



# Covid-19 and radiotherapy: a systematic review after 2 years of pandemic

Antonio Piras<sup>1</sup> · Valeria Venuti<sup>2</sup> · Andrea D'Aviero<sup>3</sup> · Davide Cusumano<sup>6</sup> · Stefano Pergolizzi<sup>4</sup> · Antonino Daidone<sup>1</sup> · Luca Boldrini<sup>5,7</sup>

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## Abstract

**Introduction** Following the Covid-19 pandemic spread, changes in clinical practice were necessary to limit the pandemic diffusion. Also, oncological practice has undergone changes with radiotherapy (RT) treatments playing a key role. Although several experiences have been published, the aim of this review is to summarize the current evidence after 2 years of pandemic to provide useful conclusions for clinicians.

**Methods** A Pubmed/MEDLINE and Embase systematic review was conducted. The search strategy was “Covid AND Radiotherapy” and only original articles in the English language were considered.

**Results** A total of 2.733 papers were obtained using the mentioned search strategy. After the complete selection process, a total of 281 papers were considered eligible for the analysis of the results.

**Discussion** RT has played a key role in Covid-19 pandemic as it has proved more resilient than surgery and chemotherapy. The impact of the accelerated use of hypofractionated RT and telemedicine will make these strategies central also in the post-pandemic period.

**Keywords** Covid-19 · Radiotherapy · Oncological practice

## Abbreviations

RT	Radiotherapy
WHO	World Health Organization
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-analyses
HFRT	Hypofractionated radiation therapy

SBRT	Stereotactic body radiation therapy
ESTRO	European Society for Radiotherapy and Oncology
ASTRO	American Society for Radiation Oncology
H&N	Head and Neck
IRT	Interventional Radiotherapy
IORT	Intraoperative Radiotherapy
GEMO	European Study Group of Bone Metastases
LDRT	Low-dose Radiotherapy
CT	Computed Tomography
CBCT	Cone Beam CT

✉ Andrea D'Aviero  
andrea.daviero@materolbia.com

<sup>1</sup> Radioterapia Oncologica, Villa Santa Teresa, Palermo, Italy

<sup>2</sup> Radioterapia Oncologica, Università degli Studi di Palermo, Palermo, Italy

<sup>3</sup> Radiation Oncology, Mater Olbia Hospital, Olbia, Sassari, Italy

<sup>4</sup> Radiation Oncology Unit, Department of Biomedical, Dental Science and Morphological and Functional Images, University of Messina, Messina, Italy

<sup>5</sup> Dipartimento di Diagnostica per immagini, Radioterapia Oncologica ed Ematologia, UOC Radioterapia Oncologica - Fondazione Policlinico Universitario Agostino Gemelli IRCCS, Roma, Italy

<sup>6</sup> Medical Physics, Mater Olbia Hospital, Olbia, Italy

<sup>7</sup> Università Cattolica del Sacro Cuore, Roma, Italy

## Introduction

An unexpected series of life threatening pneumonias and deaths began in Wuhan, China, starting in December 2019, and soon spread worldwide. On 7 January 2020, the World Health Organization (WHO) announced the official name of the disease as “coronavirus disease 2019” (Covid-19) [1, 2].

Analysis of the viral genome revealed that this new coronavirus is phylogenetically close to severe acute respiratory syndrome coronavirus (SARS-CoV) [3].

Globally, at 4:00 pm CET, 28 January 2022, 364.191.494 cases of Covid-19 were confirmed, with 5.631.457 deaths as reported to World Health Organization (WHO) by the national authorities [4].

However, thanks to the effectiveness and spread of Covid-19 vaccines around the world, there has been a decrease in mortality rate [5].

As of 28 January 2022, a total of 9.854.237.363 vaccines doses were administered [4].

The symptomatic severity of Covid-19 infection appeared to worsen with increasing age and the presence of comorbidities. In fact, older patients with basic chronic diseases, such as cancer, were more vulnerable to Covid-19 infection [6–10].

In a recent multicentre study, cancer patients were found to be a highly vulnerable group due to the weakened immune system caused by both tumor growth and anti-cancer treatment. Patients with hematologic cancer, lung cancer, or with metastatic cancer had the highest frequency of severe events. In particular, patients who received surgery had a higher risk of serious events, while patients who received only radiotherapy (RT) showed no significant difference in serious events compared to patients without cancer [11].

RT has played a role in the changes in oncological practice, including an increase in organ-sparing treatment and achieving good local control and improving survival [12].

More than 50% of cancer patients have undergone RT treatment at least one time during their disease [13].

Furthermore, Covid-19 infection had a dramatic impact on cancer diagnosis, prognosis, and therapeutic effects [6]. Serious delays in surgical, chemotherapy and RT treatments due to patients' Covid-19 infection, organizational problems in healthcare facilities and also fear of infection among patients caused a substantial increase in the number of avoidable cancer deaths [14–17].

Covid-19 has also had a great impact on radiation oncologists, and so several measures have been adopted in patient management beginning with the treatment workflow [18, 19].

Many studies related to RT and Covid-19 have been published in these 2 years of the pandemic. Therefore, the aim of this systematic review is to summarize the current evidences after these 2 years, to provide better and useful conclusions for clinicians.

## Materials and methods

A systematic database search was conducted using definite keywords, according to Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines [20].

The search strategy was performed on PubMed, Medline and Embase using the search terms: “Covid AND Radiotherapy” up to date 31/12/2021.

Original studies, editorials, letters to editor, review and case reports focusing on Covid-19 and RT were included in this review.

Studies performed not in English and conference abstract were not take into account.

## Results

A total of 2.733 papers were found at the first search, 859 of which were duplicates. Of the 1874 remaining results, 1397 were excluded after a careful screening of abstracts.

477 articles were lastly selected for further accurate analysis. Out of these, 196 were excluded, as they did not directly target Covid-19 and RT. The remaining 281 papers were lastly included in this review.

The review workflow was compliant with the PRISMA guidelines, and the relative flowchart is reported in Fig. 1 [20].

We summarize the main characteristics of the analyzed studies, divided into different cluster areas and study types (Figs. 2, 3). Table 1 resumes the main indications provided for different cancer types.

### RT general management

Fifty-four studies focused on the RT general management during Covid-19 pandemic [14, 16, 18, 21–71].

Thirteen studies recommended the use of telemedicine [22, 27, 29, 30, 33, 36, 40, 42, 44, 50–53].

Telemedicine shows its helpfulness in the RT field, and patients get the supportive care they need minimizing their access to hospitals [22].

In a single academic radiation oncology session, the physicians interviewed indicated that their experience in using telemedicine has been largely positive, and most of them envision telemedicine as part of their radiation oncology practice in the future [51].

Eight studies analyzed the results suggesting the omission or postponement of RT when possible [14, 21, 23–25, 30, 42, 44].

Indications for RT with limited improvement in oncologic outcomes were viewed critically under conditions of limited health care resources by some expert groups, including RT of low-risk breast cancer in elderly patients and of early-stage Hodgkin's lymphoma [21].

Twenty-eight studies recommended the use of hypofractionated scheduling [18, 21–23, 25, 28–37, 40–43, 47, 48, 55, 58, 59, 61, 62, 70] and appropriate hypofractionated

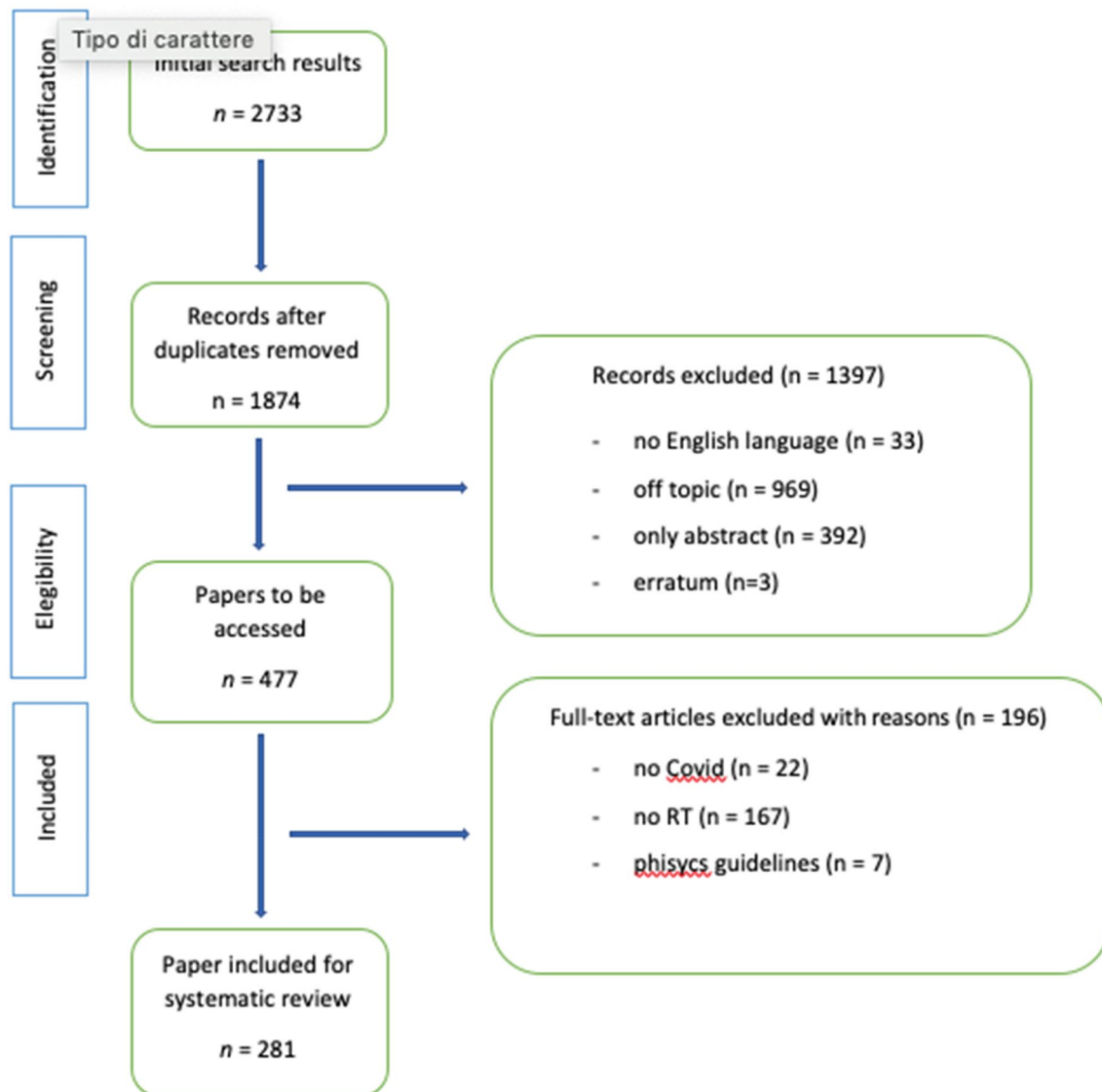


Fig. 1 Prisma diagram

regimens should be considered during a pandemic to reduce treatment duration and minimize the risk of infection [18].

Six studies discussed organization of work and staff during the pandemic [47, 50, 63–65, 71].

To ensure such continuity of services, the following measures were implemented: patients screening, temperature monitoring, patient and staff education, ensuring adequate medical supplies, continuous use of communication channels, adequate manpower should a staff member fall sick or need to be quarantined as a result of contact with patients with Covid-19, physical segregation of staff across hospitals, physical segregation of patients, formation of separated care teams, remote planning, hygiene and departmental cleaning [47].

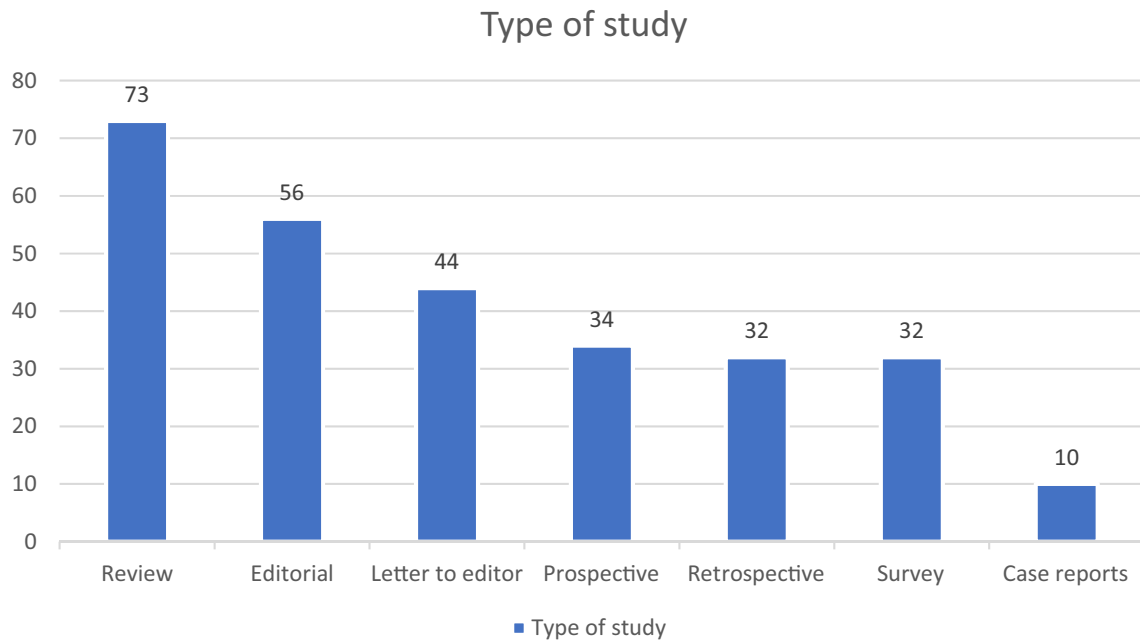
### RT management—lung cancer

Eleven studies focused on the RT management of Lung Cancer during Covid-19 pandemic [72–82].

All papers suggested an increase in the use of Hypofractionated radiation therapy (HFRT) and Stereotactic body radiation therapy (SBRT).

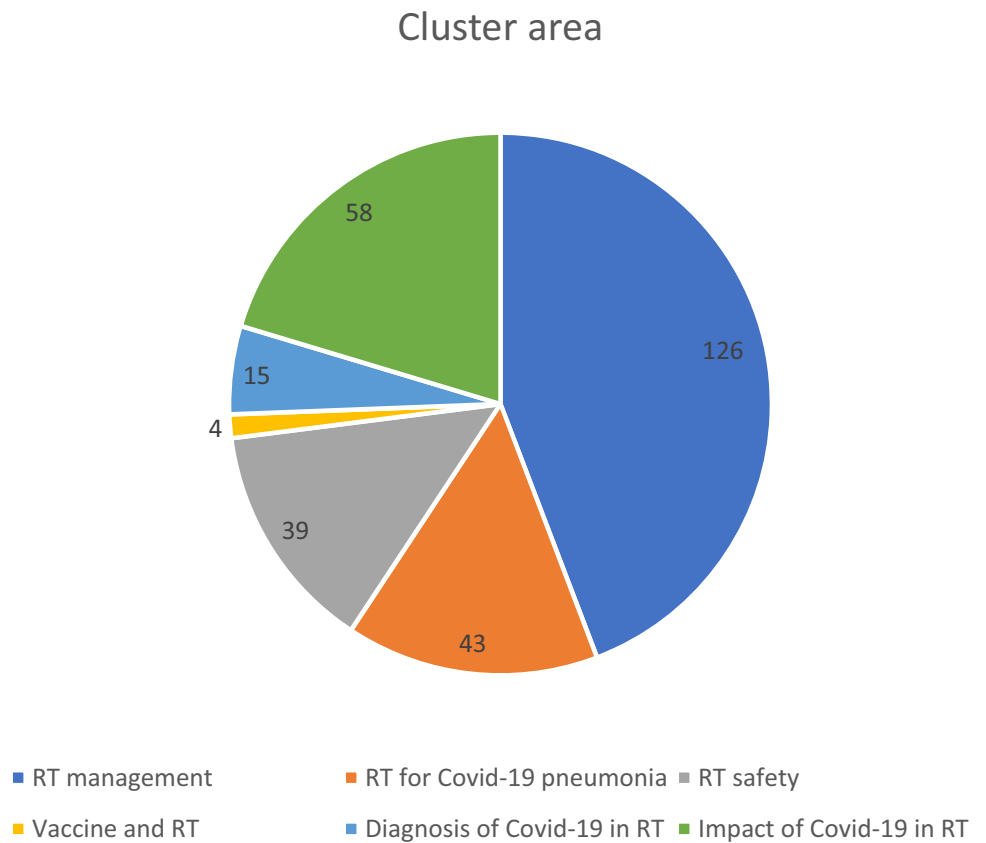
Liao et al. also suggested the delay of post-operative RT for non-small cell lung cancer, to avoid twice-daily treatments and delay or deliver prophylactic cranial irradiation during radio(chemo)therapy for limited-stage small cell lung cancer [73].

Furthermore, Couñago et al. in their review recommended for non-small-cell lung cancer early-stage central tumors, SBRT with scheme from 10 to 12 Gy/fraction (fr) with a



**Fig. 2** Type of study

**Fig. 3** Cluster area



total dose 50–60 Gy. For lesions adjacent or in contact with the chest wall, a dose of up to 48 Gy in 4 fr. For tumors in a safe zone extreme, HFRT with a single fr of 30–34 Gy [76].

The joint European Society for Radiotherapy and Oncology—American Society for Radiation Oncology (ESTRO-ASTRO) established pragmatic and balanced

**Table 1** Summary of main indication for cancer types

Site	Patient setting	RT management	RT schedules	COVID+ (asymptomatic/mild symptomatic)	COVID+ (symptomatic)	
Lung cancer [72–82]	General	Increase HFRT Increase SBRT		Continue RT(CT) with close monitoring of clinical conditions	Postpone after confirmed healing Interrupt or preliminarily terminate ongoing treatments	
	NSCLC	Delay post-operative RT Avoid twice-daily treatments				
	NSLC (early stage)	Increase SBRT	50–60 Gy in 5 fr (central tumors) 48 Gy in 4 fr (adjacent/contact with chest wall)			
	SCLC	Delay PCI Consider delivering PCI during concurrent RT(CT)				
Hematological cancer [83]	General	Shorten RT course		–		
	Palliative	Omission RT treatments				
	Localized low-grade	Omission RT for completely excised Delay for asymptomatic patients				Delay RT
	Localized nodular LH	Omission RT for completely excised Delay for asymptomatic patients				
	Diffuse large B/ aggressive LNH	Omission RT for consolidation				
Head & Neck [72, 84–93]	General	Increase HFRT		Continue RT(CT) with close monitoring of clinical conditions Use surgical mask with immobilization setup		
Prostate [94–99]	General	Increase HFRT Consider starting RT up to 6 months after OT				
	Low-risk	Increase HFRT Increase SBRT	36.25 Gy in 5 fr twice-week			

**Table 1** (continued)

Site	Patient setting	RT management	RT schedules	COVID + (asymptomatic/mild symptomatic)	COVID + (symptomatic)
Gastrointestinal [98, 100–110]	Esophageal cancer		40 Gy in 15 fr		
	Inoperable Cholangiocarcinoma	Consider SBRT			
	Pancreatic cancer	Consider SBRT in inoperable LAPC			
	Anal cancer	Increase HFRT	36/40 Gy in 20 fr to elective volume; 50 Gy in 20 fr to primary tumor with SIB		
	Liver cancer	Carbon ION RT for unresectable disease Consider SBRT for Hepato Cellular Carcinomas	30–60 Gy in 3–5 fr		
	Rectal cancer	Prefer short course treatments			
Skin [112–116]	General	Delay or omit adjuvant RT Consider HFRT Consider contact skin RT			
Breast [98, 117–121]	General	Delay or omit adjuvant RT in older adult EBC Consider HFRT			
Soft tissues – Sarcomas [122]	General	Consider HFRT	30 Gy in 10 fr 30 Gy in 5 fr 28 Gy in 8 fr 25 Gy in 5 fr		
Gynecological [123, 124]	General	Consider HFRT			
	Uterine cancer	Do not exceed 6 weeks after surgery for adjuvant RT			

RT radiation therapy, HFRT Hypofractionated radiation therapy, SBRT Stereotactic body radiation therapy, NSCLC Non-small cell lung cancer, SCLC Small cell lung cancer, PCI prophylactic cranial irradiation, LH Hodgkin lymphomas, LNH Non-Hodgkin lymphomas, LAPC Locally advanced pancreatic cancer, SIB simultaneous integrated boost, EBC Early breast cancer

consensus recommendations in common clinical scenarios of RT for lung cancer [72, 82].

In asymptomatic Covid-19 positive patients, radio(chemo)therapy may be continued as planned with precautions with caregivers in place to avoid exposure, while in mildly symptomatic Covid-19 positive patients, radio(chemo)therapy may be continued provided the patient is very closely monitored. However, in critically symptomatic Covid-19 positive patients, treatment needs to be postponed, interrupted or even preliminarily terminated [82].

#### RT management—hematological cancer

One study provided practice guidelines on the RT management of *hematological* cancers. The authors suggested three potential strategies to reduce the demand for RT during the pandemic:

- Omission in a palliative setting, for localized low-grade lymphomas if completely excised, for localized nodular lymphocyte-predominant Hodgkin lymphoma if com-

- pletely excised, in consolidation RT for diffuse large B-cell lymphoma/aggressive non-Hodgkin lymphoma.
- Delay for asymptomatic localized low-grade lymphomas, for localized nodular lymphocyte-predominant Hodgkin lymphoma, in a palliative setting for low-grade lymphomas in stable patients, or patients who develop Covid-19 infection prior to commencing RT.
  - Shortening the RT course [83].

### RT management—head & neck cancer

Eleven studies focused on head and neck cancer (H&N) RT management [72, 84–93].

Modest HFRT has been recommended by several authors. The most common schedule is 55 Gy in 20 frs. However, no studies recommended extreme HFRT [85].

Thomson et al. recommended not to stop treatment, especially if patients had already completed the first 2 weeks [55].

Three studies investigated surgical mask use in H&N cancer patients [90–92].

Ding et al. demonstrated in a small prospective study, that the setup error was affected by wearing a surgical mask. They recommended that the immobilization open mask should be used when the patients cannot finish the whole treatment with a surgical mask [90].

Wang et al. in their study revealed that mask wearing for patients undergoing daily RT is feasible and can provide basic protection for patients and staff [92].

### RT management—prostate cancer

Five studies dealt with RT management during the Covid-19 pandemic [94–99].

These studies showed that: ultra HFRT is preferred for localized, oligometastatic, and low-volume M1; while moderate HFRT is preferred for postprostatectomy and clinical node positive disease and salvage is preferred to adjuvant radiation [96].

The trial by Barra et al. recommended SBRT at a dose of 36.25 Gy in 5 frs, twice a week, as the preferred treatment option in medical emergencies in low-risk prostate cancer [97].

As regards hormone therapy in unfavorable intermediate-risk, high-risk, or very high-risk prostate cancer patients, later RT initiation up to 6 months after androgen deprivation therapy initiation was not associated with worse overall survival [94].

### RT management—gastrointestinal cancer

Twelve studies provided recommendations for the use of RT in managing patients with gastrointestinal malignancies in the era of Covid-19 [98, 100–110].

In esophageal cancer, the Walsh regimen of 40 Gy in 15 frs can be considered, whereas for inoperable cholangiocarcinoma, SBRT is the acceptable option [101].

For cases of pancreatic cancer that remain borderline resectable even after a complete course of six months of neoadjuvant chemotherapy, SBRT in 5 frs can be considered [101].

Patients with anal cancer who are not candidates to receive concurrent chemotherapy (due to comorbidities or poor performance status) can be treated with a hypofractionated regimen of 36–40 Gy in 20 frs to the elective volume with a simultaneous integrated boost to 50 Gy to the primary tumor [101].

Carbon Ion RT is an optimal treatment strategy for unresectable Liver Cancer [111].

SBRT should be considered for patients with Hepato Cellular Carcinoma from the early stage to the most advanced stages with the total dose of 30–60 Gy in 3–5 fr [101, 106, 108].

Short course RT 25 Gy in 5 fr in rectal cancer is preferable to long course RT [98, 100, 101, 105, 110].

### RT management—skin cancer

Five articles discussed RT management in skin cancer patients [112–116].

Omitting or delaying adjuvant RT should be considered where the benefit is likely to be limited [112, 113].

For Non Melanoma Skin Cancer, Veness et al. in their review, recommended HFRT (2.1–5 Gy fr sizes using 8–20 frs) in both the definitive and post-operative settings [114]. Instead, Lancellotta et al. delivered contact skin RT (brachytherapy) in 8 frs of 5 Gy each, twice a day [115].

### RT management—breast cancer

According to six studies evaluated RT management in breast cancer patients [98, 117–121].

HFRT should be the standard of care. Partial breast irradiation and ultra- HFRT regimens could be considered in selected cases due to the pandemic [117, 119].

Adjuvant RT might be omitted in a highly selected group of older adult early-stage breast cancer patients with favorable prognostic factors [117].

### RT management—sarcoma

A study investigated the use of preoperative HFRT in sarcomas. The authors suggested that HFRT is a promising treatment option providing satisfactory local control with acceptable toxicity. The recommended regimes are 3 Gy for 10 fr, 3.5 Gy for 8 fr, 5 Gy for 5 fr, 6 Gy for 5 fr [122].



## RT management—gynecological cancer

An expert consensus recommendation provided guidance for delivering radiation therapy during the Covid-19 pandemic [123].

HFRT should be used when feasible and recommendations regarding radiation dose, timing, and technique have been provided for external beam and brachytherapy treatments [123].

In a letter to editor, Matsuo et al. examined the association between post-hysterectomy RT wait-time and oncologic outcomes in women with early-stage cervical cancer.

They observed a poorer oncologic outcome with longer adjuvant RT wait-time after radical hysterectomy, and suggested the initiation of adjuvant RT within 6 weeks after surgical treatment whenever possible [124].

## Interventional radiotherapy (IRT) management

Nine articles focused on the management of IRT during Covid-19 pandemic [99, 115, 125–131].

The use of shorter IRT fractionation schedules will help minimize patient exposure and conserve resources that are important during Covid-19 [115, 127].

Muramaki et al. reported increased number of prostate cancer patients, selecting high dose-rate interstitial brachytherapy in our department [99].

IRT procedure may be a prudent choice used as a first-line treatment in early-stage cervical malignancies. IRT should not be delayed in patients without the Covid-19 symptoms [131].

Practical indications for management of patient candidates for IRT and Intraoperative Radiotherapy (IORT) during Covid-19 pandemic have been provided by AIRO (Italian Association of Radiotherapy and Clinical Oncology) Interventional Radiotherapy Working Group [125].

## Palliative RT management

Nine articles focused on the management of Palliative RT during Covid-19 pandemic [132–140].

During the Covid-19 pandemic, a short course was recommended to reduce the risk of viral exposure to all patients and staff, without compromising functional outcomes [135, 136].

Also, other studies focusing on the management of different diseases, about palliative RT recommended a single fractionation of 8–10 Gy [32, 76, 87, 112].

The Palliative Care and Supportive Therapies Working Group (AIRO-palliative) provided a comprehensive summary of the literature guideline indications of palliative RT for Metastatic Epidural Spinal Cord Compression,

Hemostasis, Mediastinal Syndrome, Painful or no bone metastasis, Oligometastases Suitable for SBRT, Brain metastases [133].

The GEMO (European Study Group of Bone Metastases) recommended the use of monofractionated RT (8 Gy) for painful bone metastases and Metastatic Epidural Spinal Cord Compression; although, RT may be postponed in Adjuvant bone metastasis RT setting [134].

## RT for Covid-19 pneumonia

Forty-three studies investigated treatment of Covid-19 pneumonia with RT [141–183]. Observations from these studies indicate that Low-dose radiotherapy (LDRT) for Covid-19 pneumonia delivers doses between 0.3 and 1 Gy. LDRT does not decrease the viability of virus directly, but it may increase the effectiveness of antiviral immune responses in the early/medium stages of SARS-CoV-2 infection [141, 146, 151, 164, 167, 171, 177, 179].

Whole-lung LDRT seems to be a promising approach for avoiding or delaying invasive respiratory support with a low risk of toxicity [142, 154, 159].

LDRT induces an anti-inflammatory phenotype that can potentially give therapeutic benefits against Covid-19-related complications [143, 148, 158, 162, 163, 175].

## RT safety

Thirty-nine studies focused on RT safety during Covid-19 pandemic [184–222]

In particular, 7 articles discussed RT on Covid-19 positive patients [184–189, 218].

In the study of Beddok et al. the observed acute and late toxicities were ultimately similar to those observed in a population not infected with Covid-19. However, these results do not prompt the modification of standard RT protocols for irradiation of Covid-19 patients [184].

Covid-19 infected cancer patients in RT practice show similar symptoms and demographic characteristics as the general population infected with SARS-CoV-2 virus [186].

Eight studies addressed the side-effects of LDRT treatment [190–194, 220–222].

The prospective trial of Arruda et al. showed that a RT dose  $\leq 0.5$  Gy provides an acceptable lifetime attributable risk estimate ( $\leq 1\%$ ) for radiation-induced cancer [191].

These studies suggest that RT may have the best benefit-risk balance for older patients with low baseline risk factors [192, 193].

The other studies focused on RT workflow and preventive protection procedures for Covid-19 infection in all patients and healthcare professionals [195, 197–200, 205, 212, 213, 216].



## Vaccine and RT

Four studies discussed the correlation between Covid-19 vaccine and RT [223–226].

Three of them were case reports reporting three skin toxicities in treatment fields and one lung toxicity in patients undergoing RT [223, 225, 226].

The prospective study of Scoccianti et al. showed that Moderna mRNA-1273 vaccine produced good results in patients who underwent RT for both early adverse events and late adverse effects [224].

## Diagnosis of Covid-19 in RT

Fifteen studies addressed the diagnosis of Covid-19 in patients during RT or its preparation phases [19, 44, 227–239].

Five studies confirmed the benefits of the systematic use of chest computed tomography (CT) screening during CT simulation for patients undergoing RT during the Covid-19 pandemic [19, 227, 228, 232, 237].

Cone Beam CT (CBCT) during the treatment also made it possible to diagnose Covid-19 [233, 239].

## Impact of Covid-19 in RT

Fifty-eight studies discussed the impact of Covid-19 in RT [15, 171, 240–296].

These studies were involved in the use of information technologies, RT prioritization, HFRT and protection procedures guarantee between patient care and safety while safeguarding the healthcare staff [243–245, 252, 270].

In a study published in *The Lancet*, the authors analyzed data relating to RT delivery for cancer patients in English National Health Service, which showed that RT activity fell significantly, but use of HFRT rapidly increased during the first peak of the Covid-19 pandemic. An increase in treatments for some cancers suggests that RT compensated for reduced surgical activity [248].

Teckie et al. emphasized that RT is more effectual compared to surgery and chemotherapy. During the pandemic, their RT department consistently maintained safe, timely and evidence-based standards of care, with very low staff and patient infection rates. While the surgical option was closed for 2 months, chemotherapy showed an increased risk of death from Covid-19 among patients traditionally receiving more aggressive chemotherapy, including those with haematological cancers, lung cancer and metastatic cancer [245].

The Covid-19 pandemic affected the regular RT delivery to oncologic patients, owing to the delay or cancelation of procedures with the likely effect of observing the worsening of local disease control and reduced survival rates in the future [241, 249, 259, 263, 267, 274, 279, 280, 285, 286].

The RT center of Renmin Hospital of Wuhan University was shut down on January 24, and reopened on March 9, 2020. Thus, many patients had impromptu interruptions of their RT treatment plan during this period and it was detected that stage IV was associated with poor prognosis compared with stage I–III [296].

A significant increase in the experience of isolation and a decrease in emotional functions and the general quality of life were observed during the Covid-19 lockdown in cancer patients [15, 253, 254, 264, 268, 273, 277, 278, 282, 287].

A survey among 543 researchers in the field of radiation oncology was carried out during the early weeks of the Covid-19 pandemic, showing a non-negligible impact on both productivity and mental health [258].

## Discussion

This is a review of all papers on RT related to the Covid-19 pandemic that have been published in the last 2 years. The search for articles was performed until 31/12/2021, so exactly 2 years after the start of the pandemic.

The importance of the topic is demonstrated by the large number of papers found during the review process.

These studies were performed all over the world, from Africa to America, from Europe to Asia.

We classified the articles into 5 cluster areas:

- *RT management* (divided into subgroups according to pathology).
- RT for Covid-19 pneumonia.
- RT Safety.
- Vaccine and RT.
- Diagnosis of Covid-19 in RT.
- Impact of Covid-19 in RT.

There was homogeneity in the type of studies published, with a slightly greater tendency for reviews and editorials. This is may be due to the significant attempt to give consensus/guidelines to clinicians during this difficult period.

In fact, the largest cluster areas are those of *RT management during Covid-19 pandemic and Impact of Covid on RT*.

Many of the articles included in the review focused on strategies for organizing work and screening for Covid-19 infection to guarantee the safety and efficiency of health services. [16, 48, 280].

There was a large general consensus on the implementation of HFRT and SBRT to reduce access to hospital and the risk of infection [70, 75, 106].

Also, concerning palliative RT, there was great concurrence for single fr treatments of 8–10 Gy [133, 136, 297, 298].

In the era of personalized treatment with research and progressive use of Radiomics and predictive dosimetric parameters, the Covid-19 pandemic has accelerated this process, leading to hypofractionation, postponement and eventually omission of treatment by evaluating risks and benefits for each individual patient [299–307].

There is a very similar scenario with regards to the digitization of the healthcare system [22, 51, 53, 308, 309].

Telemedicine was crucial during the Covid-19 pandemic allowing clinical activities to continue even during lockdown [89]. The advantages of telemedicine include its cost-effectiveness and its potential to help mitigate any shortage of physicians. Disadvantages include the lack of technological resources available in some parts of the country and problems with the security of patient data [310].

There is great concern in the literature about the effects of the suboptimal delivery of RT (including delays, interruptions or omissions). This may compromise both local control and survival [14].

The pandemic has also led to a great amount of anxiety and fear among both healthcare staff and patients. This is not to be underestimated because it can affect the proper work of healthcare staff and may contribute to interruptions or refusal of treatment by patients [258, 287]

Several studies have been published on *LDRT of Covid-19 pneumonia*. Although RT has an effective anti-inflammatory action to avoid or delay invasive respiratory disease, the risk of second tumors, though low, exists. With the advent of the *vaccine*, which is the real cure for Covid-19, LDRT is a limited treatment option [5, 144, 175].

From the analysis of the included studies, except for only 3 case reports of mild toxicity, there was no real risk of interactivity between RT and vaccine. Therefore, the vaccine seems to be safe during RT [223, 225, 226]. The only prospective study by Scoccianti et al. confirms this statement [224].

With regards to *safety*, just like the vaccine, RT in Covid-19 patients appears to be safe. Although, there seems to be no correlation between Covid-19 infection and RT. Therefore, if the patient has no severe Covid symptoms and is to continue radiation treatment, no adjustments of technique or dose should be made for his safety.

A really interesting cluster area was the *Diagnosis*. Several articles emphasized the usefulness and importance of simulation CT and CBCT in detecting suspicious interstitial pneumonias by Covid-19 [227, 233].

The most common observations on CT are ground-glass opacification air bronchograms, crazy-paving patterns, and thickening of the adjacent pleura [311].

CBCT is a medical imaging technique with inferior image quality (compared to diagnostic CT) used routinely for image guided radiotherapy (IGRT) to ensure proper positioning and visualization of any anatomical changes [230].

In *conclusion*, the Covid-19 pandemic has certainly caused innumerable deaths and injuries in the last two years. The RT world has reacted promptly by developing high quality screening and work safety systems. RT has played a key role in this period as it has proved to be more effective treatment option when compared to surgical procedures and chemotherapy. The accelerated use of HFRT and telemedicine due to the pandemic is already an added value to our discipline and will probably remain so in the years to follow.

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**Data availability** The data presented in this study are available on request from the corresponding author.

## Declarations

**Conflict of interest** All authors declare no conflicts of interests.

**Ethical approval and consent to participate** No Ethical approval was needed due to the design of the study.

**Consent for publication** No consent to publication was needed due to the design of the study.

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