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# Mortality in adult patients with solid or hematological malignancies and SARS-CoV-2 infection with a specific focus on lung and breast cancers: A systematic review and meta-analysis

Marco Tagliamento [a,b,1], Elisa Agostinetto [c,d,1], Marco Bruzzone [e], Marcello Ceppi [e], Kamal S. Saini [f], Evandro de Azambuja [c], Kevin Punie [g], C. Benedikt Westphalen [h], Gilberto Morgan [i], Paolo Pronzato [a], Lucia Del Mastro [b,j], Francesca Poggio [j], Matteo Lambertini [b,k,*]

[a] Department of Medical Oncology, Medical Oncology 2, IRCCS Ospedale Policlinico San Martino, Genova, Italy
[b] Department of Internal Medicine and Medical Specialties (DiMI), University of Genova, Genova, Italy
[c] Department of Internal Medicine, Institut Jules Bordet and Université Libre de Bruxelles (ULB), Brussels, Belgium
[d] Humanitas Clinical and Research Center – IRCCS, Humanitas Cancer Center, Rozzano, Milan, Italy
[e] Clinical Epidemiology Unit, IRCCS Ospedale Policlinico San Martino, Genova, Italy
[f] Covance Inc., Princeton, NJ, USA
[g] Department of General Medical Oncology and Multidisciplinary Breast Centre, Leuven Cancer Institute, University Hospitals Leuven, Leuven, Belgium
[h] Comprehensive Cancer Center Munich & Department of Medicine III, University Hospital, LMU Munich, Germany
[i] Department of Medical and Radiation Oncology, Skåne University Hospital, Lund, Sweden
[j] Breast Unit, IRCCS Ospedale Policlinico San Martino, Genova, Italy
[k] Department of Medical Oncology, UOC Clinica di Oncologia Medica, IRCCS Ospedale Policlinico San Martino, Genova, Italy

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ABSTRACT

*Background:* A systematic review and meta-analysis was performed to estimate mortality in adult patients with solid or hematological malignancies and SARS-CoV-2 infection.
*Methods:* A systematic search of PubMed, up to 31 January 2021, identified publications reporting the case-fatality rate (CFR) among adult patients with solid or hematological malignancies and SARS-CoV-2 infection. The CFR, defined as the rate of death in this population, was assessed with a random effect model; 95% confidence intervals (CI) were calculated.
*Results:* Among 135 selected studies (N = 33,879 patients), the CFR was 25.4% (95% CI 22.9%–28.2%). At a sensitivity analysis including studies with at least 100 patients, the CFR was 21.9% (95% CI 19.1%–25.1%). Among COVID-19 patients with lung (N = 1,135) and breast (N = 1,296) cancers, CFR were 32.4% (95% CI 26.5%–39.6%) and 14.2% (95% CI 9.3%–21.8%), respectively.
*Conclusions:* Patients with solid or hematological malignancies and SARS-CoV-2 infection have a high probability of mortality, with comparatively higher and lower CFRs in patients with lung and breast cancers, respectively.

## 1. Background

Since the start of the coronavirus disease 2019 (COVID-19) pandemic, the global cumulative number of cases all over the world has reached more than 108 million, with over 2.6 million cases of deaths as of March 2, 2021 (World Health Organization, 2021).

Patients with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection and a diagnosis of cancer are at high risk of severe symptomatic disease and death (Xia et al., 2020). Several efforts have been made to prevent SARS-CoV-2 infection among patients with cancer, as well as to ensure continuity of cancer care during the pandemic (Lambertini et al., 2020; Tagliamento et al., 2020a).

* Corresponding author at: Department of Medical Oncology, UOC Clinica di Oncologia Medica, IRCCS Ospedale Policlinico San Martino & Department of Internal Medicine and Medical Specialties (DiMI), University of Genova, Largo Rosanna Benzi 10, 16132, Genova, Italy.
*E-mail address:* matteo.lambertini@unige.it (M. Lambertini).
[1] Equal contribution.

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Cancer has been shown to be an independent adverse prognostic factor on COVID-19-related mortality (de Azambuja et al., 2020; Saini et al., 2020). However, its effect across different patient subgroups is uncertain, and wide variability seems to exist according to different tumor types. In particular, patients with lung cancer have been reported to have disproportionally higher mortality rates from COVID-19, while those with breast cancer showed relatively lower mortality rates (Luo et al., 2020; Garassino et al., 2020; Vuagnat et al., 2020).

Since the outbreak of the pandemic, several case-series and cohort studies describing the clinical outcomes and mortality of SARS-CoV-2 infection in patients with cancer have been published. However, the relatively small sample size of most reports, their retrospective design and the restriction to hospitalized patients represent important limitations to interpret the reported mortality rates, and the extent to which they can be extrapolated to the wider population of patients with solid or hematological malignancies.

A systematic review and pooled analysis assessing the mortality rate of patients with SARS-CoV-2 infection and underlying cancer was published in 2020, but it included a relatively limited number of studies (n = 52) and did not provide pooled data on mortality according to tumor types (Saini et al., 2020). Moreover, to the best of our knowledge, no systematic review and meta-analyses focusing specifically on lung and breast malignancies are available to date.

To provide updated evidence on this important topic, we performed a systematic review and meta-analysis aiming to estimate the case-fatality rate (CFR) of patients with solid or hematological malignancies and SARS-CoV-2 infection. In addition, we also focused separately on patients with lung and breast cancers, in order to evaluate the CFR associated with these common tumors.

## 2. Materials and methods

### 2.1. Literature search

A systematic search of PubMed up to 31 January 2021 was performed by two authors (M.T. and F.P.); any disagreement was discussed among all authors and resolved. The search strategy included different combinations of terms: (covid OR coronavirus OR sars) AND (cancer OR tumor OR tumour OR tumors OR tumours OR malignancy OR malignancies OR neoplasia OR neoplasm) AND (mortality OR death). Duplicated results were not included. Only the most recent and updated version of a same study was considered.

### 2.2. Study selection

The following inclusion criteria were considered: i) publications reporting the mortality rate in patients with cancer and SARS-CoV-2 infection and/or specifically the mortality rate among patients with lung or breast cancers; ii) any type of study (observational, randomized controlled trials or case series); iii) studies involving patients with solid or hematological malignancies; iv) studies involving adult patients; v) studies including at least 10 patients; vi) publications in English.

### 2.3. Data extraction

Data extracted from every publication were: name of the first author, reported number of patients with cancer and SARS-CoV-2 infection, reported number of deaths among patients with cancer and SARS-CoV-2 infection, reported number of patients with lung cancer and SARS-CoV-2 infection, reported number of deaths among patients with lung cancer and SARS-CoV-2 infection, reported number of patients with breast cancer and SARS-CoV-2 infection, reported number of deaths among patients with breast cancer and SARS-CoV-2 infection. Data extraction was performed by two authors (M.T and E.A.).

### 2.4. Statistical analysis

A meta-analysis of selected studies was performed in order to assess the CRF among adult patients with solid or hematological malignancies and SARS-CoV-2 infection, defined as the cumulative rate of deaths among patients with history of malignancy and SARS-CoV-2-infection. Moreover, the mortality rates among patients with lung and breast cancers and SARS-CoV-2 infection were separately computed. A random effect model was used to assess the CFR, and 95% confidence intervals (CI) were calculated. The likelihood of publication bias was assessed by Egger's test. The Higgins $I^2$ index was used to assess the heterogeneity between studies. Sensitivity analyses were carried out after excluding studies including less than 100 patients.

## 3. Results

The systematic search of the literature returned 1,727 records. In total, 1,551 were excluded on the basis of the title and 34 based on the abstract not fulfilling the inclusion criteria, while 7 were duplicates. A total of 135 studies were selected, including 33,879 patients with solid or hematological malignancies and SARS-CoV-2 infection (Table 1) (Lundon et al., 2020; Liu et al., 2020; Fuentes-Antrás et al., 2020; Wang et al., 2020a, 2021; Montopoli et al., 2020; Song et al., 2021; Huang et al., 2020; Sng et al., 2020; Li et al., 2020; Tagliamento et al., 2020a; de Melo et al., 2020; Bogani et al., 2020; Wang et al., 2020b; Cavanna et al., 2021; Rogado et al., 2020a; Mehta et al., 2020; Basse et al., 2021; Zhang et al., 2020a; Nakamura et al., 2021; Kalinsky et al., 2020; Jee et al., 2020; Engelhardt et al., 2020; Tian et al., 2020; Passamonti et al., 2020; Nie et al., 2021; Cattaneo et al., 2020; Zhang et al., 2020b; Sorouri et al., 2020; Yang et al., 2020a; Wu et al., 2020a; Sanchez-Pina et al., 2020; Alpert et al., 2021; Deng et al., 2020; Özdemir et al., 2020; Chari et al., 2020; Rogiers et al., 2021; Aries et al., 2020; Fox et al., 2020; Wu et al., 2020b; Guan et al., 2020; Wang et al., 2020c; Piper-Vallillo et al., 2021; Stroppa et al., 2020; Rubio et al., 2020; Singh et al., 2020; Lattenist et al., 2021; Ramachandran et al., 2020; Rüthrich et al., 2021; Luo et al., 2020; Tsimafeyeu et al., 2020; Garassino et al., 2020; He et al., 2020; Breccia et al., 2020; Hultcrantz et al., 2020; Boilève et al., 2020; Lara Álvarez et al., 2020; Mehta et al., 2021; Kathuria-Prakash et al., 2021; Lee et al., 2020; Nichetti et al., 2020; Scarfò et al., 2020; Brar et al., 2020; Rogado et al., 2020b; Ali et al., 2020; Ramaswamy et al., 2020; Shoumariyeh et al., 2020; Infante et al., 2020; Angelis et al., 2020; Robilotti et al., 2020; Ferrari et al., 2021; Miyashita et al., 2020; Ciceri et al., 2020; Borah et al., 2021; Kabarriti et al., 2020; Russell et al., 2020; Gupta et al., 2020; Docherty et al., 2020; Bhogal et al., 2021; Elkrief et al., 2020; Assaad et al., 2020; Barbui et al., 2021; Hanna et al., 2021; Kvåle et al., 2020; Antrim et al., 2021; García-Suárez et al., 2020; de Azambuja et al., 2020; Caffo et al., 2020; Lee et al., 2021; Nepogodiev et al., 2020; Martínez-López et al., 2020; Lunski et al., 2021; Biernat et al., 2020; Cherri et al., 2020; COVIDSurg Collaborative et al., 2020; Ganatra et al., 2020; Mato et al., 2020; Calles et al., 2020; Duarte et al., 2020; Zhang et al., 2020c; Wood et al., 2020; Joharatnam-Hogan et al., 2020; de Oliveira et al., 2021; Thompson et al., 2020; Dai et al., 2020; Ayhan et al., 2021; Pinato et al., 2020a; Fillmore et al., 2020; Ramtohul et al., 2020; Lara et al., 2020; Sun et al., 2021; Cui et al., 2020; Cook et al., 2020; Booth et al., 2020; Grasselli et al., 2020; Lièvre et al., 2020; Yang et al., 2020b; Yarza et al., 2020; Reale et al., 2020; Laurenge et al., 2021; Pinto et al., 2020; Yu et al., 2020; Westblade et al., 2020; Glenthøj et al., 2021; Martín-Moro et al., 2020; Wang et al., 2020d; Sadeghi et al., 2020; Morjaria et al., 2020; Erdal et al., 2021; Burn et al., 2021; Yigenoglu et al., 2021; Rivera et al., 2020; Rajasekaran et al., 2020; Wang et al., 2020e).

Overall, the CFR was 25.4% (95% CI 22.9%–28.2%; Egger's test p = 0.001) (Fig. 1). A sensitivity analysis of the 66 studies (N = 31,184) including at least 100 patients showed a CFR of 21.9% (95% CI 19.1%–25.1%) (Fig. S1).

In total, 42 and 31 studies reported the mortality rate among COVID-

**Table 1**
Details of reported number of patients and deaths in the studies selected for the meta-analysis.

| Author | Total patients with cancer and SARS-CoV-2 infection | Deaths in patients with cancer and SARS-CoV-2 infection | Total patients with lung cancer and SARS-CoV-2 infection | Deaths in patients with lung cancer and SARS-CoV-2 infection | Total patients with breast cancer and SARS-CoV-2 infection | Deaths in patients with breast cancer and SARS-CoV-2 infection |
|---|---|---|---|---|---|---|
| Ali et al. | 201 | 16 | | | | |
| Alpert et al. | 421 | 129 | | | | |
| Angelis et al. | 113 | 29 | | | | |
| Antrim et al. | 50 | 5 | | | | |
| Aries et al. | 35 | 14 | | | | |
| Assaad et al. | 55 | 8 | 7 | 3 | | |
| Ayhan et al. | 46 | 0 | | | | |
| Barbui et al. | 175 | 50 | | | | |
| Basse et al. | 141 | 30 | 18 | 6 | | |
| Bhangu et al. | 78 | 15 | | | | |
| Bhogal et al. | 179 | 66 | | | | |
| Biernat et al. | 10 | 7 | | | | |
| Bogani et al. | 19 | 3 | | | | |
| Boilève et al. | 16 | 2 | | | | |
| Booth et al. | 66 | 34 | | | | |
| Borah et al. | 130 | 26 | | | | |
| Brar et al. | 117 | 29 | | | | |
| Breccia et al. | 36 | 8 | | | | |
| Burn et al. | 5595 | 670 | | | | |
| Caffo et al. | 34 | 13 | | | | |
| Calles et al. | 23 | 8 | 23 | 8 | | |
| Cattaneo et al. | 102 | 40 | | | | |
| Cavanna et al. | 51 | 25 | 12 | 7 | 4 | 2 |
| Chari et al. | 650 | 222 | | | | |
| Cherri et al. | 53 | 16 | | | | |
| Ciceri et al. | 22 | 11 | | | | |
| Cook et al. | 75 | 41 | | | | |
| COVIDSurg Collaborative | 189 | 43 | | | | |
| Cui et al. | 32 | 9 | 26 | 7 | | |
| Dai et al. | 31 | 8 | 31 | 8 | | |
| Dai et al. | 105 | 12 | 22 | 4 | 11 | 0 |
| De Azambuja et al. | 832 | 283 | | | | |
| de Melo et al. | 181 | 69 | 7 | 4 | 40 | 21 |
| de Oliveira et al. | 83 | 68 | 5 | 4 | 31 | 27 |
| Deng et al. | 107 | 6 | | | | |
| Docherty et al. | 1743 | 617 | | | | |
| Duarte et al. | 681 | 442 | 51 | 38 | 90 | 51 |
| Elkrief et al. | 249 | 71 | | | | |
| Engelhardt et al. | 21 | 0 | | | | |
| Erdal et al. | 77 | 17 | 7 | 1 | 11 | 1 |
| Ferrari et al. | 198 | 33 | 16 | 7 | 58 | 5 |
| Fillmore et al. | 1794 | 251 | 121 | | | |
| Fox et al. | 52 | 18 | | | | |
| Fuentes-Antras et al. | 73 | 18 | 14 | 5 | 10 | 4 |
| Ganatra et al. | 195 | 48 | | | | |
| Garassino et al. | 200 | 66 | | | | |
| García-Suárez et al. | 697 | 230 | | | | |
| Glenthøj et al. | 66 | 16 | | | | |
| Graselli et al. | 331 | 202 | | | | |
| Guan et al. | 18 | 3 | | | | |
| Gupta et al. | 112 | 60 | | | | |
| Hanna et al | 32 | 7 | | | | |
| He et al. | 13 | 8 | | | | |
| Huang et al. | 16 | 3 | 2 | | | |
| Hultcrantz et al. | 100 | 22 | | | | |
| Infante et al. | 41 | 15 | | | | |
| Jee et al. | 309 | 31 | | | | |
| Joharatnam-Hogan et al. | 30 | 11 | 5 | 3 | 4 | 1 |
| Kabarriti et al. | 107 | 24 | | | | |
| Kalinsky et al. | 27 | 1 | | | 27 | 1 |
| Kathuria-Prakash et al. | 21 | 2 | | | | |
| Kvåle et al. | 372 | 36 | | | | |
| Lara Álvarez et al. | 36 | 15 | | | | |
| Lara et al. | 193 | 34 | | | | |
| Lattenist et al. | 13 | 6 | | | | |
| Laurenge et al. | 13 | 3 | | | | |
| Lee L et al. | 1044 | 319 | 111 | 43 | 143 | 26 |

(*continued on next page*)

**Table 1** (*continued*)

| Author | Total patients with cancer and SARS-CoV-2 infection | Deaths in patients with cancer and SARS-CoV-2 infection | Total patients with lung cancer and SARS-CoV-2 infection | Deaths in patients with lung cancer and SARS-CoV-2 infection | Total patients with breast cancer and SARS-CoV-2 infection | Deaths in patients with breast cancer and SARS-CoV-2 infection |
|---|---|---|---|---|---|---|
| Lee RJ et al. | 302 | 104 | | | | |
| Li et al. | 65 | 18 | 5 | 2 | 8 | 1 |
| Lièvre et al. | 1289 | 370 | | | 173 | 26 |
| Liu et al. | 216 | 37 | 49 | 14 | 34 | 1 |
| Lundon et al. | 149 | 35 | | | | |
| Lunski et al. | 312 | 66 | 26 | 8 | 70 | 8 |
| Luo et al. | 102 | 25 | 102 | 25 | | |
| Martinez-Lopez et al. | 167 | 56 | | | | |
| Martín-Moro et al. | 34 | 11 | | | | |
| Mato et al. | 198 | 66 | | | | |
| Mehta A et al. | 218 | 61 | 11 | 6 | 28 | 4 |
| Mehta V et al. | 186 | 27 | 17 | 0 | 19 | 1 |
| Miyashita et al. | 334 | 37 | | | | |
| Montopoli et al. | 430 | 75 | | | | |
| Morjaria et al. | 304 | 53 | | | | |
| Nakamura et al. | 32 | 11 | 2 | 1 | 2 | 0 |
| Nichetti et al. | 11 | 6 | 1 | 1 | 4 | 3 |
| Nie et al | 45 | 11 | 45 | 11 | | |
| Ozdemir et al. | 1523 | 77 | 157 | 18 | 302 | 2 |
| Passamonti et al. | 536 | 198 | | | | |
| Pinato et al. | 204 | 59 | | | | |
| Pinto et al. | 138 | 47 | | | | |
| Piper-Valillo et al. | 24 | 7 | 24 | 7 | | |
| Rajasekeran et al. | 12 | 4 | | | | |
| Ramachandran et al. | 53 | 32 | | | | |
| Ramaswamy et al. | 198 | 23 | | | 30 | 3 |
| Ramtohul et al. | 70 | 17 | 11 | | | |
| Reale et al. | 18 | 8 | 10 | 4 | | |
| Rivera et al. | 2186 | 357 | | | | |
| Robilotti et al. | 423 | 51 | | | | |
| Rogado et al. | 25 | 5 | 25 | 5 | | |
| Rogado et al. | 45 | 19 | 17 | 9 | | |
| Rogiers et al. | 110 | 18 | 17 | 4 | | |
| Rubio et al. | 28 | 9 | | | | |
| Russell et al. | 156 | 34 | | | | |
| Rutrich et al. | 435 | 114 | | | | |
| Sadeghi et al. | 41 | 26 | | | | |
| Sanchez-Pina et al. | 39 | 14 | | | | |
| Scarfò et al. | 190 | 56 | | | | |
| Shoumariyeh et al. | 39 | 8 | | | | |
| Singh et al. | 85 | 32 | | | | |
| Sng et al. | 94 | 41 | 15 | 5 | 8 | 4 |
| Song et al. | 248 | 40 | 61 | 16 | 37 | 2 |
| Sorouri et al. | 53 | 27 | 5 | 0 | 4 | 2 |
| Stroppa et al. | 25 | 9 | 8 | 2 | 2 | 2 |
| Sun et al. | 67 | 9 | | | | |
| Tagliamento et al. | 17 | 4 | | | | |
| Thompson et al. | 87 | 47 | | | | |
| Tian et al. | 232 | 46 | 23 | 9 | 31 | 5 |
| Tsimafeyeu et al. | 37 | 1 | | | | |
| Wang QQ et al. | 670 | 100 | | | | |
| Wang J et al. | 12 | 3 | 3 | 1 | 1 | 0 |
| Wang L et al. | 15 | 3 | | | | |
| Wang J et al. | 283 | 50 | 51 | 13 | 38 | 2 |
| Wang B et al. | 58 | 14 | | | | |
| Westblade et al. | 100 | 30 | | | | |
| Wang Q et al. | 420 | 40 | | | | |
| Wood et al. | 250 | 70 | | | | |
| Wu Y et al. | 14 | 6 | | | | |
| Wu Q et al. | 11 | 4 | | | | |
| Yang B et al. | 37 | 7 | 37 | 7 | | |
| Yang K et al. | 205 | 40 | 24 | 6 | 40 | 3 |
| Yarza et al. | 63 | 16 | 17 | 6 | | |
| Yigenoglu et al. | 740 | 102 | | | | |
| Yu et al. | 12 | 3 | 7 | 2 | 1 | 0 |
| Zhang B et al | 35 | 0 | | | 35 | 0 |
| Zhang H et al. | 107 | 23 | 21 | 5 | | |
| Zhang L et al. | 28 | 8 | | | | |

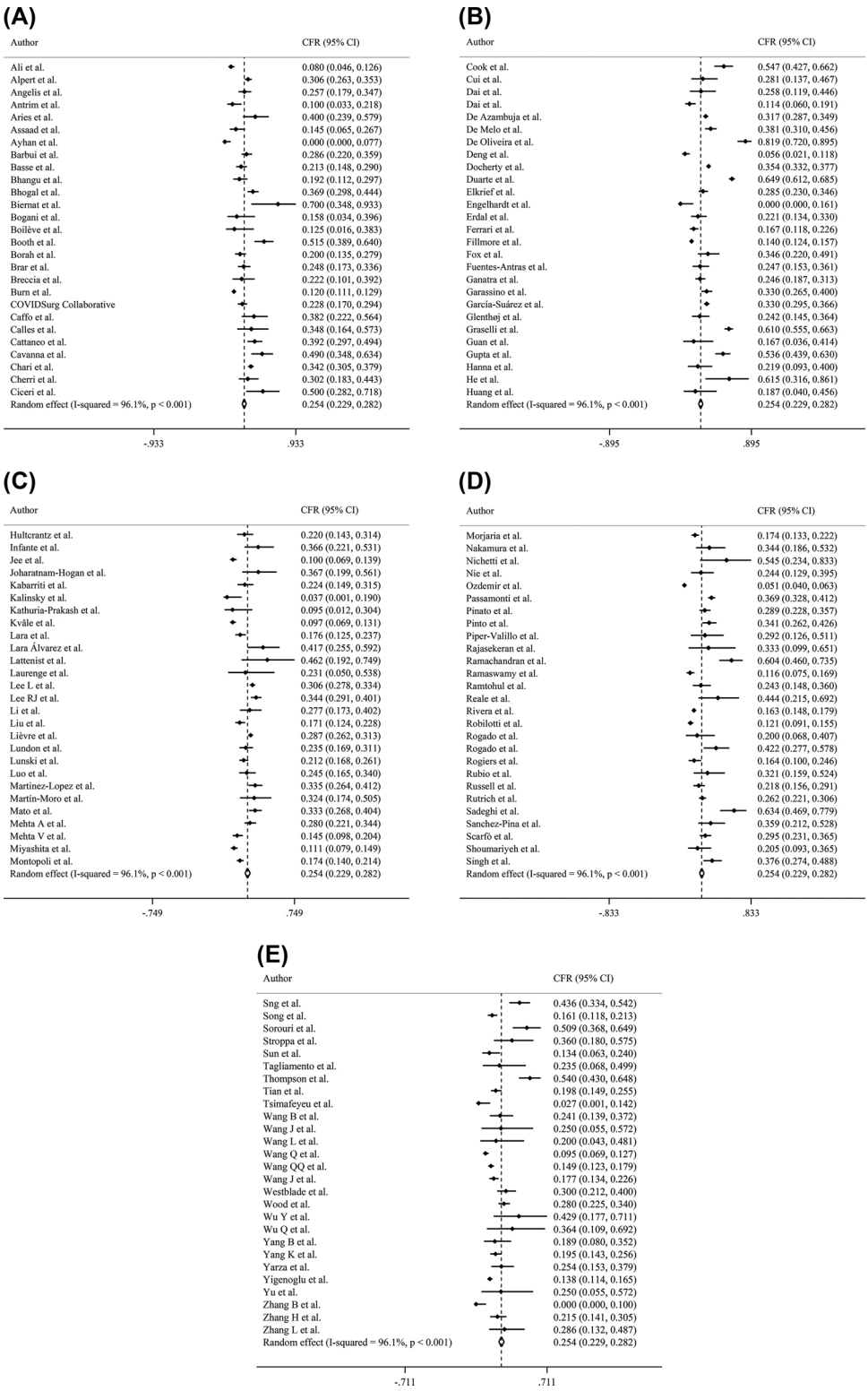


**Fig. 1.** (A, B, C, D, E). Forest plot of studies reporting the CFR among patients with solid or hematological malignancies and SARS-CoV-2 infection. (A) Authors from A to C. (B) Authors from C to H. (C) Authors from H to M. (D) Authors from M to S. (E) Authors from S to Z.
*Abbreviations*. CFR: case-fatality rate; 95% CI: 95% confidence interval.

19 patients with lung (N = 1,135) and breast (N = 1,296) cancers, respectively (Table 1). The CFR among patients with lung cancer and SARS-CoV2 infection was 32.4% (95% CI 26.5%–39.6%) when including all studies (Fig. 2) and 22.7% (95% CI 11.8%–43.8%) at the sensitivity analysis after excluding studies with less than 100 patients (Fig. S2). The CFR among patients with breast cancer and SARS-CoV2 infection was 14.2% (95% CI 9.3%–21.8%) when including all studies (Fig. 3) and 9.4% (95% CI 4.0%–22.4%) at the sensitivity analysis after excluding studies with less than 100 patients (Fig. S3).

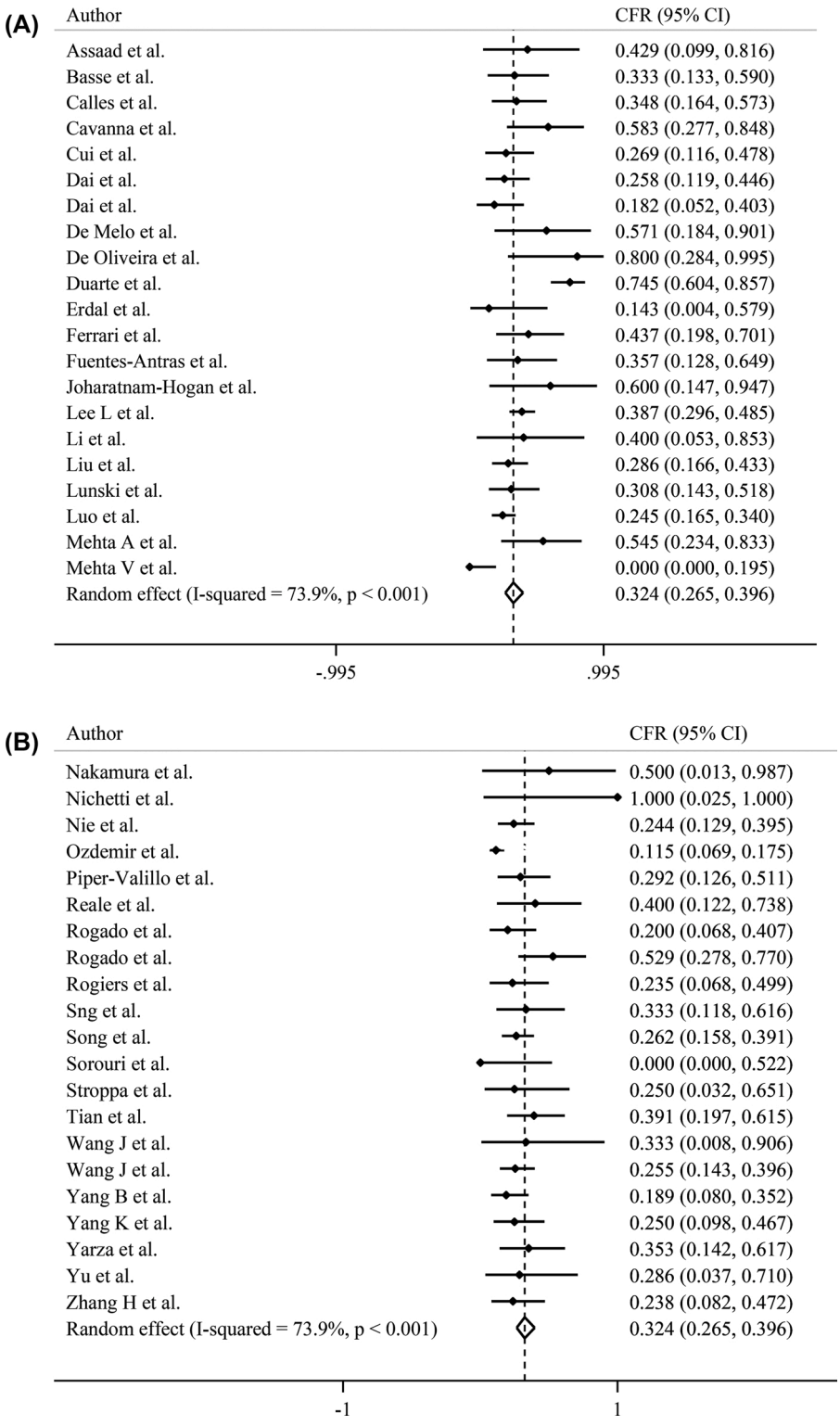


**Fig. 2.** (A, B). Forest plot of studies reporting the CFR among patients with lung cancer and SARS-CoV-2 infection. (A) Authors from A to M. (B) Authors from N to Z. *Abbreviations*. CFR: case-fatality rate; 95% CI: 95% confidence interval.

## 4. Discussion

Over a year after the outbreak of the pandemic, this large meta-analysis reports the impact of COVID-19 in patients with solid or hematological malignancies. Overall, these patients were found to have a high probability of mortality (CFR = 25.4%); the absolute rate was particularly high among patients with lung cancer (32.4%), while it was lower in those with breast cancer (14.2%). These findings strongly highlight the need to dedicate special attention to patients with cancer during the ongoing pandemic.

Overall, there is a growing evidence that patients with a history of cancer have a higher mortality rate due to COVID-19 as compared with the general population. Several international registries, such as the International Severe Acute Respiratory and Emerging Infections

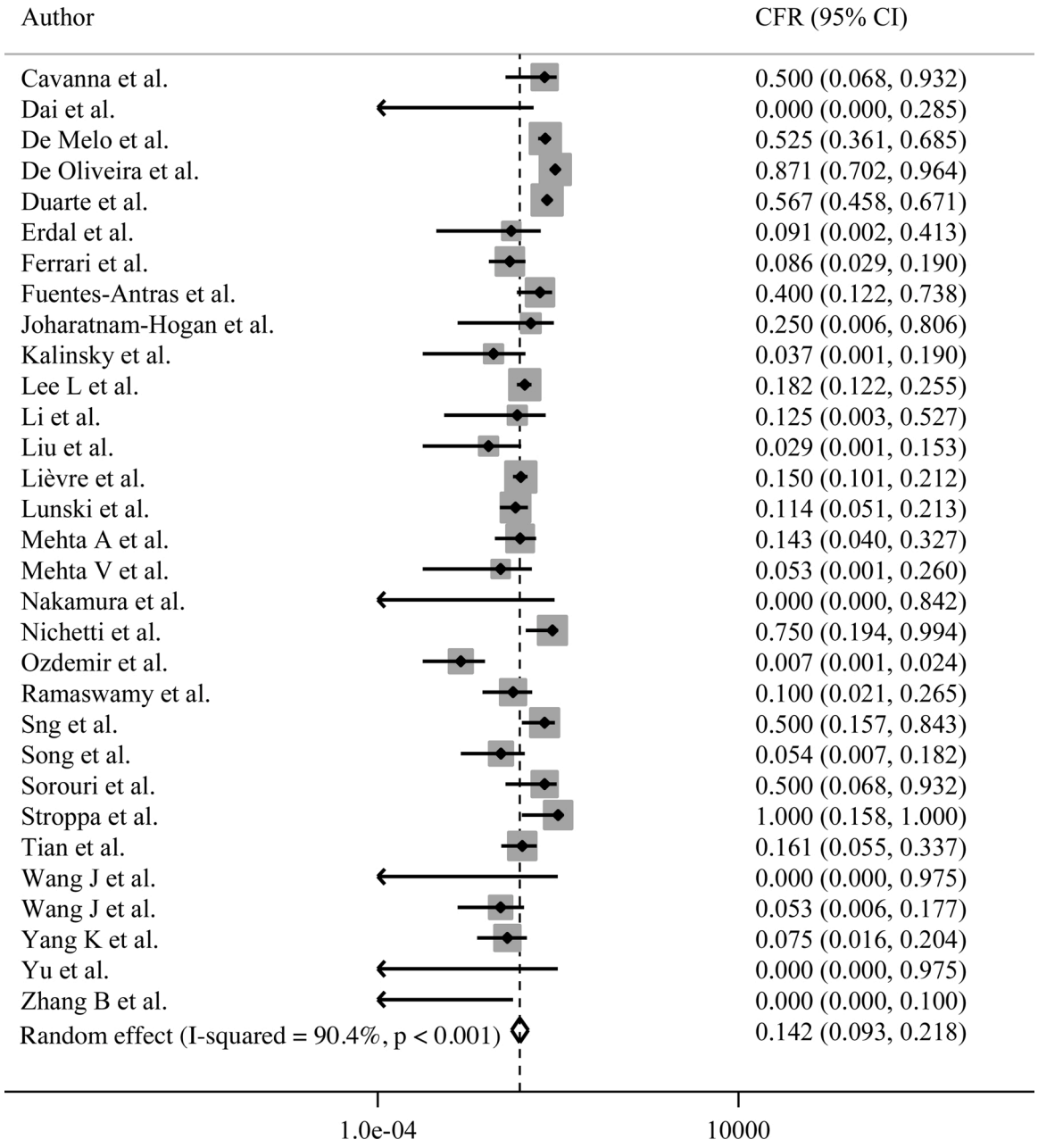


**Fig. 3.** Forest plot of studies reporting the CFR among patients with breast cancer and SARS-CoV-2 infection.
*Abbreviations*. CFR: case-fatality rate; 95% CI: 95% confidence interval.

Consortium (ISARIC) (Docherty et al., 2020), the OnCOVID (Pinato et al., 2020b), the Clinical impact of COVID-19 on patients with Cancer (CCC-19) (Kuderer et al., 2020), the GCO-002 CACOVID-19 (Lièvre et al., 2020), reported a mortality rate of oncological patients with SARS-CoV-2 infection up to 40% (Lee and Purshouse, 2021). The majority of these studies did not foresee a control group of patients with COVID-19 without cancer. Instead, a recent retrospective study, evaluating by a multivariate model the difference in mortality from COVID-19 between 312 patients with cancer and 4,833 patients without cancer in the U.S., found a higher death rate in the cancer group. Among patients with cancer, having an active or progressive disease was shown to increase the likelihood of mortality ($p < 0.001$) (Lunski et al., 2021). Our findings confirm a high mortality rate in patients with solid or hematological malignancies and SARS-CoV-2 infection.

Since the COVID-19 outbreak, major efforts have been implemented to protect most vulnerable patients from SARS-CoV-2 infection. Among them, the following measures have been suggested in cancer care: the rationalization of working practices, the adaptation of chemotherapy regimens as well as other systemic treatments, the deferral of procedures for diseases with favorable biology or not requiring urgent care, and additional measures related to specific subtypes of cancer (Poggio et al., 2020; Tagliamento et al., 2020b; Burki, 2020; Onesti et al., 2020, 2021). Aggressive preventive measures include preferential access to COVID-19 vaccination, which should be administered as early as possible (Garassino et al., 2021). Furthermore, ensuring cancer care continuity during the COVID-19 pandemic should represent a priority, considering treatment interruptions or discontinuations only on a case-by-case basis, taking into account patient and tumor characteristics (Lambertini et al.,

2020; Tagliamento et al., 2020a).

In our meta-analysis, patients with lung cancer had a comparatively higher CFR than the overall population, consistent with the data reported in the Thoracic Cancers International COVID-19 Collaboration (TERAVOLT) registry (not included in our separate analysis of the CFR in lung cancer, since patients with non-lung thoracic malignancies were included as well, like in the study by Lièvre et al.) (Garassino et al., 2020; Lièvre et al., 2020), and with previous reports in patients from China (Yu et al., 2020; Liang et al., 2020; Zhang et al., 2020b). Whether this high mortality rate may be reduced with special management of such patients in intensive care is an open question (Garassino et al., 2020).

On the contrary, a comparatively lower CFR was observed in patients with breast cancer, suggesting that breast cancer *per se* does not seem to be a major determinant of COVID-19 mortality. One potential explanation might be that patients with lung cancer tend to be older than those with breast cancer. Furthermore, co-existing pulmonary conditions might further raise the risk for an unfavorable outcome in patients with lung cancer diagnosed with COVID-19, as well as the different spectrum of anticancer treatments received compared to breast cancer. Conversely, the delays in cancer diagnosis and treatment due to the COVID-19 pandemic may have an impact on outcomes, considering that a significant proportion of the important gain in disease-specific overall survival observed in the last 20–30 years are attributable to early detection and improved treatments (Gathani et al., 2021). The long-term effect on cancer-specific survival outcomes of the temporary suspension of routine screening during the peak of the pandemic will be only and fully revealed in the future (Gathani et al., 2021).

Our meta-analysis has some limitations that should be acknowledged. It included heterogeneous cohorts, involving hospitalized and non-hospitalized patients, with both solid or hematological malignancies currently receiving or not active anticancer treatments (and different types) at the time of SARS-CoV-2 infection. Some studies only reported on in-hospital mortality, and sometimes exclusively on 30-day rate. Moreover, we evaluated the mortality rate considering death from any cause, instead of focusing specifically on death due to COVID-19 or due to cancer progression (this specific information was frequently unavailable in the studies included in the meta-analysis). As expected, the heterogeneity in the analyses was significant ($p < 0.001$) probably due to the high number of evaluated studies characterized by different study design, population, sample size, and the geographical variability in the spread of the pandemic. Nevertheless, notably, more than 75% of CFRs reported in the individual studies ranged between 10% and 39%, so our pooled estimate (CFR = 25.4%) reflects this trend.

Our study has also several strengths. The present meta-analysis included a large number of studies (n = 135) and patients (n = 33,879). All studies published in the first year since the start of the pandemic were evaluated. The CFR computed among the overall population is consistent with a previous analysis (Saini et al., 2020). In addition, we also separately focused on patients with lung and breast cancers, in order to evaluate the CFRs associated with these two common malignancies.

## 5. Conclusions

Our systematic review and meta-analysis showed that patients with solid or hematological malignancies and SARS-CoV-2 infection have a high probability of mortality, with a comparatively higher CFR in patients with lung cancer, and a comparatively lower CFR in patients with breast cancer. Based on these results, patients with underlying cancer deserve special attention with aggressive preventive measures that should also include early access to COVID-19 vaccination.

## Authors' contribution

Conceptualization: Marco Tagliamento, Matteo Lambertini.

Data curation: Marco Tagliamento, Elisa Agostinetto, Marco Bruzzone, Marcello Ceppi, Francesca Poggio, Matteo Lambertini.

Formal analysis: Marco Bruzzone, Marcello Ceppi.

Methodology: Marco Tagliamento, Elisa Agostinetto, Marco Bruzzone, Marcello Ceppi, Francesca Poggio, Matteo Lambertini.

Project administration: Marco Tagliamento, Matteo Lambertini.

Validation: all authors.

Writing - original draft: Marco Tagliamento, Elisa Agostinetto, Matteo Lambertini

Writing - review & editing: all authors.

## Disclosures

Dr. Tagliamento reported travel grants from Roche, Bristol-Myers Squibb, AstraZeneca, Takeda and Honoraria as medical writer from Novartis, Amgen outside the submitted work.

Dr. Lambertini acted as a consultant for Roche, Novartis, Lilly and AstraZeneca, and received honoraria from Novartis, Pfizer, Takeda, Roche, Sandoz and Lilly outside the submitted work.

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## Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.critrevonc.2021.103365.

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**Marco Tagliamento** is a Medical Oncology Resident and PhD Student in Translational Oncology at the University of Genova (Italy). His clinical and research activity is particularly focused on lung cancer. He is involved as researcher in clinical and translational trials in Oncology. He is member of the European Organization for Research and Treatmemt of Cancer (EORTC) Lung Cancer Group.

**Elisa Agostinetto** is a Clinical Research Fellow at Institut Jules Bordet in Brussels (Belgium) and a Medical Oncology Resident at Humanitas Research Hospital in Milan (Italy). In 2015, she received her degree in Medicine from the University of Udine (Italy), and she undertook her specialist training in Medical Oncology at Humanitas University. Her research activity focuses on her main fields of interest, namely breast cancer and immuno-oncology.

**Marco Bruzzone** is in Staff at the Clinical Epidemiology Unit of the IRCCS Ospedale Policlinico San Martino in Genova (Italy), where he works as biostatistician in the area of scientific research, mainly oncological. He is co-author of almost 50 scientific publications and of about 30 congress abstracts. The main topics of his research are the prognostic role of clinical, pathological and biological characteristics of patients with breast cancer in their survival and the relevance of genetic factors, lifestyle and occupational exposures as predictors of diseases, especially oncological. He took the bachelor's degree in Mathematical Statistics at the University of Genova (Italy) in 2011 and the master's degree in Biostatistics and Experimental Statistics at the University of Milano-Bicocca (Italy) in 2014.

**Marcello Ceppi** is a researcher at the Clinical Epidemiology Unit of the IRCCS Ospedale Policlinico San Martino in Genova (Italy). His area of expertise is the statistical analysis of epidemiological and clinical data in the field of oncology with particular reference to advanced statistical methods applied to cohort and case-control studies, clinical trials and meta-analysis. He was responsible for data analysis in several projects funded by Italian Association for Cancer Research (AIRC) and Italian Ministry of Health.

**Kamal S. Saini**, MBBS, MD, MRCP (UK), DM, is the Executive Medical Director at Covance Inc., and also works as a locum consultant medical oncologist at the NHS (UK). He has over 16 years of experience in drug development, which includes enrolling patients into cancer trials, helping design and execute studies, medical monitoring and data analysis of global trials, interfacing with regulatory bodies, and working with biotech and pharmaceutical companies to refine drug development strategies. His main areas of interest are breast and lung cancers, optimization of oncology trial design, intersection of COVID-19 and cancer, and adopting a precision medicine-based approach to the treatment of patients with cancer.

**Evandro de Azambuja** is a medical oncologist form the Institut Jules Bordet, Brussels (Belgium). He is a breast cancer specialist and the head of the Medical Support Team. He

has been extensively involved in large phase III registration trials in breast cancer and had a special interest in cardiac toxicity cause by anticancer treatments. He is also the Chair of the ESMO Fellowship Committee.

**Kevin Punie** is a medical oncologist working as a staff member at the department of General Medical Oncology in the University Hospitals Leuven (Belgium). His main areas of interest are breast cancer and hereditary cancer syndromes. He is deeply involved in clinical cancer research as principal investigator for several phase I-III trials with a focus on triple negative breast cancer. He is currently working on a PhD investigating plasma and tissue single-cell multiomics in early triple negative breast breast cancer. He is involved in the EORTC Breast Cancer Group, board member of the Belgian Society of Medical Oncology and Committee member of ESMO Young Oncologists Committee and ESMO Resilience Task Force.

**Benedikt Westphalen** studied Medicine and Molecular Biology in Hamburg, Philadelphia, New York and Bern. After graduating from medical school, he started training in Internal Medicine at the University of Hamburg (Germany), in 2008. In 2010, Dr Westphalen joined the laboratory of Timothy C. Wang at Columbia University in New York City as a postdoctoral fellow. His studies were focused on cellular plasticity and the origins of gastrointestinal malignancies. After his postdoctoral training, he joined the department of haematology and oncology at the University of Munich (Germany), in 2013. In Munich, Dr Westphalen has focused on clinical and translational research in pancreatic cancer and early phase clinical trials. Since 2017 he heads the "Molecular Diagnostics and Therapy Programme" and the "Molecular Tumour Board" at the University of Munich (Germany). Furthermore, he serves as the medical lead for early phase clinical trials in medical oncology. He has received research support from the German Research Foundation, the Universities of Hamburg and Munich and young investigator awards from the AACR and GRG/AGA. Dr Westphalen has authored and co-authored more than seventy research papers. Dr Westphalen joined ESMO in 2017 and was a participant in the "ESMO Leaders Generation Programme" in 2018. He joined the ESMO Translational Research and Precision Medicine Working Group as well as the ESMO GI faculty Group in 2019.

**Gilberto Morgan** is an American oncologist with a background in molecular biology currently practicing in Lund (Sweden).

**Paolo Pronzato** is Head of the Medical Oncology Unit at the IRCCS Ospedale Policlinico San Martino in Genova (Italy). His clinical activity is dedicated to the care of different type of cancer, and particularly focused on patients with breast cancer. He has been extensively involved as PI or co-PI in phase II/III clinical trials in advanced and early breast cancer, as well as supportive care trials.

**Lucia Del Mastro** received his M.D. degree with full marks and honors from the University of Naples (Italy) in 1989. She took the specialty in Medical Oncology in 1993 at the University of Naples. She is the director of the Breast Unit at the IRCCS Ospedale Policlinico San Martino in Genova (Italy), and professor of oncology at the University of Genova. She is PI of phase II and III trials in metastatic and early breast cancer patients, and PI of toxicity and supportive care studies. She is PI of many research projects on breast cancer. She is reviewer of research projects for Cancer Research UK and EORTC. She is member of the Scientific Committee of GIM (Gruppo Italiano Mammella), secretary of the breast cancer working group of Alliance Against Cancer, chairperson of the steering committee of the AIOM (Associazione Italiana Oncologia Medica) recommendations for fertility preservation in cancer patients and she is a member of the steering committee of the AIOM recommendations for the management of breast cancer patients. She is author of more than 200 peer-reviewed publications in internationally recognized journals.

**Francesca Poggio** is a medical oncologist working in the Breast Unit at the IRCCS Ospedale Policlinico San Martino in Genova (Italy). Since the beginning of her career, she focused on the clinical management of early and advanced breast cancer, developing expertise and specific skills in breast cancer care. She is mainly involved as sub-investigator in several studies regarding breast cancer, including spontaneous, non-profit studies, as well as clinical trials.

**Matteo Lambertini** is adjunct professor and consultant in medical oncology at the IRCCS Ospedale Policlinico San Martino - University of Genova in Genova (Italy). He is mainly focused on the care of breast cancer patients and is deeply involved in cancer research. Above all, he has a particular expertise in the management of breast cancer in young women, with a specific attention to the fertility and pregnancy-related issues that they have to face after diagnosis. He is member of the guideline group on fertility preservation in cancer patients for the European Society for Medical Oncology (ESMO), the European Society of Human Reproduction and Embriology (ESHRE) and the Italian Association of Medical Oncology (AIOM).