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Indirect Calorimetry during the COVID-19 Pandemic: Practical Guidance for Infection Control

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ABSTRACT

Introduction: Indirect calorimetry (IC) is the optimal tool for the assessment of the resting energy expenditure, as well as the reference standard for energy expenditure measurement. During the outbreak of coronavirus, performing respiratory tests such as IC has become challenging. The current guidance was designed to prevent the virus spread at calorimetry centers.

Methods: This protocol was devised in accordance with the latest recommendations of the World Health Organization (WHO) and Centers for Disease Control (CDC), as well as the related articles.

Conclusion: Due to the specific features of COVID-19, unnecessary ICs should be avoided in the hotspots of the disease. If these tests must be performed, adherence to the validated infection control recommendations is critical.

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Introduction

The coronavirus disease 2019 (COVID-19) is caused by the recently recognized severe acute respiratory syndrome coronavirus 2 (SARS-CoV2) (1). COVID-19 is believed to be transmitted mainly through respiratory droplets in close contacts of individuals with an infected patient (i.e., within one-meter distance) and via aerosols and contaminated surfaces (i.e., fomite transmission) (2). Although the symptomatic patients have been considered the main source of transmission, contracting the virus from asymptomatic carriers has also been reported (2–4), which has been primarily attributed to the surprisingly long asymptomatic incubation period of the virus (3). The Centers for Disease Control and Prevention (CDC) and the World Health Organization (WHO) have estimated that the symptoms of COVID-19 may become visible within 2-14 days of exposure (5,6). Furthermore, some references consider the latency period of the disease to be even more than 24 days (3). The healthcare system is no exception as it is suffering substantially from the adverse effects of the current pandemic. Therefore, it is essential to devise thoughtful plans in order to minimize these impacts as soon and as far as possible (7).

Due to the specific features of the SARS-CoV2 (particularly its high transmission rate), conducting respiratory tests safely has recently become a monumental challenge. Indirect calorimetry (IC) is one of the leading techniques used for the accurate determination of the energy requirements of patients, which improves the quality of nutritional support and minimizes the adverse effects of under- and over-feeding. IC encompasses similar methods to other respiratory tests, such as spirometry (8). In both mechanically ventilated and spontaneously breathing patients, IC could be used to measure the resting energy expenditure (REE). In spontaneously breathing subjects, a ventilated canopy hood or a fitted face-mask is used to collect the inspired and expired gas. In mechanically ventilated patients, respiratory gas sampling is acquired by the circuit that connects the endotracheal tube to the ventilator and should be measured by 'breath-by-breath' or mixing chamber analyses (8,9).

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In brief, ICs measure the energy expenditure through breath gas analysis, which is the measurement of the oxygen consumption (VO_2) and carbon dioxide production (VCO_2) using a canopy or face mask to capture the gas exchange (8). These particular features necessitate devising a strict plan for infection control.

The present study aimed to design a protocol for infection control to be followed for IC during the COVID-19 pandemic.

Materials and Methods

This protocol was devised in accordance with the latest recommendations of the WHO and CDC, as well as the related articles regarding respiratory tests during the coronavirus epidemic.

we looked into the following databases: The World Health Organization, the Centers for Disease

Control and Prevention (CDC) and PubMed. We use the keyword terms "COVID-19", "Coronavirus", "Indirect Calorimetry", "health-care protection", "masks", "Disinfection," "Respiratory tests", "pulmonary function test", "infection control", "workplace" , "personal protective equipment" and "Hand hygiene" in several combinations.

After reviewing the articles; the generalizable and usable tips for indirect calorimetry were extracted from the articles and prepared in the form of instruction for Indirect calorimetry in coronavirus epidemics. Overall, our recommended strategies for the infection control could be classified into the three major categories, including preliminary assessment and rigorous screening before scheduling each appointment, adjusting the number of reservations per day and time intervals between the appointments, and adherence to the validated infection control recommendations during and after each appointment.

Using IC during the COVID-19 Pandemic

Preliminary Assessment and Patient Selection

Based on the recommendations of the ESPEN and ASPEN societies, IC is the optimal tool for REE assessment, as well as the reference standard for energy expenditure measurement (10,11).

Indications for Performing IC in Normal Conditions

(a) Clinical conditions that remarkably alter REE (e.g., severe burns, trauma, prolonged septic states, other inflammatory states);
(b) Failure of patients to respond to nutritional support based on other methods of estimating energy requirements to maintain/restore the body weight;
(c) For appropriative nutritional support in the ICU and in patients with acute critical diseases

For instance, patients with modified body composition have been reported to experience continuous weight loss despite adequate nutritional intake. Therefore, IC is recommended for the survey of the results of the nutritional interventions used to prevent the complications of improper nutrition (i.e., under- or over-feeding) (8,12).

IC in Hospitalized and Critically Ill Coronavirus Patients

Several guidelines are available regarding the need for IC in patients with coronavirus. According to theASPEN guidelines, energy requirements could ideally be regulated by IC rather than using weight-based equations to estimate energy requirements. IC has also been recommended as a practical measure for COVID-19 patients (13). ESPEN states that if safely available, the energy requirements in COVID-19 patients could be measured by IC; otherwise, weight-based formula or predictive equations could be applied as the alternatives (14). Due to potential aerosol exposure and the increased risk of infection in medical staff and technicians, AuSPEN guidelines do not recommend the use of IC in COVID-19 patients (15). Therefore, we suggest that the need for IC in the patients with the coronavirus be determined by a specialist physician individually and specifically based on the patients' condition.

Recommendations for IC in Outpatients and Healthy Individuals during COVID-19 Pandemic *(current study recommendations):*

Coronavirus screening is essential for the outpatients and healthy individuals seeking IC. The screening and determining the importance of the test for these individuals should be carried out before appointments and attendance at the healthcare center. Furthermore, the test must be postponed if the individual is suspected

of or confirmed with the coronavirus. Therefore, we recommend that physicians or a health provider who is familiar with the approach of the COVID 19 select patients and supervising the IC process during the pandemic.

The most suitable candidates for IC during the COVID-19 Pandemic (current study recommendations):

a) Critically ill patients (whether or not infected with the coronavirus) in case of irresponsiveness to nutritional interventions or physician-recommended IC;
b) Outpatients or healthy people, if they are not suspected or infected with coronavirus, and a specialist confirmed the need for IC.

Patient Screening

Although symptom screening questionnaires cannot diagnose asymptomatic or pre-symptomatic patients with SARS-CoV2, symptom screening remains an important tool for the identification of COVID-19 patients (6). However, the long latency period of the disease and high rate of asymptomatic patients must be borne in mind (16).

A symptom screening questionnaire must be administered by a trained technician via telephone interviews within 48-72 hours before an appointment (17) in order to screen for upper respiratory and other suspicious symptoms, as well as obtaining the possible history of travel to the hotspots of the disease within the past two weeks. Following that, patient reservation is allowed for those screened as negative; nevertheless, even these clients must undergo a mandatory screening at the entrance of the laboratory, which is conducted by measuring the body temperature to detect fever (body temperature>37.3◦C) (17). The mentioned questionnaires screen for the major clinical symptoms of COVID-19, such as fever, dry cough, anorexia, dyspnea, myalgia, headache, pain, weakness, lethargy, diarrhea, nausea, vomiting, sore throat, nasal congestion, anosmia, and ageusia. In addition, data must be obtained on the patients' travel, occupation, contact, and cluster (TOCC) history status in the screening. Cluster exposure to confirmed or suspected COVID-19 patients, having a patient with COVID-19 in the family, travel to SARS-CoV2 hotspots within the past 14 days, and having a risky job define a positive TOCC history (18).

Patient Reservation

For the clients who are screened as positive or feverish, pulmonary tests should be postponed and be rescheduled for a later date (17). Moreover, patients with confirmed COVID-19 must not be tested for 30 days after recovery or until they have two negative COVID-19 reverse transcription polymerase chain reaction tests performed at a 24-hour interval (17,19,20).

According to Crimi et al., some guidelines recommend that the interval between the visits for respiratory tests should be at least one hour (17). As such, the number of the clients per day must be limited, and the exact time of reservation for each person must be determined. These measures prevent the potential congestion of the clients in the waiting areas and allow the necessary time for the disinfection of the equipment.

Recommendations for Infection Control during and after Appointments

Using Personal Protective Equipment

Personal protective equipment (PPE) includes gloves, goggles, face shields, face masks, and other similar equipment that help protect against disease transmission (7). The recommendations for PPE use are case-specific and depend on various factors, such as the specific tasks of a given job, hazard assessment, and different types of exposure (7). According to the WHO, using face masks is a critical preventive action to restrict the spread of COVID-19, and healthcare workers should wear a face mask during their routine activities (2,21). In fact, most guidelines recommend using a surgical mask as an acceptable infection control measure during routine care (22). Although using physical barriers (e.g., glass or face shields) is recognized as an appropriate procedure to reduce the hazard of COVID-19 transmission (especially when physical distancing is not feasible), face masks and eye protection are considered to be more important (23).

There is a lack of data about whether the respiratory tests should be regarded as aerosol-generating procedures(17,24). Nevertheless, a European Respiratory Society expert group and the UK body, responsible for clinical respiratory physiology, the Association for Respiratory

Technology and Physiology (ARTP) indicates that full PPE should be used and that respiratory test should only be done when vital(24). the highest level of PPE includes eye protection, a full gown (ie, covering the shoulders and lower arms), and the use of a high specification facemask (ie, FFP3 or ventilated hood)(24). Also, most other societies agree on this and they say when FFP3 not feasible, FFP2, and eye protection, are suitable alternatives (17). Considering the need for a close distance between technicians and patients during an IC test, calorimetry technicians are at exposure risk. Thus in line with the recommendations mentioned above, we also recommend, the use of the highest level PPE must be mandatory for all technicians and healthcare workers in the IC centers. The following instructions must be followed exactly under such circumstances:

Table 1. How to use personal protective equipment (6)

A] How to put on PPE	*B] How to take off PPE*
1. Identify the proper PPE	1. Remove gloves
2. Perform hand hygiene	2. Remove gown
3. Put on a gown (if needed)	3. Perform hand hygiene
4. Put on a face mask	4. Remove face shield or goggles
5. Put on a face shield or goggles	5. Remove face mask
6. Put on gloves	6. Perform hand hygiene

Table 2. Summary of Preventive Measures against COVID-19 for Indirect Calorimetry Centers (PPE: personal protective equipment, IC: indirect calorimetry)

Issue	Solutions
Preventing virus spread	Telephone screening questionnaire 24-48 hours before referral; Screening upon arrival by measuring temperature
Technician Protection	PPE (filtering facepiece respirators FFP3 or FFP2, gloves, goggles/face shields); Hand hygiene (alcohol-based hand antiseptics, soap and water)
Patient Protection	Surgical masks; Hand hygiene; Minimum one-hour interval between visits; Determining exact time of visits
Disinfection of Equipment and Environment	Using 70-90% ethanol or sodium hypochlorite (0.1-0.5%) (Or other alternative disinfectants based on the recommendations of the World Health Organization)
Room Ventilation	Room closed for one hour after IC test or 15 minutes with open windows and closed doors

Performing Hand Hygiene

Hand hygiene is an essential measure to decrease the transmission of SARS-CoV2. It is widely recommended to wash hands with soap and water for a minimum of 20 seconds or use an alcohol-based hand sanitizer (6). Although the appropriate percentage of ethanol varies in different guidelines, the CDC guidelines recommend hand sanitizers with 60-95% ethanol content as effective (6).

We believe that providing separate places for clients and technicians to wash their hands with soap and water is paramount. If soap and water are not available, hand sanitizers with the minimum 60% of ethanol content should be provided preferably via automatic dispensers (7). In addition, instructions on proper hand hygiene (e.g., hand-washing steps using the WHO technique) should be provided in appropriate locations. It is emphasized that hands must be washed or sanitized before touching a patient or starting a procedure and also after any contact with contaminated PPE or other contaminated objects or surfaces (25,26).

Waiting Areas

Not only is it necessary to urge all clients to wear surgical face masks before entering the IC center, special attention should be paid to fact that they keep the masks on in waiting areas. Furthermore, all clients must be unaccompanied and keep a safe physical distance of at least 1-2 meters (17,23). Due to the CDC and WHO emphasis on hand hygiene (6,23), soap and water and/or hand sanitizers are also required in waiting rooms and hallways, and patients must be urged to disinfect their hands upon arrival.

Disinfection of Environmental Surfaces and IC Equipment

The SARS-CoV2 survives on surfaces for a few hours to several days depending on

determinants such as humidity, temperature, and the surface material. As such, the disinfection of surfaces is recognized as an important measure in the prevention of the disease transmission (25,27).

According to the WHO recommendations, all the surfaces that are in contact with a confirmed or suspected COVID-19 patient in outpatient/ambulatory care rooms, as well as any high-touch surfaces (e.g., tables, doorknobs, handles, phones, keyboards, light switches), must be cleaned with surface disinfectants immediately after patient visits are completed. On the other hand, low-touch surfaces must be cleaned daily (18,27). In general, standard alcohol-based (62-90% ethanol) or hypochlorite-based surface disinfectants (0.1-0.5% sodium hypochlorite) are capable of killing the coronaviruses by destroying their proteins and nucleic acids within one minute of exposure (25,26). While alcohol-based products are considered to be more appropriate for the disinfection of smaller surfaces (e.g., external surfaces of medical equipment), hypochlorite-based products are more suitable for larger surfaces (25). Notably, some guidelines also advocate the use of ultraviolet light in adjunction to these routine disinfection procedures (17,25,26,28).

In addition to following the mentioned disinfection recommendations in a IC center, it is essential to disinfect the IC equipment and change the beddings after each patient visit. As these procedures take approximately 30-60 minutes (19), appointments must be scheduled to allow the required time. In brief, the disinfection of equipment with a standard alcohol-based disinfectant twice (three minutes each) is highly recommended after each patient visit (17,20).

One of the most probable sources of infection and disease transmission in IC is the use of common face masks by different clients. As some of these face masks are not disposable, their proper and regular disinfection is of paramount importance. Therefore, we recommend that face masks be soaked in a standard alcohol-based disinfectant for a few minutes and be washed with soap and water after each appointment. The internal parts of IC devices may also become contaminated and contribute to the transmission of the disease. As the regular disinfection of these parts is not feasible, the only reasonable solution would be to lower the daily frequency of IC tests as far as possible.

Filter

Although there is a lack of data about whether the respiratory tests should be regarded as aerosol-generating procedures(17). ARTP has published guidance that advised the use of a visor and FFP3 (or equivalent) facemask for all those undertaking spirometry(24). But some guidelines do not specify any precaution in this regard(17). Also in IC tests, an article suggests using a high-efficiency filter placed at the canopy blower/port (during the canopy tests)(29). Also, a recent study found that using a filtering facepiece(FFP2) did not alter REE estimated by IC(30). Therefore, we also recommend in the event of a coronavirus epidemic, to perform an IC test, if possible, use a filter (Especially for patients with coronavirus).

Proper Ventilation

Proper ventilation is crucial to any attempts to reduce the transmission of respiratory diseases. Air changes per hour (ACH) is the number of the times the total air in an area is replaced within one hour (19). It has been estimated that in a properly ventilated room, approximately 63% and 99% of airborne contaminants are removed with 2 and 5 ACH, respectively. Since it takes a minimum of 10 minutes for every ACH in a hospital setting (17), some guidelines have suggested that the room be closed for a minimum of one hour after each respiratory test (17). Furthermore, we recommend that the time interval between each visit be at least one hour.

The practical guidance for the use of IC during the current pandemic in clinical settings could be summarized, as follows:

1. Appropriate patient selection to avoid unnecessary tests and initial coronavirus screening for outpatients and the healthy candidate of IC using screening questionnaires via phone 24-48 hours before referral, followed by screening upon arrival by measuring the temperature; we recommend a physician or health provider who is familiar with the COVID approach for the task of selecting the patients and supervising the IC process.
2. Proper timing, determining the exact time of the patient's appointment, and limiting

the number of the referring patients per day to limit the exposure time; the minimum one-hour interval between the end of the previous individual's test to the start of the next individual's test

3. In order to reduce the contact time with the patient, all the required information must be obtained from the patient beforehand and entered into the software before the patient enters the room(29).
4. Provision of technician safety using personal protective equipment (filtering facepiece respirators FFP3 or FFP2, gloves, and goggles/face shields) and performing proper hand hygiene
5. For canopy tests, use a high-efficiency filter (placed at the canopy blower/port) helps to reduce the risk of spreading the disease(29).
6. Provision of disinfectant solutions in hallways and waiting rooms and obliging patients to disinfect their hands before entering the test room.
7. All clients should wear surgical face masks before entering the IC center, as well as in waiting areas.
8. Disinfection of all equipment and supplies by 70-90% ethanol or sodium hypochlorite (0.1-0.5%) after each use (twice, three minutes each) and use of disposable appliances (canopy hood, face mask, flow meter, sampling lines, filters) as far as possible
9. If it is not possible to use disposable face masks, the masks should be immersed in a proper disinfectant solution for a few minutes after each use, washed, and rinsed. If possible, each mask should only be used once a day.
10. After each time of using, all the disposable supplies and equipment should be removed.
11. High-touch surfaces (e.g., beds, tables, doorknobs, handles, phones, keyboards, light switches) must be cleaned with surface disinfectants immediately after each patient's visit, and low-touch surfaces must be cleaned daily.
12. For proper ventilation, the room should be closed for one hour after an IC test or windows should be opened and doors should be closed for 15 minutes.
13. This guideline has been designed for the Indirect calorimetry of outpatients and healthy individuals. Notably, IC in patients with the coronavirus requires more stringent and specialized considerations.

Conclusion

Due to the specific features of COVID-19 (i.e., high transmission rate, long latency period, and high rate of asymptomatic patients) and the fact that the regular disinfection of some parts of the IC devices is not feasible, unnecessary IC tests should be avoided, particularly in the hotspots of the disease. However, if the test must be performed, some of the essential measures are rigorous screening before scheduling each appointment, adjusting the number of reservations per day and the time intervals between the appointments, and adherence to validated infection control recommendations during and after each appointment.

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