# Implementation of Tele-ICU during the COVID-19 pandemic

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**Table S1.** Characteristics of the hospitals participating in the Tele-ICU program coordinated by the *Instituto do Coração do Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo* (InCor-HCFMUSP, University of São Paulo School of Medicine *Hospital das Clínicas* Heart Institute).

| Hospital | Type | Number of ICU beds | Municipality | Distance to InCor-HCFMUSP (km) |
|---|---|---|---|---|
| H1 | Public | 60 | São Paulo | 11 |
| H2 | Public | 62 | São Paulo | 11 |
| H3 | Public | 36 | São Paulo | 7 |
| H4 | Public | 50 | Osasco | 14 |
| H5 | Public | 37 | Guarulhos | 19 |
| H6 | Public | 40 | Santos | 84 |
| H7 | Public | 35 | São Paulo | 13 |
| H8 | Public | 40 | São Paulo | 10 |
| H9 | Public | 40 | São Paulo | 16 |
| H10 | Public | 32 | Itaquaquecetuba | 37 |
| H11 | Public | 14 | Francisco Morato | 38 |
| H12 | Public | 42 | São Paulo | 17 |
| H13 | Public | 58 | Guarulhos | 25 |
| H14 | Public | 25 | Itapevi | 34 |
| H15 | Public | 60 | Presidente Prudente | 552 |
| H16 | Public | 42 | Piracicaba | 160 |
| H17 | Public | 16 | Assis | 428 |
| H18 | Public | 10 | Mirandópolis | 589 |
| H19 | Public | 55 | Franca | 400 |
| H20 | Public | 19 | Jales | 588 |

**Table S2.** Invasive mechanical ventilation settings after Tele-ICU discussions, demonstrating that the objective of implementing a lung-protective ventilation strategy (i.e., low $V_T$, low driving pressure, and low plateau pressure) was duly achieved.[a]

| Variable | Patients on IMV (n = 278) |
|---|---|
| IMV settings on D1 | |
| Compliance, mL/cm$H_2O$ | 30 (25-37) |
| $V_T$, mL/kg of predicted ideal body weight | 6.1 (5.6-6.9) |
| Plateau pressure, cm$H_2O$ | 25 (21-28) |
| Driving pressure, cm$H_2O$ | 13 (11-15) |
| PEEP, cm$H_2O$ | 12 (10-14) |
| $FIO_2$, % | 60 (40-80) |
| $PaO_2/FIO_2$ | 148 (104-223) |
| IMV settings on D2 | |
| $V_T$, mL/kg of predicted ideal body weight | 6.1 (5.6-6.8) |
| Plateau pressure, cm$H_2O$ | 24 (21-28) |
| Driving pressure, cm$H_2O$ | 12 (10-14) |
| IMV settings on D3 | |
| $V_T$, mL/kg of predicted ideal body weight | 6.2 (5.7-6.8) |
| Plateau pressure, cm$H_2O$ | 24 (20-26) |
| Driving pressure, cm$H_2O$ | 12 (10-14) |

IMV: invasive mechanical ventilation; and D: day of Tele-ICU discussion. [a]Values expressed as median (IQR).

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## TREATMENT PROTOCOL FOR PATIENTS WITH COVID-19

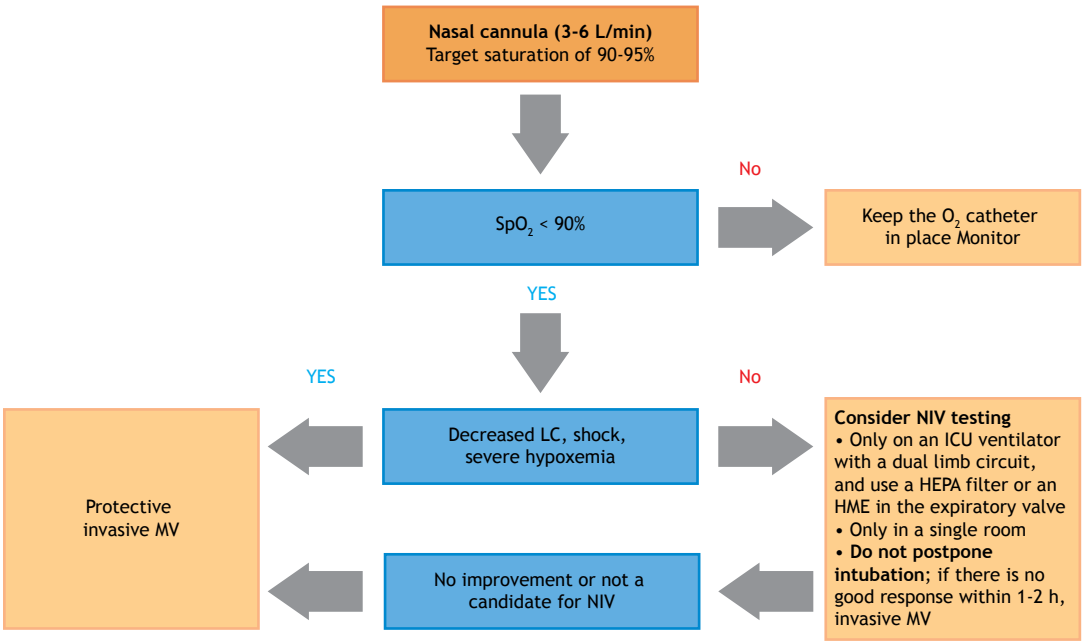


**Chart S1.** Flow chart for initiating oxygen therapy and ventilatory support in patients with respiratory failure. LC: level of consciousness MV: mechanical ventilation; NIV: noninvasive ventilation; HEPA: high efficiency particulate air; and HME: heat and moisture exchanger.

- VCV mode initially (you can switch to PCV if the ventilator alarm is going off)
- $V_T$ = 6 mL/kg of ideal body weight (see table on the right)
- Adjust flow 30-60 L/min ( ◣ wave if possible)
- $FiO_2$ = 60% and PEEP = 10 $cmH_2O$
- RR = 25 breaths/min (check for auto-PEEP on the flow curve)
- Driving pressure < 16 $cmH_2O$ preferably (reduce $V_T$ if necessary)
- Neuromuscular blockade if $V_T$ > 6 mL/kg. the patient is "fighting the ventilator", or IMV > 12 L/min (assess daily the possibility of discontinuation)
- Based on $SpO_2$, adjust PEEP and $FiO_2$ (see below) every 30-60 s until reaching target $SpO_2$
- At target $SpO_2$: perform a control blood gas analysis after 30 min
- If pH < 7.15, consider increasing RR to 35 breaths/min or increasing $V_T$ if driving pressure < 16 $cmH_2O$
- Assess whether $SpO_2$ is at its target value every 2-6 h
- Avoid reducing PEEP in the first 12-24 h
- On the subsequent days, adjust settings according to table and assess the possibility of weaning from IMV

| Men | | Women | |
|---|---|---|---|
| Height (cm) | $V_T$ = 6 (mL/kg) | Height (cm) | $V_T$ = 6 (mL/kg) |
| 140 | 230 | 140 | 205 |
| 145 | 260 | 145 | 235 |
| 150 | 290 | 150 | 260 |
| 155 | 315 | 155 | 290 |
| 160 | 340 | 160 | 315 |
| 165 | 370 | 165 | 340 |
| 170 | 400 | 170 | 370 |
| 175 | 425 | 175 | 400 |
| 180 | 450 | 180 | 425 |
| 185 | 480 | 185 | 450 |
| 190 | 505 | 190 | 480 |
| 195 | 535 | 195 | 510 |
| 200 | 560 | 200 | 530 |

Source: COVEM protocol

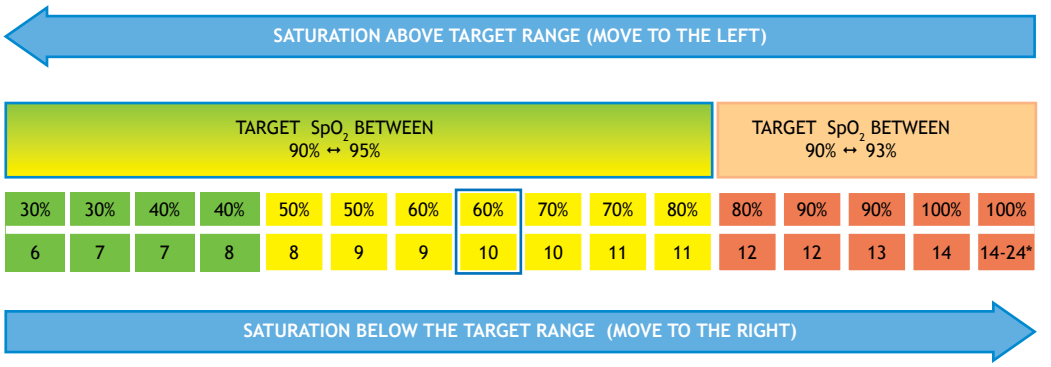


**Chart S2.** Initial settings of the lung-protective ventilation strategy. VCV: volume-controlled ventilation; PCV: pressure-controlled ventilation; and IMV: invasive mechanical ventilation.

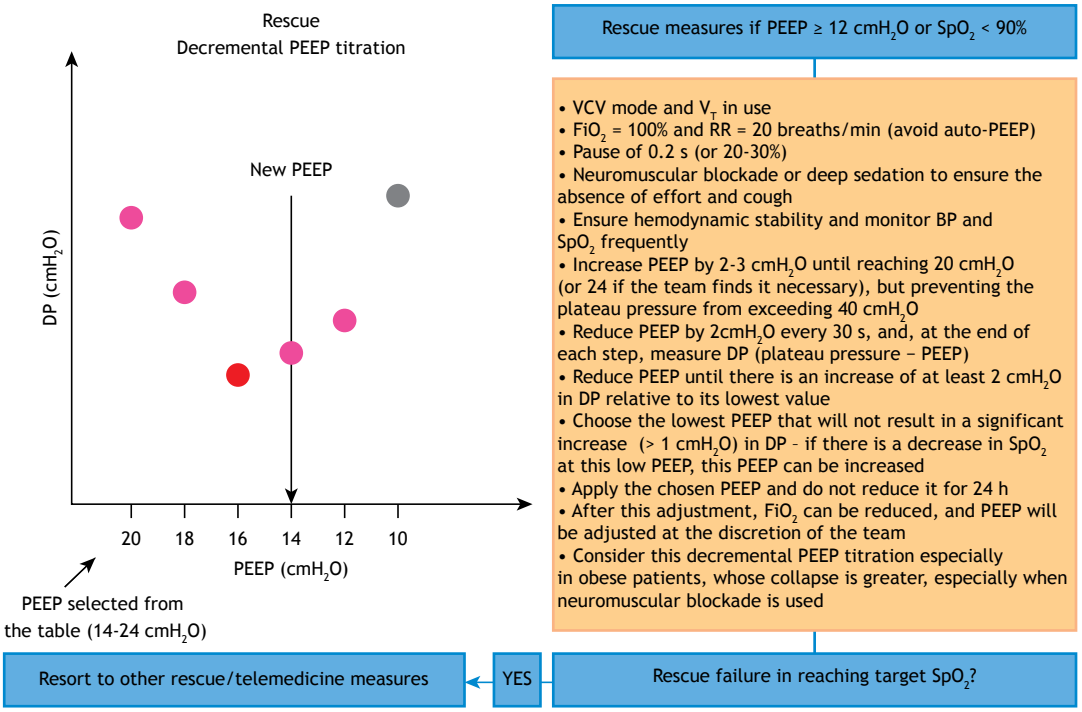


**Chart S3.** Rescue maneuvers if $FiO_2$ ≥ 80% or PEEP ≥ 12 mmHg. VCV: volume-controlled ventilation; BP: blood pressure; and DP: driving pressure.

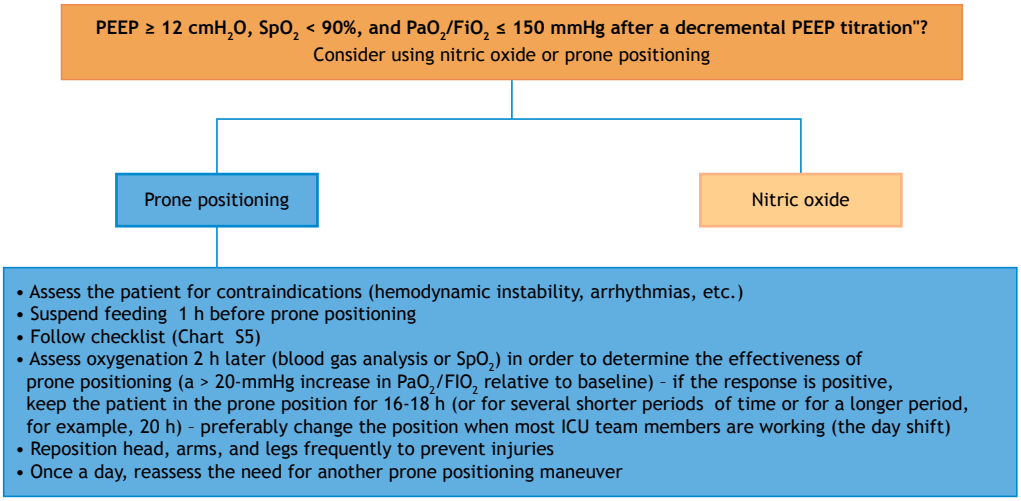


**Chart S4.** Rescue maneuvers after a downward adjustment in PEEP.

## PRONE POSITIONING CHECKLIST - ARDS:

Date and start time of the proning maneuver: __/__/__ __:__

Date and start time of supine positioning: __/__/__ __:__

| Steps Before the Maneuver |
|---|
| ( ) Assess for indication and contraindications in conjunction with the team.<br>Relative contraindications: hemodynamic instability, 2nd/3rd trimester pregnancy, polytrauma, and spine instability |
| ( ) Ensure that adequate staff are present (at least 5 people, including a physician, a nurse, and a respiratory therapist) and gather supplies (cushions and a mattress).<br>Cushions: thoracic, hip, and leg cushions and a ring-shaped head cushion |
| ( ) The team should determine whether there is a need for procedures (CT, invasive procedures, etc.) before the proning maneuver and if so, perform them before proning. |
| ( ) Lubricate the patient's eyes and provide oral hygiene care. |
| ( ) Ensure the patient's clinical hemodynamic stability. |
| ( ) Have airway equipment available for complications. |
| ( ) Check endotracheal tube (ETT) position on chest X-ray. Secure ETT properly. Disconnection from the ventilator can lead to derecruitment and worsening of oxygenation. Perform endotracheal aspiration prior to the procedure and use a closed-suction system. |
| ( ) Ensure that all devices (central access catheter, IBP catheter) are secured. If the patient does not have a central venous catheter or an IBP catheter in place >> perform the procedure. Disconnect the bladder catheter because of risk of injury. |
| ( ) Assess cervical mobility. |
| ( ) Suspend feeding, ideally 1 h before proning. |
| ( ) Always protect bony prominences with thin hydrocolloid dressings. The use of cushions should be decided on a case-by-case basis. |
| ( ) Gather the team and decide on the maneuver protocol. All team members should know their role and how they will carry it out. A physician will be in charge of the airway and should be ready to reintubate if necessary. |
| **Steps During the Maneuver** |
| ( ) Immediately before the maneuver - $FiO_2$ = 100%, provide deeper sedation if necessary. |
| ( ) Position catheters/infusions (from the waist up -> at the head of the bed// from the waist down -> at the foot of the bed). If the patient is undergoing chest tube drainage, the collection tube should be moved to the side the patient will be lying on. |
| ( ) Place the patient in the horizontal supine position. |
| ( ) The team leader should be at the foot of the bed at all times to direct the team, and ensure that the ETT and the patient's head are secured. |
| ( ) Remove any material that can potentially cause injury (electrodes, folds in sheets, etc.). |
| ( ) Remove anterior electrodes and maintain oximetry monitoring only. Disconnect and adjust the cables connected to the monitors. |
| ( ) Restart feeding after everything is adjusted. |
| **Steps After the Maneuver** |
| ( ) Quickly reconnect monitoring equipment; reassess ETT and IMV settings. |
| ( ) Reassess prominence protection, skin, and cushions. |
| ( ) Position the patient in the swimmer's position. |
| ( ) Determine the need for another aspiration. |
| ( ) Keep the bed in reverse Trendelenburg (10°-20°). |
| ( ) Restart feeding after everything is adjusted. |
| **Maintenance -> Goal: 16-18 h in the Prone Position** |
| ( ) Reposition the arms and head every 2 h. |
| ( ) Check the eyes (there should be no contact between the eye and the surface). |
| ( ) Slightly lateralize the patient's body (place cushions on the same side as the patient is facing). |
| ( ) Document procedures and adverse events, as well as the times at which adverse events occurred and procedures were performed. |

**Chart S5.** Checklist for the use of prone positioning in ARDS. IBP: invasive blood pressure; and IMV: invasive mechanical ventilation.

**Acidosis and hypercapnia goals**

- Goal pH ≥ 7.25: if pH < 7.25, increase RR up to 30-35 breaths/min (tolerate pH as low as 7.15)
- pH < 7.15 and RR > 35 breaths/min:
  - Treat metabolic acidosis
  - Reduce dead space (remove the plastic extension from the HME)
  - Increase VT by 1 mL/kg at a time (up to a maximum of 8 mL/kg) even if it results in nonprotective parameters (i.e., increased driving pressure)
  - Reduce $CO_2$ output (treat fever and adjust feeding)
  - Increase RR up to 40-50 breaths/min (be alert to the risk of auto-PEEP and barotrauma)

**Driving pressure > 16 cm$H_2O$ or plateau pressure > 30 cmHO?**

- Consider alveolar recruitment maneuvers and downward titration of PEEP
- Consider prone positioning

**Refractory hypoxemia or hypercapnia?**

- Consider alveolar recruitment maneuvers and downward titration of PEEP
- Consider evaluation by a team of ECMO specialists

**Chart S6.** Acidosis and hypercapnia: goals and control measures. HME: heat and moisture exchanger; and ECMO: extracorporeal membrane oxygenation.

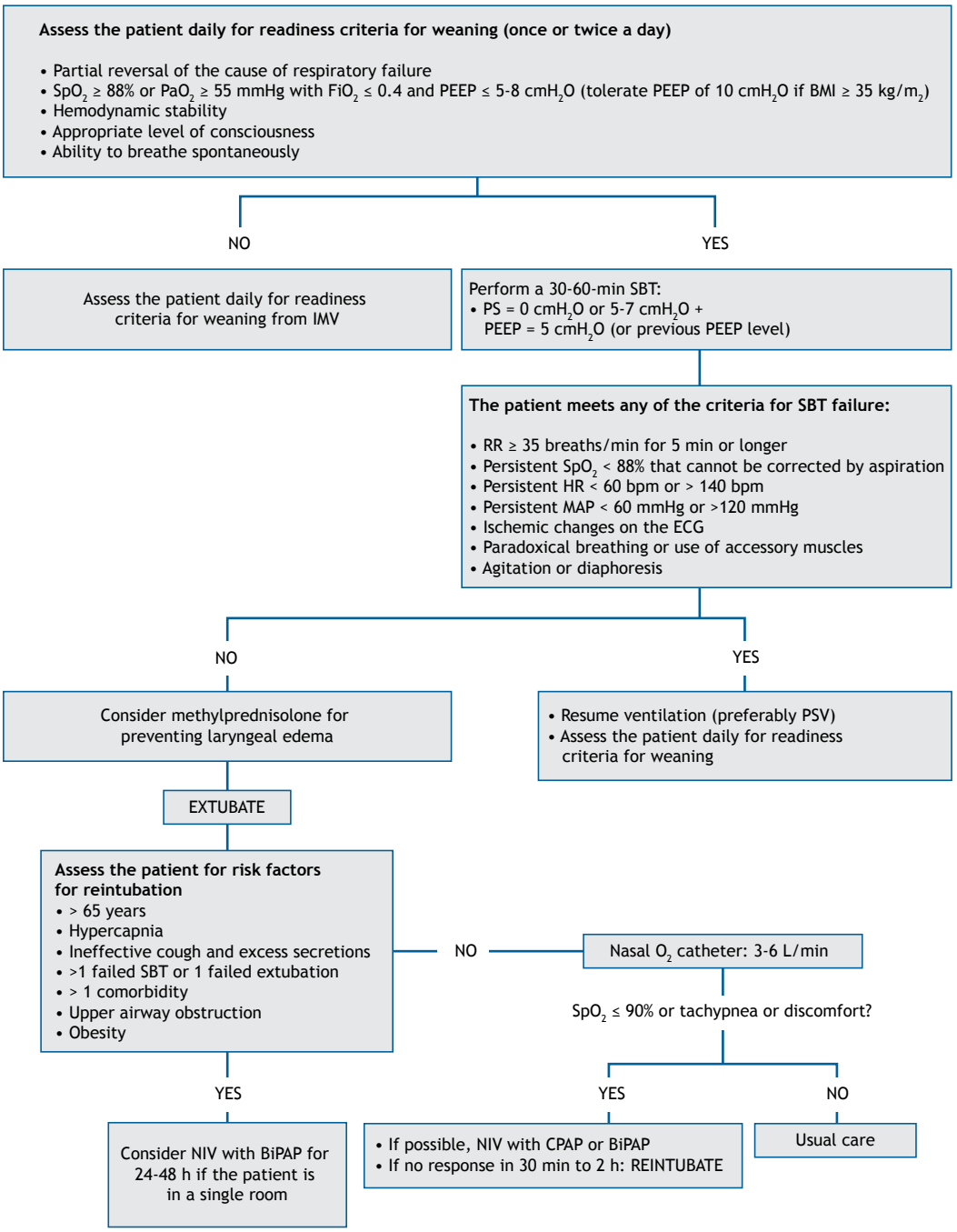


**Chart S7.** Protocol for weaning from invasive mechanical ventilation. IMV: invasive mechanical ventilation; SBT: spontaneous breathing trial; PS: pressure support; MAP: mean arterial pressure; ECG: electrocardiogram; PCV: pressure-controlled ventilation; and NIV: noninvasive ventilation.

## DEVELOPMENT OF THE ICONF PLATFORM

In order to meet the new demands and challenges involved in providing Tele-ICU services to public hospitals, the *Instituto do Coração* developed its own platform, designated iConf, which includes the main web conferencing features of a commercial system but under an open-source license. The decision to develop its own platform was made to prevent potential conflicts regarding leaks of sensitive personal data, such as test results and patient diagnoses. On the iConf platform, all Tele-ICU data are stored on a server at InCor and are not shared with or handled by third parties, as is the case with commercial systems.

The main resources available on iConf include audio or audio/video sharing; presentations with extended whiteboard capabilities, such as a pointer, zooming, and drawing; public/private chat; screen sharing and an integrated Voice over Internet Protocol (VoIP) using FreeSWITCH (https://freeswitch.org); and support for the presentation of PDF documents and Microsoft Office documents. Such resources are available through public domain libraries (https://bigbluebutton.org/).

The iConf platform was built with the standard HTML5 user interface and uses web browsers (Google Chrome, Firefox, Opera, and Safari) for real-time communications, such as sending or receiving audio or audio/video and sharing screens, through WebRTC. In addition to these features, the iConf platform allows recording of telemedicine sessions for auditing and traceability purposes, as well as integration with third-party systems through a standardized communication interface (Figure S1).

In order to use iConf, one just needs to share the URL defined for the telemedicine session, which can be done either automatically, using an external scheduling system, or manually by the operator. The defined URL can be associated with a date, time, and duration, as well as with a six-digit token. The URL and the token are both shared with those involved in the discussion; however, the URL and the token cease to be valid when the discussion date and time expire, ensuring that they will not be used in other discussions.

In order for iConf to be operational, telemedicine stations were set up with dual high-resolution monitors, a camera, an echo-canceling microphone, and an audio playback device. The web conferencing sessions between health care professionals are displayed on one of the dual monitors, whereas information from electronic medical records of the hospitals participating in the discussion is displayed on the other. In addition, in order for all variables of interest collected during the discussion of clinical cases to be recorded safely, following international standards such as the Health Insurance Portability and Accountability Act, all discussions are recorded in MPEG-4 file format. Therefore, if there is a need to review a case, all discussions are available for consultation.

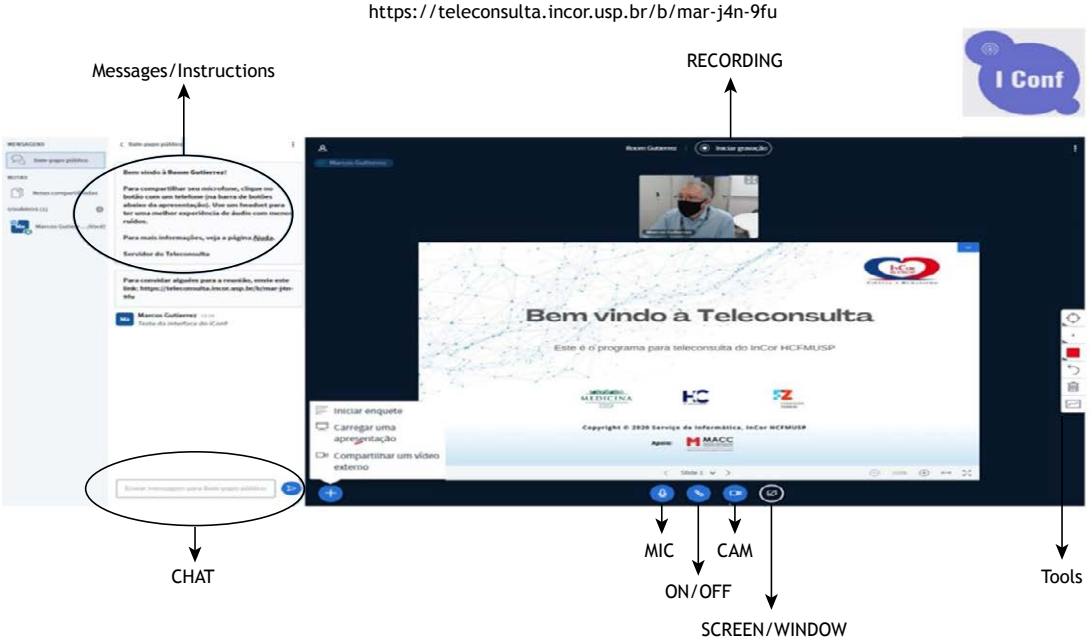


**Figure S1.** Interface and main resources available on iConf, a Tele-ICU platform.

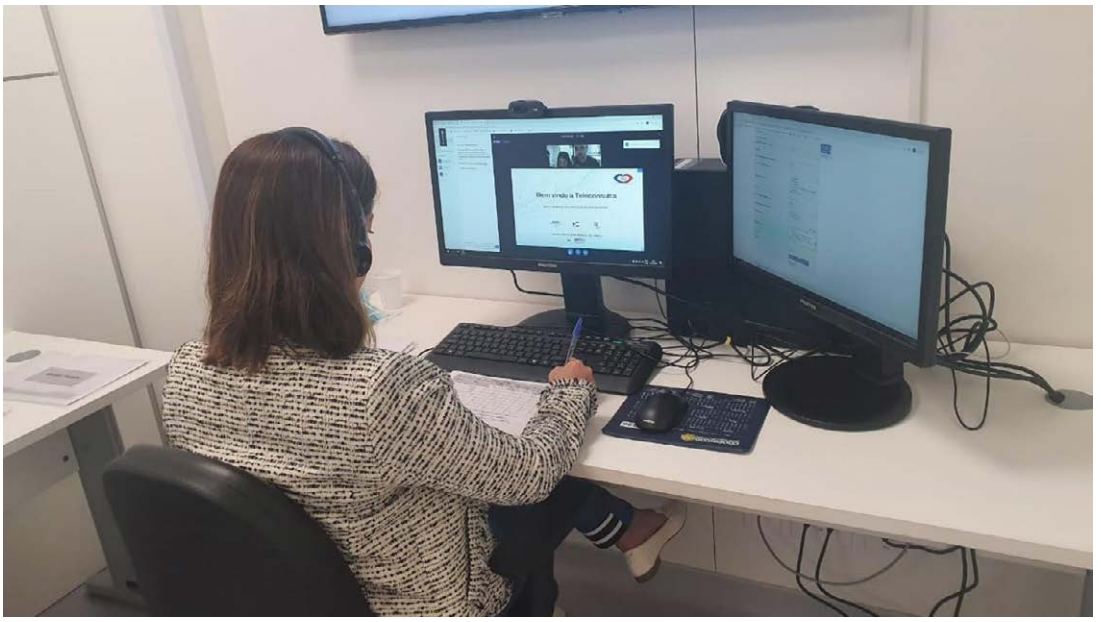

**Figure S2.** Photo illustrating a teleconsultation.