. In the area where PPEs are removed, medical waste bins for contaminated PPEs should be available within the framework of hospital infection control measures. Healthcare workers should not go outside the laboratory with PPE.
- The order of donning PPE should be first gown, then mask, goggles/face shield, and gloves. While doffing PPE, this order should be first gloves, then goggles/face shield, gown, and mask. Hand hygiene should be maintained every time when donning or doffing each piece of the equipment. For hand hygiene, hands should be washed with soap and water for at least 20 seconds, or an alcohol-based hand antiseptic should be used [13].
- After each PFT, the healthcare worker performing the test should leave the area after the patient leaves the test area within the necessary precautions to ensure the hygiene of the test area, go to the separated area to doff the PPE as indicated, then move to the clean area. After the disinfection of the test area is completed, the healthcare worker repeats the same procedure for the next PFT session [22].
- It is recommended to use separate PPE for each patient. However, if there is no opportunity to change the N95/FFP2/FFP3 mask for each patient, a new clean surgical mask can be placed on the worn N95/FFP2/FFP3 mask and face shield and maintained for 8 hours. If it is necessary to reuse the N95/FFP2/FFP3 mask, it should be removed after washing the hands and wrapped in a breathable paper bag or paper towel and stored in a clean environment. Bag or towel should be changed after each use. It is not recommended to use nylon bags for this purpose. The mask should not be used more than 5 times under these storage conditions [23-25].

Cleaning and Infection Control

Human-to-human transmission of SARS-CoV-2 caused the emerging health problem to develop into a global pandemic. In the absence of adequate infection control precautions, healthcare setting is one of the most high-risk environments where human-to-human transmission might occur. Implementation of appropriate infection control practices is strictly required to avoid healthcare setting-associated transmission. SARS-CoV-2 is spread via droplets and contaminated hands and surfaces. During PFTs, especially the maximal respiratory maneuvers performed by forced exhalation from total lung capacity to residual volume may generate aerosols [17]. In addition to forced respiratory maneuvers, the patient may start coughing during or after the PFT. There is no direct evidence in the literature on the actual risk of the spread of SARS-CoV-2 during PFTs [17]. However, studies showing the recovery of organisms from the mouthpieces and the surfaces of tubing that patient breathe may be indirect evidence [26, 27]. It is believed that the flow generated during forced maneuvers may be high enough to generate aerosols [2, 28]. Because PFTs may generate aerosols and require sharing common surfaces, they should be restricted to a specific group of patients whose tests cannot be postponed as previously described in this document. In this selected group of patients, PFTs should be performed with precautions to avoid both aerosol generation and contact transmission of SARS-CoV-2.

Environmental Considerations, Cleaning, and Disinfection

Environmental cleaning aims to reduce the concentration of infectious respiratory aerosols in the air and to decrease the contamination of surfaces and inanimate objects. Adequate environmental ventilation is especially important to reduce the transmission of aerosols [29]. Aerosol clearance in the air is dependent on the ventilation and air change in the room where the test is performed [17]. Air changes per hour (ACH) is the number of times the total air volume in a room or space is completely removed and replaced in an hour [30]. If we take all the air out of the room within 60 minutes, that is equivalent to 1 air change in an hour. The actual volume of air changed in a well-ventilated space will be 63.2% after 1 hour and 1 ACH [17, 31]. That means as the patient leaves the testing room, a single air change removes 63% of the air. After 5 air changes, less than 1% of the original airborne contamination is thought to remain [17].

SARS-CoV-2 can remain infectious on surfaces at room temperature for up to 9 days. The contamination of surfaces in the healthcare setting is a potential source for SARS-CoV-2 spread. For this reason, thorough cleaning of environmental surfaces with water and detergent is mandatory. Inactivation of SARS-CoV-2 by different types of biocidal agents has been studied previously [32]. Many studies have shown that the disinfection of surfaces with 0.1% sodium hypochlorite or 62 to 71% ethanol significantly reduces SARS-CoV-2 infectivity on surfaces within 1 minute of exposure [29].

Detergent/soap and water are the first defense to remove the virus from the surfaces. Soap interferes with the lipids in the virus shell and lifts the virus from surfaces, which is then rinsed off by water [17].

Alcohol: Ethyl alcohol is a powerful germicide and more effective than isopropyl alcohol. Ethanol destroys the proteins and RNA of the virus and can kill coronaviruses in around 30 seconds [17]. Alcohol can be used to disinfect small surfaces such as thermometers and external surfaces of medical equipment such as stethoscopes and ventilators. Prolonged use may cause discoloration, hardening, and cracking of rubber and plastic materials [17, 29].

Bleach: The active ingredient in bleach is sodium hypochlorite. Bleach is a strong disinfectant and effective in killing bacteria, fungi, and viruses. Bleach works by destroying the RNA of the virus. Diluted bleach disinfects within 10 to 60 minutes [29]. Accordingly, the bleach should be left for 10 to 15 minutes; then the surface should be wiped with a clean cloth [17]. Bleach should be used with caution, because it has the potential to irritate mucous membranes and the skin. The ventilation of the room should be adequate, and it should be used in the recommended dilutions to avoid reducing its effectiveness [29]. Bleach should be diluted with cold water. Diluted bleach should be prepared by using a mask, rubber gloves, waterproof apron, and goggles to protect the eyes from splash. If diluted bleach is used, it should be prepared fresh daily, labeled and dated. Most household bleach solutions contain 5% sodium hypochlorite. A 1:100 dilution of 5% sodium hypochlorite is the usual recommendation for surface disinfection and is prepared as 1 part bleach to 99 parts cold tap water. A solution of 1:100 of 5% sodium hypochlorite (50.000 ppm available chlorine) results in a concentration of 0.05% [29]. Data show that a concentration of 0.1-0.5% of sodium hypochlorite (~corresponding to a dilution of 1:10 of 5% sodium hypochlorite) is effective in disinfection for human coronaviruses [29, 32]. Bleach should not be used with other household detergents because it can cause dangerous chemical reactions [29].

Disinfection is not required for surfaces and equipment that do not have direct contact with patients but is required for surfaces or medical equipment used by patients. When disinfection is required, a thorough cleaning is done before disinfection. Surfaces and materials cannot be disinfected if they are not cleaned first of patient's secretions, dirt, etc. [29].

Spirometry devices are not designed to be sterile. Spirometry equipment should be disassembled to allow physical removal of particulate matter [20, 33]. The plastic mouthpiece and available equipment should be cleaned and washed thoroughly with a suitable detergent and then rinsed with tap water to remove traces of detergent. Disinfection should be performed according to the Centers for Disease Control category of the item: semi-critical items coming in contact with mucous membranes, such as non-disposable mouthpieces, pneumotachographs, and breathing valves, should be cleaned and disinfected between consecutive patients [20, 33]. In the case of COVID-19 pandemic, 70% ethanol solution for 20 minutes appears suitable. Non-critical items that come in contact with intact skin or no direct contact with patients, such as closed or open breathing hoses distal to the breathing valve, should be cleaned with a suitable detergent and rinsed thoroughly with water [20, 33].

When devices are intended for multi-person use, a new BVF should be used for every patient to avoid cross-contamination. Used BVFs should be disposed at the end of the test session. Before the use by the next patient, the outside surfaces of the mouthpiece, body, and external surfaces of the device should be cleaned with a cloth using alcohol. If a touchscreen area is available, it should be cleaned as well. Disposable inline BVFs are considered to be effective for preventing equipment contamination by preventing the aspiration of saliva and other fluids. In contrast, BVFs are relatively inefficient in filtering microorganisms, especially small microorganisms such as viruses at high flows that are often reached in PFTs [28]. Although such filters may cause significant differences in measurements of forced expiratory volume in one minute and forced vital capacity with and without filters, the limits of the agreement were within the range of measurement repeatability [33]. For this reason, the effect of a BVF on measurement is not considered to be clinically significant. If the filter used appears to have a significant effect, the measurements must be adjusted accordingly [34].

Waste Management

According to the World Health Organization recommendations, the waste should be classified by local regulations and classified as infectious, when necessary. The waste disposal should be safe for those handling the waste and for the environment. Healthcare workers should use appropriate PPEs whenever there is a risk of aerosolization when handling the waste material [29].

Post-Pandemic Control Measurements

The return of PFT laboratories to normal standards as before the pandemic should be done step by step, and laboratory precautions should be continued until a definitive treatment or vaccine is found.

SARS-CoV-2 is a new virus, and this raises the concern that it will lead to more severe respiratory function loss than SARS cases detected in 2010. Therefore, the follow-up of patients with COVID-19 for pulmonary functions is necessary [4].

In conclusion, the published recommendations of the societies and our experts were analyzed, and it was demonstrated that PFTs should be applied with various precautions during and after the COVID-19 pandemic, if necessary. The triage of patients is important before PFT. Because of the high contamination risk of COVID-19 among patients and the pulmonary function laboratory staff, only essential tests should be performed during the pandemic period. The staff performing the PFT should use full PPE. Disinfection of surfaces with 0.1 to 0.5% sodium hypochlorite or 62 to 71% ethanol significantly reduces the SARS-CoV-2 infectivity on surfaces within 1 minute of exposure.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - B.G., Ş.B., A.G.D., G.U., Ö.A., S.S.; Design - B.G.; Supervision - B.G., Ş.B., A.G.D., G.U., S.S.; Resources - B.G., Ş.B., A.G.D., G.U., Ö.A., S.S.; Materials - B.G., Ş.B., A.G.D., G.U., Ö.A., S.S.; Data Collection and/or Processing - B.G., Ş.B., A.G.D., G.U., Ö.A., S.S.; Analysis and/or Interpretation - B.G., Ş.B.,

A.G.D., G.U., Ö.A., S.S.; Literature Search - B.G., Ş.B., A.G.D., G.U., Ö.A., S.S.; Writing Manuscript - B.G., Ş.B., A.G.D., G.U., Ö.A., S.S.; Critical Review - B.G., Ş.B., A.G.D., G.U., Ö.A., S.S.

Acknowledgements: The authors would like to thank the experts A. Sayiner, A. Çımrın, A. Uysal, A. Özgen Alpaydın, AC. Ögüş, E. Şen, E. Kıryan, E. Sercan Özgür, F. Özyener, F. Eyüboğlu, M. Polatlı, M. Erdinç, N. Köktürk, Ö. Akkkoca, S. Umut, T. Demir who contributed the paper by rating the questionnaire of recommendations in Table 1.

Conflict of Interest: The authors declare that they have no conflict of interest.

Financial Disclosure: The authors declare that they have no financial disclosure.

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Appendix 1. Possible COVID-19 case inquiry guide of the Ministry of Health of the Republic of Turkey for outpatients (adapted from reference 13)

Triage Questionnaire

Triage is performed by a medical staff dressed in accordance with the COVID-19 PPE.

- | | | |
|---|------------------------------|-----------------------------|
| Do you have fever or fever history? | <input type="checkbox"/> Yes | <input type="checkbox"/> No |
| Do you have cough? | <input type="checkbox"/> Yes | <input type="checkbox"/> No |
| Do you have shortness of breath or dyspnea? | <input type="checkbox"/> Yes | <input type="checkbox"/> No |

If the answer to any of the above questions is yes, the patient is fitted with a mask and directed to the reserved area for COVID-19. Or other diagnostic tests for COVID-19 required.

If the answer to all of the above questions is NO, the patient is asked the following questions.

- | | | |
|--|------------------------------|-----------------------------|
| Have you been abroad in the last 14 days? | <input type="checkbox"/> Yes | <input type="checkbox"/> No |
| Has one of the households come from abroad in the last 14 days? | <input type="checkbox"/> Yes | <input type="checkbox"/> No |
| In the last 14 days, any of your relatives have been diagnosed or hospitalized with respiratory disease? | <input type="checkbox"/> Yes | <input type="checkbox"/> No |
| Has anyone been diagnosed with COVID-19 disease in the last 14 days? | <input type="checkbox"/> Yes | <input type="checkbox"/> No |

If the answer to any of the above questions is yes, the patient is fitted with a mask and directed to the reserved area for COVID-19. Or other diagnostic tests for COVID 19 required.

In the patient who says no to all of them, procedures can be initiated for respiratory function testing.

Appendix 2. General triage questionnaire

General triage questionnaire for COVID-19 before performing PFTs

Patient First and Last Name:

Patient Date of Birth:

Patient Phone:

Patient's Fever:

Pre-Diagnosis:

Filling Last Name

Filled in date:

The signature that fills in:

Triage Questionnaire

If the answer to any of the following questions is yes, the patient is taken to the reserved area for COVID-19, or other necessary diagnostic tests are requested or referred to the relevant branch physician.

Developed in the last week:

- | | | |
|--|------------------------------|-----------------------------|
| Do you have fever or fever history? | <input type="checkbox"/> Yes | <input type="checkbox"/> No |
| Do you have cough and/or sputum? | <input type="checkbox"/> Yes | <input type="checkbox"/> No |
| Do you have shortness of breath or dyspnea? | <input type="checkbox"/> Yes | <input type="checkbox"/> No |
| Do you have sore throat? | <input type="checkbox"/> Yes | <input type="checkbox"/> No |
| Do you have cold or rhinitis symptoms? | <input type="checkbox"/> Yes | <input type="checkbox"/> No |
| Is there any obvious fatigue weakness? | <input type="checkbox"/> Yes | <input type="checkbox"/> No |
| Do you have myalgia, pain in your muscles? | <input type="checkbox"/> Yes | <input type="checkbox"/> No |
| Do you have nausea, vomiting and/or diarrhea? | <input type="checkbox"/> Yes | <input type="checkbox"/> No |
| Do you have conjunctivitis? | <input type="checkbox"/> Yes | <input type="checkbox"/> No |
| In the last 14 days, did you have close contact with COVID 19 patient, or patient with respiratory symptoms in your environment? | <input type="checkbox"/> Yes | <input type="checkbox"/> No |

Conclusion

(At the end of the triage questions, please select the appropriate response or responses)

- PFT can be performed
- The patient was referred to the relevant physician for evaluation for COVID 19
- Patients were asked for PCR for COVID-19 and told to isolate himself or herself
- The patient was asked for PCR brushing for COVID-19 and was told to isolate himself, but the appointment is given for after 2 or 3 days, thought of COVID-19 negativity. When negativity is observed PFT can be performed.