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SERIES: RADIOLOGY AND COVID-19

Managing the pandemic from the radiology department's point of view[☆]



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Abstract The COVID-19 pandemic is forcing our entire society to adopt numerous changes, at least until an effective treatment and/or vaccine becomes widely available. Because COVID-19 is a new disease that has required us to make complex decisions based on scant evidence, the pandemic is having an enormous impact on our health system.

Radiology departments play a fundamental role in the management of COVID-19, both in the diagnosis of the disease and in the posterior management of patients. To ensure the safety of patients and healthcare professionals, it is essential to understand the infection so that safe circuits can be implemented.

This article summarizes the pathophysiology of COVID-19 infection and explains the measures that radiology departments need to adopt during the pandemic.

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PALABRAS CLAVE

Infección por coronavirus;
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Gestión

Gestión de la pandemia. Visión del radiólogo

Resumen La infección COVID-19 está obligando a toda la sociedad a adoptar numerosos cambios, al menos hasta que exista un tratamiento o vacuna eficaces. El impacto que está produciendo en nuestro sistema sanitario tiene pocos precedentes similares, al tratarse de una patología nueva y que ha obligado a tomar decisiones complejas a partir de una evidencia escasa.

Los servicios de radiología tienen un papel fundamental en el manejo de esta patología, tanto en el diagnóstico como en el manejo posterior de los pacientes. Pero, para ello, se debe

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entender la infección, de forma que se puedan poner en marcha circuitos seguros para pacientes y trabajadores.

En este artículo se resume la fisiopatología de la infección COVID-19 y se presentan las medidas que se deben adoptar en el servicio de radiología.

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Introduction

The Covid-19 infection began as a pneumonia of unknown origin, the first cases being reported in the People's Republic of China in December 2019.¹ Following these first reports, the disease's origin was investigated, the infected population was isolated and other preventive measures were taken. By 7 January 2020, the virus causing the infection had already been isolated²: a coronavirus named 2019-nCoV ("new coronavirus detected in 2019"). A few days later, the virus's genome was available³ and work began on developing tests to detect and diagnose it. The infection spread to 24 countries in under a month. On 11 February 2020, the World Health Organisation called this new infection Covid-19,⁴ and just one month later, on 11 March, declared it a worldwide pandemic. Since then, the number of cases has continued to grow at differing rates all over the world, and by the beginning of July 2020, more than 11 million cases and over half a million deaths due to Covid-19 infection had been reported.

The first study on cases of Covid-19-induced pneumonia was published in January 2020, involving 41 patients.⁵ Since then, the number of publications has grown almost exponentially⁶ and, in the field of radiology, not only on cases with pulmonary pathology but also with Covid-19 infection symptoms in different organs and systems.

Covid-19 infection continues to pose numerous question marks with regard to epidemiology, virology, response to treatment and the development of an eventual vaccine. The percentage of the population that is immune is also unclear, as is the infection's prevalence outside the highest spikes in incidence. All these data render it very complex to establish recommendations for adapting healthcare processes in radiology departments.

Different studies have been carried out on the analysis of the possible impact of Covid-19 infection in the coming months and even years.⁷ In view of the difficulty involved in obtaining robust data and the scientific novelty of this infection, analyses are normally based on extrapolating the results of infections produced by similar viruses (other coronaviruses) and on the study of mathematical models based on the different variables available. In this context, conclusions can change as new data are obtained, although certain points do appear to be clear:

- The current crisis, with a worldwide pandemic and areas with a very high prevalence, will not disappear in a matter of months. Social distancing and lockdown measures have

made it possible to attenuate the number of deaths and infections, although this has also results in a low percentage of immunised people. This means that any approach to phasing out distancing measures (if indeed they are eliminated) must be staggered and slow.

- It is not clear how the virus will behave as the seasons change, or if it will mutate in the future. Coronaviruses usually present frequent mutations,⁸ although it is not clear that these mutations are taking place faster than expected or that they may impact the disease or its transmission.⁹
- There are clinical trials underway to test the efficacy of medical treatments to prevent infection. There are already projects for obtaining vaccines that could be available in the first quarter of 2021. All of these variables have a big influence on the management of the infection and on protection measures. Therefore, the risk of infection continues, which is why a set of safety measures must be maintained in radiology departments. The intensity of these measures should be bolstered when the prevalence of the disease increases, which is to be expected given the possibility of new periodic crises of different intensity. Therefore, all radiologists should be familiar with Covid-19 infection, the SARS-CoV-19 virus and how to prevent infection. This will make it possible to design safe and efficient healthcare pathways.

The Covid-19 infection. What the radiologist should know SARS-CoV-2 virus

The SARS-CoV-2 virus is a β genus coronavirus (one of the four genera of coronavirus), with a structure and a genome very similar to other known coronaviruses, such as SARS-CoV and MERS-CoV.¹⁰ It is a virus with a single capsid-enveloped RNA chain of variable morphology (normally rounded and ovoid) with a size of between 60 and 140 nm.¹¹ The nucleocapsid is protected by a phospholipid envelope into which the surface glycoproteins are inserted (S, HE, M and E).¹² Of these, the S protein is particularly relevant, as it binds to the cell receptor to allow the virus to enter the cell.¹³ The S protein is divided functionally into two domains: S1 (responsible for binding with the cell receptor) and S2 (which permits fusion with the cell membrane).¹⁴

Pathophysiology of Covid-19 infection. The basics

When the virus makes contact with the mucosa cells (nasopharyngeal or respiratory), it binds to the ACE2

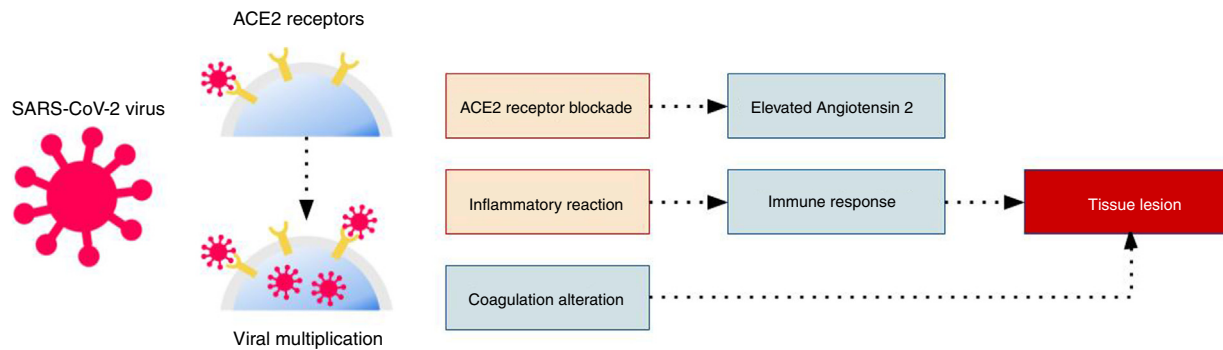


Figure 1 General pathophysiology of the Covid-19 infection. The SARS-CoV-2 virus binds to the ACE2 receptor which is located on the surface of certain cells. Once bound to the membrane, it enters the cell and replicates, while also blocking the receptor. The phenomena produced by the virus can be divided into three major groups: those caused by inflammatory response and the immune system, those due to alteration of the angiotensin II system through receptor blockade, and those that are secondary to the coagulopathy and thrombotic phenomena produced by the virus.

(angiotensin-converting enzyme 2) receptor.¹⁵ The ACE2 receptor is fundamental in the renin-angiotensin-aldosterone system, and in normal conditions is very important in the regulation of homeostasis and the balance of fluids and electrolytes. In this way, besides playing a fundamental role in cell infection, the fact that the virus blocks this receptor could be another of the virus's pathogenesis factors.¹⁶ Once inside the cell, the virus releases its RNA gene into the cellular cytoplasm and replication begins. Once the new viral particles have been formed, they are released in order to re-initiate the cycle. This cycle has been studied, and different therapeutic strategies have been proposed that seek to block the different phases. The ACE2 receptors are involved in many cell tissues, particularly the lungs (type II pneumocytes), heart, blood vessels, kidneys, liver and gastrointestinal tract.¹⁶ Although certain tissues present a greater density of ACE2 receptors than the lungs, Covid-19 infection usually begins in the lungs,¹⁷ and certain tissues with a greater density of ACE2 receptors than the lungs present less or little involvement in Covid-19 infection, as occurs in the gallbladder, the kidneys, seminal glands or testicles.¹⁷ What happens once the infection begins depends on many factors. The pathophysiology of Covid-19 infection is complex and not fully understood, involving several different mechanisms:

- Alveolar inflammatory reaction.
- Involvement of the capillaries adjacent to the alveoli, which may lead to thrombotic microangiopathy phenomena.
- ACE2 receptor blockade.
- Coagulation alteration, with hypercoagulability state.
- Triggering of an important immune response, in the so-called "cytokine storm".

The basic pathophysiology of Covid-19 infection is presented in Figs. 1–3. These figures are adaptations of the series published in references.^{12,16,18,19–26} These references should be reviewed in order to further explore the pathophysiology. In summary, the main points that must be considered in order to understand the pathogenesis, radi-

ological manifestations and treatment possibilities are the following:

- The virus activates inflammatory and immune response in the lungs, with the production of cytokines and interferon and activation of lymphocytes.
- This response may be insufficient, so the organism reacts, by amplifying it. This gives rise to the so-called cytokine storm and may trigger lymphocyte depletion.
- At the same time, a coagulopathy is produced, in which local factors (endothelial aggression), venous stasis and a state of hypercoagulability play a part.
- In severe cases, the sum of all these factors gives rise to symptoms that have been called diffuse pulmonary intravascular coagulopathy which, unlike the classic symptoms of disseminated intravascular coagulopathy, does not present thrombocytopenia.²²

Although the virus can affect other organs directly, many of the changes that occur outside the lungs are related more to systemic, thrombotic and microangiopathic involvement than to the direct action of the virus on the specific organ,^{22,27} although in some cases, such as kidney disease, the mechanisms can be more complex.²⁸

Covid-19: transmission and prevention

The main form of transmission of the SARS-CoV-2 virus from one human being to another is via the secretions of infected persons, mainly through direct contact with respiratory droplets of more than 5 microns (and which can be transmitted at distances of up to 2 metres).²⁹ Contact between the hands or contaminated fomites with the mucosa of the mouth, nose or eyes can constitute an a route of infection. The virus has also been detected in the saliva of infected patients,³⁰ which opens up the door to diagnosis via saliva samples.³¹ The virus is known to be able to persist for up to 9 days³² on certain surfaces (metal, plastic or glass), although it can be neutralised by means of the usual disinfection measures. The virus has been isolated in smaller droplets, and while the possibility of airborne transmission is still being debated,³³ some cases of this type of transmission

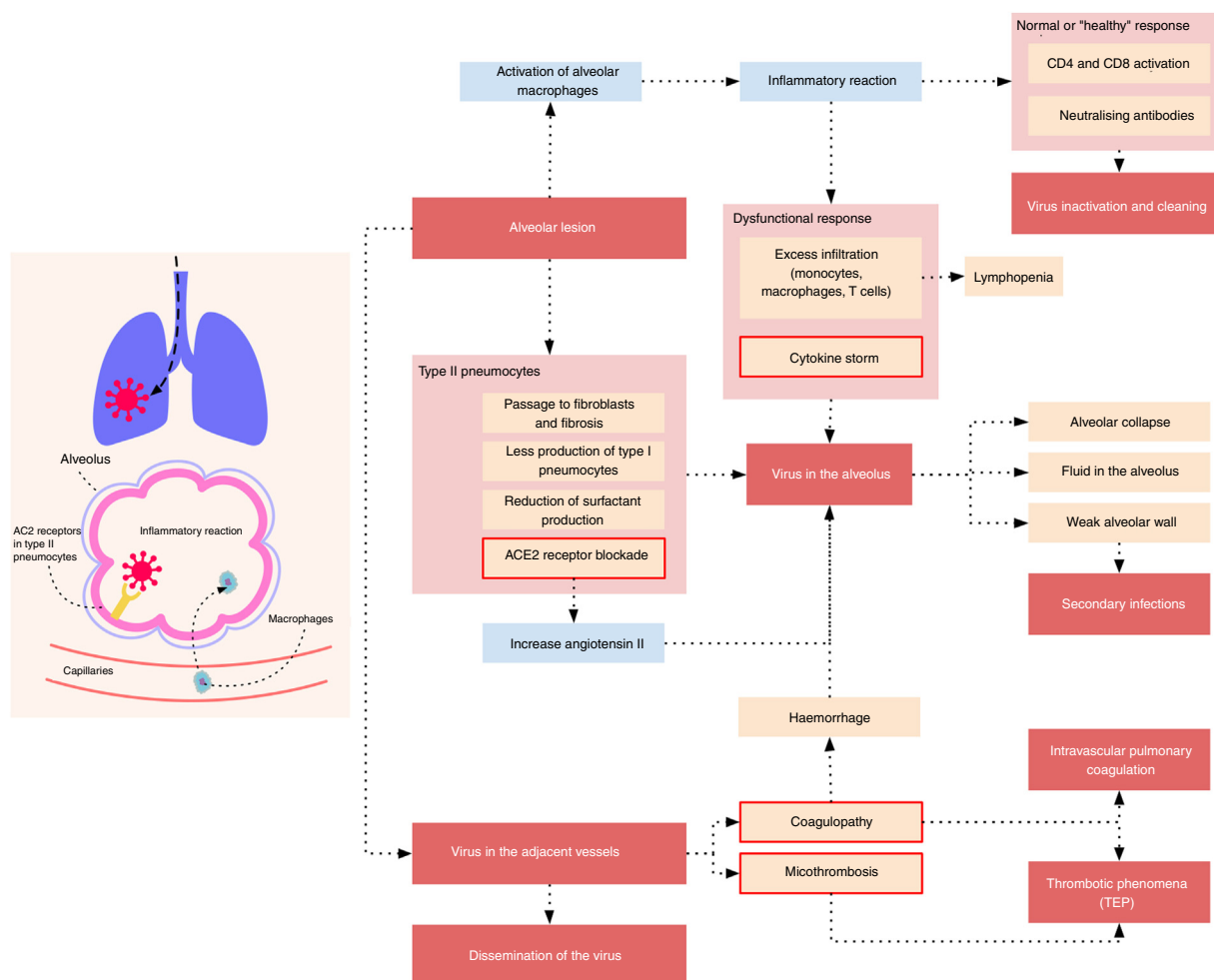


Figure 2 General pathophysiology of Covid-19 infection. The chart summarises the different phenomena occurring in the tissues once the infection has been triggered. The mechanisms of infection are complex and are not fully understood. The effects on tissues are the result of the direct action of the virus and the host's response, both the indirect inflammation and immune response. The so-called dysfunctional response determines what is known as the 'cytokine storm', and this abnormal response is one of the main causes of severe pathology in cases with a poor clinical evolution. This effect is compounded by the action of thromboembolic alterations (virus induces an abnormal thrombotic response) and the effects produced by the alteration of the angiotensin 2 metabolic circuit.

have been demonstrated in closed and poorly-ventilated environments.³⁴ For these reasons, and while not all recommendations include measures for preventing airborne transmission, it is important to maintain good hygiene and suitable ventilation of all rooms.³⁵ The frequency of bowel involvement means that faecal transmission is a possibility. One recent review³⁶ shows that this has yet to be clarified, and that although there is no evidence of transmission, strict hygiene measures must be taken to prevent it. Vertical (mother-to-child) transmission seems somewhat unlikely, although some isolated cases have been published.³⁷ The presence of the virus in the semen of a small group of patients has been demonstrated, albeit only in the initial days of convalescence.³⁸ Nevertheless, sexual transmission seems somewhat unlikely.³⁹

One important problem in the prevention of this disease is the possible transmission by asymptomatic individuals. The median incubation period is 5-6 days, with a range of

1-14 days, although 97.5% of symptomatic cases develop within 11.5 days following exposure.⁴⁰ It has been shown that asymptomatic individuals can transmit the infection,⁴¹ which makes it necessary to be very strict with the preventive measures and requires the development of detection policies for these potentially contagious individuals.

With regard to the transmission capacity of symptomatic patients, it has been seen that most of those infected have a high viral load before and during the first few days after the onset of symptoms.⁴² In patients with mild clinical symptoms, viral load is low as of the second week following the appearance of the symptoms, there being little likelihood of their transmitting the infection at that point, even although the virus can be detected with microbiology techniques (PCR).⁴³ In this way, transmission would mainly occur in the first week after the onset of symptoms (between days 2 and 3 and days 7 and 8) in mild cases. In more severe cases, transmission would be more intense and longer lasting.⁴

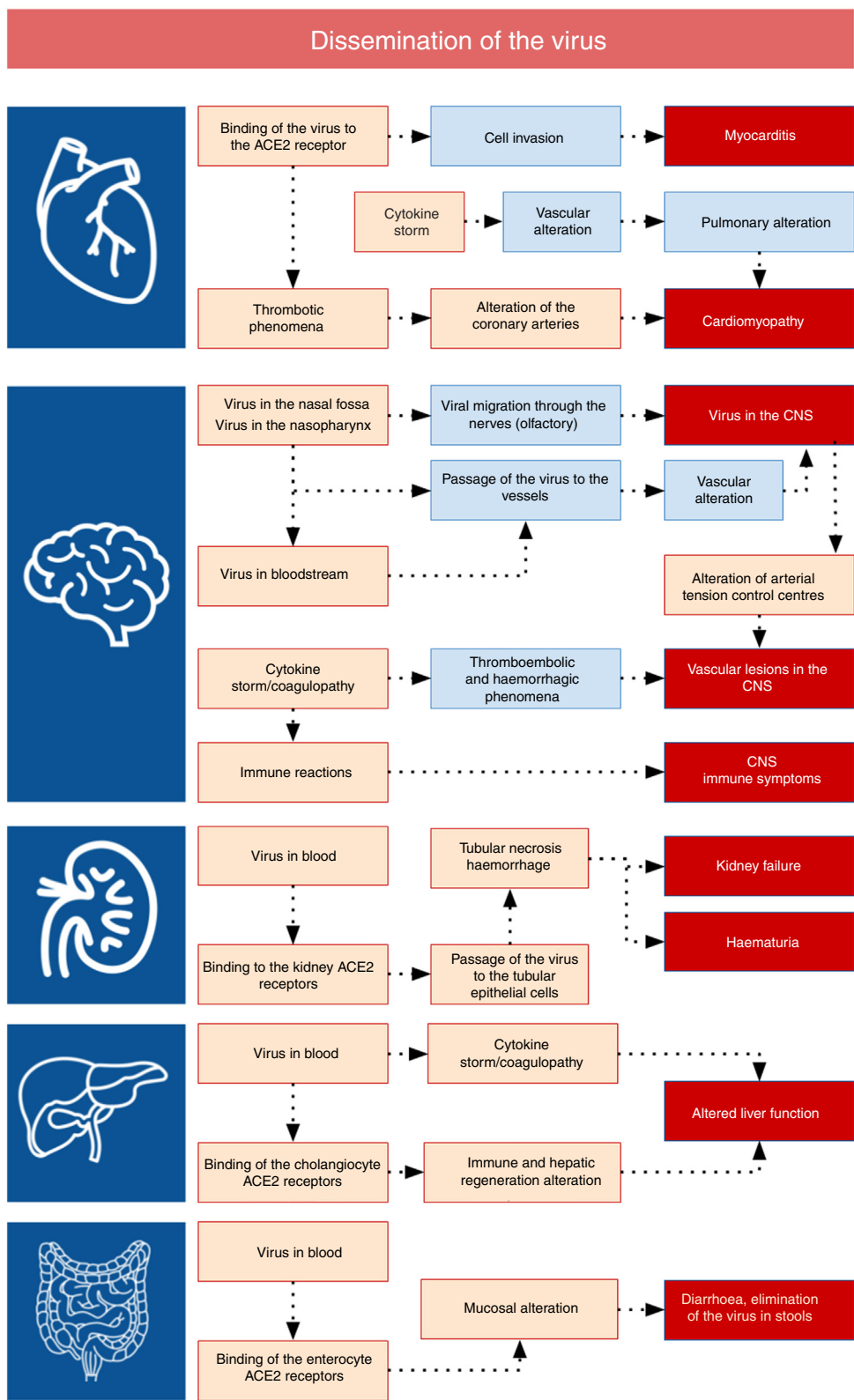


Figure 3 Basic diagram of the published theories about the pathophysiology of Covid-19 infection in different organs. In all of them, the main agent is the ACE2 receptor, which allows the virus to bind to the cell. However, the phenomena related to immune response and coagulopathy sometimes play a more important role.

Prevention (basic measures)

In view of the above, the preventive measures with regard to staff are based on:

- Establishing barriers (distance or physical barriers) between people. The basic measures would be the safety distance (2 metres) and the use of face masks. When dealing with infected or possibly infected patients, the use of personal protective equipment (PPE).
- Hygiene. Hand sanitisation is the simplest and most effective way of preventing the transmission of microorganisms, including SARS-CoV-2.⁴⁴ Washing the hands with soap and water will suffice (there is no need to use antibacterial soaps), rubbing the hands for at least 40-60 seconds. Hydroalcoholic hand sanitisers are an alternative for quick disinfection although they should only be used once the hands are clean.
- Identifying infected patients and possible carriers. In the case of symptomatic patients, it is easier to comply with the measure.: However, it is important to maintain a detection policy for asymptomatic carriers and to avoid any possible exposure. The policies put in place may vary from one site to another, although, generally speaking, carrying out tests on all workers is recommended,⁴⁵ as is enforcing certain measures that will make it possible to identify potentially infected persons when they come to the radiology department.

Diagnosis of Covid-19 infection

Diagnosis of Covid-19 infection is based on the direct or indirect detection of the virus.⁴⁶ Microbiological and laboratory tests have improved in terms of sensitivity and specificity, although results must be interpreted with caution in view of the possibility of false negatives and false positives. Imaging tests are of great value in the management of patients with Covid-19 infection, as will be seen in forthcoming articles in *RADIOLOGÍA*, although their usefulness in the initial diagnosis is limited to specific cases (mainly patients with a high suspicion and negative laboratory tests, or cases in which a quick diagnosis is required and no laboratory tests are available).^{47,48}

Safe management of the Radiology department in the Covid era

The *Sociedad Española de Radiología Médica* [Spanish Society of Medical Radiology] (SERAM) has drafted a document focusing on the management of radiology departments during the Covid-19 pandemic⁴⁹ which reviews the existing literature and issues a set of recommendations. A Delphi questionnaire on these recommendations was used to ascertain the consensus among different radiologists in Spain. This questionnaire yielded 34 recommendations, which can be consulted in the cited reference.

Measures and recommendations

Fig. 4 is an infographic that summarises the main measures that should be taken in a radiology department to guarantee a safe working environment. It is a general document that can be applied both to a pandemic situation and to situations with a low prevalence of the disease, but in which safety measures must still be taken.

Some of the measures that must be addressed are listed below.

Basic protection measures

Personal Protective Equipment (PPE): these are barrier systems that should be used by staff to minimise the risk when studying a patient with conformed or suspected Covid-19 infection. Certain basic measures (specific clothes, surgical face masks, caps and gloves – if deemed necessary) are used to establish three levels of protection according to the risk⁵⁰:

- 1 First level (areas with possible contact with patients).
- 2 Second level (when there is going to be contact with patients).
- 3 Third level (when aerosols may be produced).

It is important to remember that both the recommendations and the material used may change, so the latest guidelines of the Spanish Ministry of Health or the local Ministries of Health should be checked. Table 1 includes the recommended measures at the time this document was drafted.

Face masks: the use of face masks has become widespread as the Covid-19 pandemic has advanced. At the time of writing this document, face coverings are obligatory for patients and health staff alike.

Structural measures: in coordination with the corresponding organic and functional manager, and consisting basically of:

- Adapting waiting rooms to make sure that the minimum distance is guaranteed (2 metres, or 1.5 metres if patients are wearing face masks).
- Mark out corridors and safe zones.
- Adequate signage.
- Partitions and isolation measures for administrative staff.

Measures to guarantee distancing

- Among the staff: ensure suitable distribution of workstations; facilitate non-attendance-based radiology, with appropriate shifts; define a policy for the use of common rooms; avoid visits from staff from other departments (telephone inquiries, virtual meetings, etc.).
- Reduce the number of people having to go to the department (staggered appointments, one-off tests, ask patients not to come accompanied but, if they do, never by more than one person, etc.).

Measures for preventing the transmission of infection at workstations

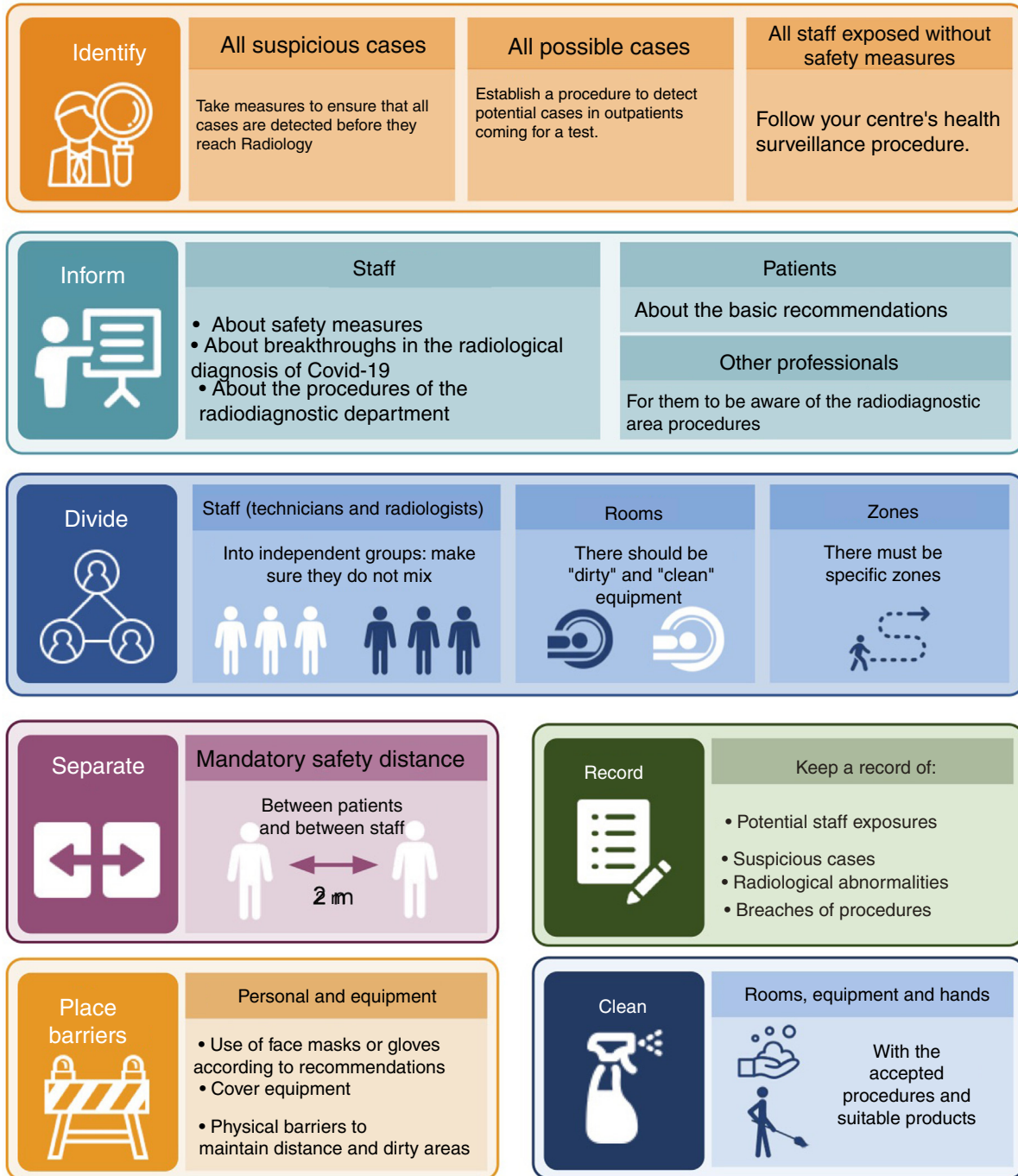
- Facilitate hand hygiene, with informative signage, bottles of hand sanitiser, etc.

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Concept and design: Pablo Valdés Solís



SEGECA and SERAM recommendations on measures in radiodiagnostics for Covid-19 infection. They should be adapted to the situation (prevalence) at all times.

Figure 4 The main measures that should be taken in a radiology department to guarantee a safe working environment.

Table 1 Use of personal protective equipment. Recommendations may change from week to week, depending on the new discoveries about the aetiopathogenesis of Covid-19 infection.

Type of patient care	Examples	Respiratory protection equipment	Gown and eye protection	Gloves	Hand hygiene
More than 2 metres away	Walking in corridors	Respiratory protection not required	Usual uniform	According to standard precautions	Always
Between 1 and 2 metres	Performing tasks in the room more than 1 m away from the patient	Surgical mask (and/or face shield)	Disposable gown	According to standard precautions	Always
Less than 1 m away/physical contact	Performing imaging tests	Surgical mask (and/or face shield)	Waterproof gown (and eye protection if face shield is not used)	Whenever there is contact with the patient and their environment	Always
Procedures that generate aerosols	Respiratory tract procedures (such as bronchoscopy or intubation) or which may cause coughing (such as chest interventions)	FFP (FFP2 or FFP3), depending on availability	Waterproof gown and watertight eye protection	Always	Always

Observations:

- If certain items of equipment are not available, the preceding one on the scale should be used.
- If surgical masks are not available, a face shield may be used, which offers sufficient protection against droplet transmission.
- A disposable gown may be used over the waterproof gown so that the waterproof gown can be reused.

- Personalise workstations, making sure that staff do not share material. Clean all workstations thoroughly at the beginning and the end of shifts.
- Use disposable gloves when shared equipment is to be handled (such as workstations).
- Prohibit food or eating at workstations. Use only disposable containers for drinks.
- Wear clean uniforms for each shift. Do not take used clothes home to wash.

Ascertain the risk of exposure

By reviewing the patient's medical record, performing diagnostic tests or specific questionnaires,⁵¹ depending on the situation or the level of infection in the community. Some protocols include the performance of analytical tests (PCR) prior to surgical procedures or interventions, although these protocols are variable. In any event, these procedures should never replace personal protective measures, in view of the possibility of false negatives in laboratory tests.⁵² Generally speaking, performing radiological tests (CT scan or chest X-ray) is not recommended as a screening method of asymptomatic patients,⁵³ particularly in low-prevalence situations. In a high prevalence environment, the CT scan could be justified on account of its high negative predictive value in situations in which a quick decision needs to be taken and no accessible laboratory tests are available. There are no analyses that demonstrate this measure is cost-effective.⁵⁴

Ascertain immune status of staff

All radiology department staff should be tested to ascertain their immune status. A substantial percentage of workers are known not to be infected by patients but rather by colleagues.⁵⁵ The most susceptible staff should be relocated to suitable and low-risk work areas.⁵⁶

Redesign of the imaging process

All the above measures and recommendations will call for a redesign of the imaging process. Some recommendations about this adaptation are provided by way of a summary in [Table 2](#).

Impact on other processes

Impact on budget control. The economic crisis produced by Covid-19 infection is so important that some specialists regard it as the most important one since the World War II, although the reduction in gross domestic product per capita is the most widespread since 1870, due to the number of countries affected.⁵⁷ Hospitals and radiology departments have been affected by this crisis, facing increased costs (safety measures), reduced production and, at private centres, reduced billing. Profitability will be impacted in all cases due to the costs of producing studies not ultimately conducted. An analysis performed in the USA⁵⁸ pointed to a reduction in billable activity of between 50% and 70%, with a simultaneous increase in expenditure. In the initial stages of the crisis, it was estimated that this unfavourable situation

Table 2 Some recommendations regarding the adaptation of the imaging process.

Subprocess	Action	Observations
Appointments: agenda design	Redesign of each room's agenda to adapt to contaminated and clean zones	
Appointments: agenda design	Take into account the times required for cleaning, disinfection and the use of protective equipment	The extra time needed will vary depending on the room and the circuit, although it may lead to a delay of between 15 minutes and 2 hours in certain situations
Appointments: agenda design	Adapt the number of appointments to waiting room capacity at all times	The number of patients given an appointment at the same time must not surpass the waiting room's capacity once all the safety measures (distancing) have been taken into account
Appointments: agenda design	Adjust the number of the staff required	Adapt the type and number of professionals in order to take the safety measures into account
Request validation	The radiologist must validate all imaging test requests	Besides evaluating suitability, the zone in which the test will be included must be taken into account
Patient appointments	Prioritise one-off tests	Try to ensure the patient comes to the radiology department the fewest possible number of times and spends the least possible time there
Patient appointments	Give the patient safety instructions	Short questionnaire about the possibility of infection; ask the patient not to come accompanied
Receiving the patient	Detect possible infected patients or transmitters	With a questionnaire on receiving the patient
Performance of the test	Define specific procedures for each room	Insist on safety procedures, particularly regarding cleaning and disinfection of rooms and equipment, and staff hygiene
Test report	Report chest X-rays	The chest X-ray report can be useful for detecting unsuspected cases
Test report	Use preconfigured reports	The use of template reports for X-rays and chest CT scans is recommended
Test report	Design teleradiology stations	Teleradiology stations should be available to guarantee continued activity in the event of a high-prevalence situation

could last for up to 9 months. This all means that it is important to monitor expenditure, coupled with good accounting management.

Impact on training and research. The safety measures affect all the activities of the radiology department, including training, both training sessions and on-the-job training of students (medical students or higher-level diagnostic imaging technicians) and doctors in training (in radiology or other specialties).⁵⁹⁻⁶² In view of the economic impact of the crisis and its potential duration, it is important that all training programmes are maintained and that all departments establish, using the new technologies, measures to overcome the difficulties posed by the current situation.

Hospital training activities (courses and congresses) have also been impacted⁶³ through the suspension of attendance-based activities and the development of online training activities. There is no consensus as to the possible medium- and long-term impact of the crisis on these activities, as this will depend on factors such as the development of a vaccine or the safety regulations that are applied.

The Covid-19 crisis has also had an impact on research, particularly in processes not related to this infection.⁶⁴ Moreover, the crisis has generated scientific output at an unprecedented speed. This, which on the one hand has permitted key breakthroughs in a very short time, has also meant that in some cases editorial control has not been

applied with the usual rigour,⁶⁵ sometimes having a big impact worldwide.⁶⁶

Risk management. Covid-19 infection is a threat to staff and patients and a core item in the way that a radiology department approaches its activity consists of good risk management, both prospectively and retrospectively. It is no different to other risk analyses, meaning that risk assessment studies will follow the same methodology.⁶⁷

Impact on structure. The latest report published by the *Federación Española de Empresas de Tecnología Sanitaria* [Spanish Federation of Medical Technology Companies] (FENIN) on medical technology⁶⁸ highlights the precarious situation of research into high-tech hospital equipment, which has accumulated a deficit since the crisis of 2008. The Covid-19 crisis has heightened this situation. Although many devices or equipment have been used less, in other cases they have been overused, and intensive cleaning and disinfection have affected some of them. For several months, the normal rhythm of machine maintenance has been altered. In this scenario, it is important that radiology departments have an updated plan addressing the situation of the equipment and renewal needs, supported by a clear rationale. Moreover, the first Covid-19 infection crisis has demonstrated the advantages of having direct portable conventional radiology equipment and portable ultrasound equipment. Radiology will play a key role in the management of the crisis, and for this it is essential that managers and politicians must comprehend the importance of maintaining reliable and safe technology.

Impact on radiology professionals. The organisation of radiology departments has been greatly impacted by the Covid-19 crisis. During the pandemic, many departments have had to change their focus and dedicate their activities almost exclusively to the diagnosis of Covid-19. To this end, workforces have been restructured, both technicians and radiologists, with unequal working days and positions with different degrees of healthcare pressure. As the pressure of the Covid-19 infection decreases, organisations are returning to normal, but the need to maintain certain safety measures renders it necessary to reinforce certain aspects of healthcare that were not envisaged in initial staffing plans. Some examples include the need to bolster technical personnel for jobs with greatest risk (operating portable devices for infected patients, radiology in dirty zones), or the need to adapt radiologists' workstations so they can continue to perform simple X-rays, which is considered essential. It is important to clearly define all the department's activities in each one of the Covid-19 infection stages (prevalence), in order to be able to adjust the resources available. Sometimes, these measures involve redesigning workstations and the functions of each position, adapting them to specific conditions.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

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