Journal of the National Cancer Center 4 (2024) 54–62

Contents lists available at ScienceDirect

Journal of the National Cancer Center

journal homepage: www.elsevier.com/locate/jncc

Full Length Article

# Cancer survival analysis on population-based cancer registry data in Zhejiang Province, China (2018–2019)

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ARTICLE INFO

*Keywords:*
Cancer registry
Cancer survival
Hybrid analysis
Relative survival
Net survival

ABSTRACT

*Objective:* This is a comprehensive overview of long-term cancer survival in Zhejiang Province, China. Hybrid analysis, a combination of cohort and period analysis, has been proposed to derive up-to-date cancer survival estimates. Using this approach, we aimed to timely and accurately analyze the 5-year relative survival (RS) and net survival (NS) in cancer registries of Zhejiang Province, China.

*Methods:* A total of 255,725 new cancer cases diagnosed during 2013–2017 were included in 14 cancer registries in Zhejiang Province, China, with a follow-up on vital status until the end of 2019. The hybrid analysis was used to calculate the 5-year RS and 5-year NS during 2018–2019 for overall and stratifications by sex, cancer type, region, and age at diagnosis.

*Results:* During 2018–2019, the age-standardized 5-year RS and NS for overall cancer in Zhejiang was 47.5% and 48.6%, respectively. The age-standardized 5-year RS for cancers of women (55.4%) was higher than that of men (40.0%), and the rate of urban areas (49.7%) was higher than that of rural areas (43.1%). The 5-year RS declined along with age, from 84.4% for ages <45 years to 23.7% for ages >74 years. Our results of the RS and NS showed the similar trend and no significant difference. The top five cancers with top age-standardized 5-year RS were thyroid cancer (96.0%), breast cancer (84.3%), testicular cancer (79.9%), prostate cancer (77.2%), and bladder cancer (70.6%), and the five cancers with the lowest age-standardized 5-year RS were pancreatic cancer (6.0%), liver cancer (15.6%), gallbladder cancer (17.1%), esophageal cancer (22.7%), and leukemia (31.0%).

*Conclusions:* We reported the most up-to-date 5-year cancer RS and NS in Zhejiang Province, China for the first time, and found that the 5-year survival for cancer patients in Zhejiang during 2018–2019 was relatively high. The population-based cancer registries are recognized as key policy tools that can be used to evaluate both the impact of cancer prevention strategies and the effectiveness of health systems.

## 1. Introduction

Population-based cancer survival analysis can effectively evaluate the effect of cancer prevention and control measures and reflect the prospects of cancer prognosis.[1] The CONCORD Working Group has published three consecutive issues of population-based global cancer survival since 2008, and China has joined this collaborative group since CONCORD-II.[2–4] In 2018, CONCORD-III updated the global 5-year net survival of cancer patients.[4] Meanwhile, the National Cancer Center of China reported that the 5-year relative survival of cancer patients in China increased significantly from 30.9% in 2003–2005 to 40.5% in 2012–2015.[5,6] In the past few decades, cancer has become the leading cause of death in Zhejiang Province, one of the most developed provinces, which lies in eastern China with a population of 50 million.[7] Moreover, cancer registration in Zhejiang Province started early, and the excellent cancer surveillance data of this cancer registry have been included in the "Cancer Incidence in Five Continents" and CONCORD series for several times. Nevertheless, there have been limited large population-based cancer survival studies in China.

Long-term survival estimates, such as 5-year relative survival (RS) proposed by Ederer et al., and net survival (NS) proposed by Pohar Perme et al., are the most widely used and the most commonly reported

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https://doi.org/10.1016/j.jncc.2023.12.003
Received 29 July 2023; Received in revised form 20 December 2023; Accepted 20 December 2023

outcome measures of cancer patients in the world. The RS and NS are different methods for calculating cancer-specific survival. When survival data from population-based cancer registries are used, RS is especially helpful because the causes of deaths may exist but may not be certain. Ederer reproduced an oversimplification commonly made in conventional survival analysis in a competing risk situation where the deaths of the causes, which are not of primary interest, are simply censored. This method was often called Ederer II.[8] The RS makes it possible to calculate the percentage of cancer deaths while adjusting for the variations in mortality from other causes.[9] Besides the RS, Pohar Perme developed an NS estimator, which takes unbiased account of the higher competing risks of death in elderly people.[4,9] The NS estimates the observed hazard by dividing it into risks owing to the disease and risks resulting from other causes, with the assumption being that the disease under study is the sole conceivable cause of mortality.[10] The assessment of the 5-year survival rates has been commonly used by complete, cohort, and period approaches.[11] However, in many cancer registries, completion of registration of new cases for a given calendar year often lags behind by one or two years compared to mortality follow-up. In these situations, the hybrid approach—described and empirically validated by Brenner and Rachet—could be used to compute current survival estimates by left-truncating the survival probabilities at the beginning of the period of interest in addition to right-censoring it at its end.[12] In our study, the approach was applied to patients diagnosed during 2013–2017 who were alive during the follow-up interval 2013–2019, and we didn't have enough data to use cohort or period approaches for the latest year of follow up. The estimates produced by the hybrid approach herein can be interpreted as the predicted survival probabilities for patients diagnosed during 2018–2019.

We aimed to derive the most up-to-date survival estimates of cancer patients diagnosed with a first primary cancer during 2018–2019 using hybrid analysis and population-based cancer registry data from Zhejiang Province, China to provide a scientific basis for further promoting and evaluating the strategy of cancer prevention and control.

## 2. Materials and methods

### 2.1. Data sources

The Zhejiang Provincial Office for Cancer Prevention and Control is responsible for cancer data collection, evaluation, and analysis from local population-based cancer registries. The cancer registry data in this study were submitted from 14 population-based cancer registries (five urban registries: Hangzhou, Yinzhou, Lucheng, Jiaxing, and Shangyu; nine rural registries: Cixi, Jiashan, Haining, Changxing, Yongkang, Kaihua, Daishan, Xianju, and Longquan). The 14 cancer registries covered about 14 million residents, accounting for 29.30% of Zhejiang population.[13] Data were collected from hospitals and community health centers, including the New Rural Cooperative Medical System andthe Basic Medical Insurances for Urban Residents and Disease Surveillance Points System. The International Classification of Diseases, 10th Revision (ICD-10) and the third edition of the International Classification of Diseases for Oncology (ICD-O-3) were used for cancer coding. New cancer patients diagnosed between 1 January 2013 and 31 December 2017 were included. All registries had follow-up information for all registered patients on vital status and death from any cause up to 31 December 2019, using the Zhejiang Chronic Disease Surveillance Information and Management System. With this system, the electronic card reporting was gradually promoted, and connected with the Hospital Information System (HIS) and the All-Death Surveillance System. Meanwhile, the follow-up management system of reported cases was established, which realized the organic integration of the whole chain of incidence, follow-up, and death management of cancer registration, and significantly improved the efficiency and quality of cancer registration.

Follow-up time, years

| Year at diagnosis / Year | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|
| 2013 | 0/1 | 1/2 | 2/3 | 3/4 | 4/5 | 5/6 | 6/7 |
| 2014 | | 0/1 | 1/2 | 2/3 | 3/4 | 4/5 | 5/6 |
| 2015 | | | 0/1 | 1/2 | 2/3 | 3/4 | 4/5 |
| 2016 | | | | 0/1 | 1/2 | 2/3 | 3/4 |
| 2017 | | | | | 0/1 | 1/2 | 2/3 |

**Fig. 1.** Years of diagnosis and years of follow-up included in the calculations of hybrid estimates of 5-year relative survival of patients for the years 2013–2019. The numbers within the cells indicate the years following diagnosis.

### 2.2. Quality control and exclusions

According to the "Guideline of Chinese Cancer Registration", we performed a complete set of quality control procedures using the inclusion criteria from "Cancer Incidence in Five Continents Volume X", which was required by the International Agency for Cancer Registry (IACR) and International Agency for Research on Cancer (IARC).[6,14] Before being included in the survival analysis, the quality and completeness of the cancer registry data were checked by IARC-crgTools, which was developed by IARC to verify the consistency of sex, age at diagnosis, cancer site, diagnostic basis, morphology, and differentiation degree. In our study, a total of 261,485 new cancer cases were collected. 4784 cases (1.83%) with death certificates only (DCO), 479 cases (0.18%) with unknown vital status, 494 cases (0.19%) with none-survival time, and 3 cases (0.00%) with other errors were excluded. Thus, a total of 255,725 cases were included in this study, and the case inclusion rate was 97.80% (Supplementary Table 1), indicating the high integrity and validity of the cancer registry data.

### 2.3. Statistical analysis

The hybrid analysis was used to predict the 5-year survival of cancer patients diagnosed in 2018–2019, because there were more recent follow-up data (2013–2019) than incident data (2013–2017). The hybrid approach allowed us to combine the most recent follow-up and incident data available, borrowing diagnosis from previous years (Fig. 1, dashed frame). We used RS ($S_R(t)$) as the main survival indicator, which was calculated as the ratio of the observed survival ($S_O(t)$) in the group of patients with cancer to the expected survival ($S_P(t)$) from a comparable group of the general population in the following Eq. (1).[8,9]

$$S_R(t) = \frac{S_O(t)}{S_P(t)} \tag{1}$$

Observed survival ($S_O(t)$) is the probability that a patient is still alive at a certain time point $t$ after the diagnosis. It is directly related to the overall hazard rate of dying $\lambda_O$ – knowing one quantity implies knowing the other, as shown in the following Eq. (2):

$$S_O(t) = \exp\left(-\int_0^t \lambda_O(u)du\right) \tag{2}$$

We also calculated the NS for the overall cancer, which was the cumulative probability of surviving up to a given time since diagnosis after correcting for other causes of death (background mortality).[9,10] Net survival ($S_N(t)$) should be considered if the hazard attributed to cancer is the only hazard of interest; therefore $\lambda_O$ in Eq. (2) gets replaced by

**Table 1**
Characteristics of study population, by sex and type of cancer.

| Cancer site | ICD-10 | All patients | | Male patients | | Female patients | |
|---|---|---|---|---|---|---|---|
| | | No. | Proportion,% | No. | Proportion,% | No. | Proportion,% |
| Oral cavity and pharynx | C00–10, C12–14 | 2959 | 1.16 | 2105 | 1.57 | 854 | 0.70 |
| Nasopharynx | C11 | 2848 | 1.11 | 2025 | 1.51 | 823 | 0.68 |
| Esophagus | C15 | 8407 | 3.29 | 6998 | 5.21 | 1409 | 1.16 |
| Stomach | C16 | 22,395 | 8.76 | 15,482 | 11.52 | 6913 | 5.70 |
| Colorectum | C18–21 | 26,539 | 10.38 | 15,501 | 11.53 | 11,038 | 9.10 |
| Liver | C22 | 17,859 | 6.98 | 13,273 | 9.88 | 4586 | 3.78 |
| Gallbladder | C23–24 | 4029 | 1.58 | 1689 | 1.26 | 2340 | 1.93 |
| Pancreas | C25 | 7597 | 2.97 | 4373 | 3.25 | 3224 | 2.66 |
| Larynx | C32 | 1312 | 0.51 | 1244 | 0.93 | 68 | 0.06 |
| Lung | C33–34 | 52,601 | 20.57 | 33,999 | 25.30 | 18,602 | 15.33 |
| Bone | C40–41 | 817 | 0.32 | 458 | 0.34 | 359 | 0.30 |
| Melanoma of skin | C43 | 609 | 0.24 | 322 | 0.24 | 287 | 0.24 |
| Breast | C50 | 18,449 | 7.21 | 152 | 0.11 | 18,297 | 15.08 |
| Cervix | C53 | 6692 | 2.62 | – | – | 6692 | 5.52 |
| Uterus | C54–55 | 3454 | 1.35 | – | – | 3454 | 2.85 |
| Ovary | C56 | 2752 | 1.08 | – | – | 2752 | 2.27 |
| Prostate | C61 | 8332 | 3.26 | 8332 | 6.20 | – | – |
| Testis | C62 | 197 | 0.08 | 197 | 0.15 | – | – |
| Kidney | C64–66, C68 | 4466 | 1.75 | 2824 | 2.10 | 1642 | 1.35 |
| Bladder | C67 | 4846 | 1.90 | 3814 | 2.84 | 1032 | 0.85 |
| Brain | C70–72 | 6682 | 2.61 | 2866 | 2.13 | 3816 | 3.14 |
| Thyroid | C73 | 30,371 | 11.88 | 6863 | 5.11 | 23,508 | 19.37 |
| Lymphoma | C81–85, C88, C90, C96 | 7061 | 2.76 | 4105 | 3.05 | 2956 | 2.44 |
| Leukaemia | C91–95 | 5096 | 1.99 | 2996 | 2.23 | 2100 | 1.73 |
| All others | A_O | 9355 | 3.66 | 4768 | 3.55 | 4587 | 3.78 |
| All | C00–97, D32–33, D42–43, D45–47 | 255,725 | 100.00 | 134,386 | 100.00 | 121,339 | 100.00 |

Abbreviation: ICD-10, International Classification of Diseases 10th Revision.

hazard $\lambda_C$, as shown in the following Eq. (3):

$$S_N(t) = \exp\left( - \int_0^t \lambda_C(u) du \right) \tag{3}$$

We estimated expected survival according to the Ederer II method, using life tables stratified by registry, sex, age, and calendar year. Abridged life tables were smoothed to complete life tables and extended to the age of 99 years using the Elandt–Johnson method. We presented 5-year age-standardized RS (5-y ASRS) and 5-year age-standardized NS (5-y ASNS) for each cancer using the International Cancer Survival Standard (ICSS) weights, in which age at diagnosis was categorized into five groups: 0–44, 45–54, 55–64, 65–74, and ≥75 years. For the most of cancer types and all cancers combined, survival rates were standardized by ICSS1 age structure (7% for 0–44 years, 12% for 45–54 years, 23% for 55–64 years, 29% for 65–74 years, and 29% for ≥75 years old). For nasopharyngeal cancer, melanoma, cervical cancer, brain cancer, thyroid cancer, and bone cancer, the survival rates were age-standardized by ICSS2 age structure (28% for 0–44 years, 17% for 45–54 years, 21% for 55–64 years, 20% for 65–74 years, and 14% for ≥75 years old). For testicular cancer and leukemia, the survival rates were age-standardized by ICSS3 age structure (60% for 0–44 years, 10% for 45–54 years, 10% for 55–64 years, 10% for 65–74 years, and 10%% for ≥75 years old). All analyses were performed using Stata version 17.0 (StataCorp LP, College Station TX) and R version 4.1.1 (R Foundation for Statistical Computing, Vienna, Austria).

## 3. Results

### 3.1. Basic characteristics of study population

Overall, 261,485 records of new cancer cases were registered during 2013–2017 and 255,725 patients were included in survival analyses (97.80% of those eligible). The basic characteristics of the study population are presented in Table 1, including 134,386 males (52.55%) and 121,339 females (47.45%). The four most common cancers (lung, thyroid, colorectum, and stomach) comprised over half (51.58%) the 255,725 cases included in the survival analyses. Lung cancer patients accounted for the largest proportion (20.57%), followed by thyroid cancer

**Table 2**
The 5-year relative survival and net survival for all cancers combined in Zhejiang Province, China (2018–2019).

| Categories | 5-year RS, % (95% CI) | Age-standardized 5-year RS, % (95% CI) | 5-year NS, % (95% CI) | Age-standardized 5-year NS, % (95% CI) |
|---|---|---|---|---|
| Sex | | | | |
| Males | 41.2 (40.8–41.7) | 40.0 (39.6–40.5) | 41.7 (41.3–42.2) | 41.3 (40.8–41.7) |
| Females | 66.2 (65.7–66.6) | 55.4 (54.9–55.9) | 66.0 (65.6–66.5) | 56.5 (55.9–57.0) |
| Region | | | | |
| Urban areas | 55.6 (55.2–56.0) | 49.7 (49.3–50.1) | 55.7 (55.3–56.1) | 50.9 (50.5–51.3) |
| Rural areas | 48.6 (48.0–49.1) | 43.1 (42.6–43.7) | 48.4 (47.9–49.0) | 44.1 (43.5–44.7) |
| Age group | | | | |
| 0–44 | 84.4 (83.6–85.1) | – | 84.6 (83.9–85.2) | – |
| 45–54 | 71.8 (71.1–72.4) | – | 72.0 (71.4–72.6) | – |
| 55–64 | 58.0 (57.3–58.6) | – | 58.3 (57.7–58.9) | – |
| 65–74 | 44.1 (43.4–44.7) | – | 44.9 (44.2–45.5) | – |
| ≥75 | 23.7 (23.1–24.4) | – | 26.2(25.5–27.0) | – |
| All | 53.3 (52.9–53.6) | 47.5 (47.2–47.8) | 53.3 (52.9–53.6) | 48.6 (48.2–48.9) |

Abbreviations: CI, confidence interval; NS, net survival; RS, relative survival.

(11.88%), colorectal cancer (10.38%), stomach cancer (8.76%), breast cancer (7.21%), liver cancer (6.98%), etc.

### 3.2. Overall cancer survival in Zhejiang, China, 2018–2019

As shown in Table 2, the 5-year RS and 5-year NS for all cancers combined were both 53.3%. After standardization, the 5-y ASRS and 5-y ASNS were 47.5% and 48.6%, respectively. We found women had higher 5-y ASRS and ASNS compared to men (55.4% vs. 40.0%, 56.5% vs. 41.3%). And urban areas had higher 5-y ASRS and ASNS compared to rural areas (49.7% vs. 43.1%, 50.9% vs. 44.1%). The 5-year RS and NS varied considerably according to age group, declining from 84.4% and 84.6% for the group whose age at diagnosis was <45 years to 23.7% and 26.2% for the group whos age at diagnosis was ≥75 years. We also found the ASRS decreased with the increase of survival time by sex, region, and age group (Fig. 2).

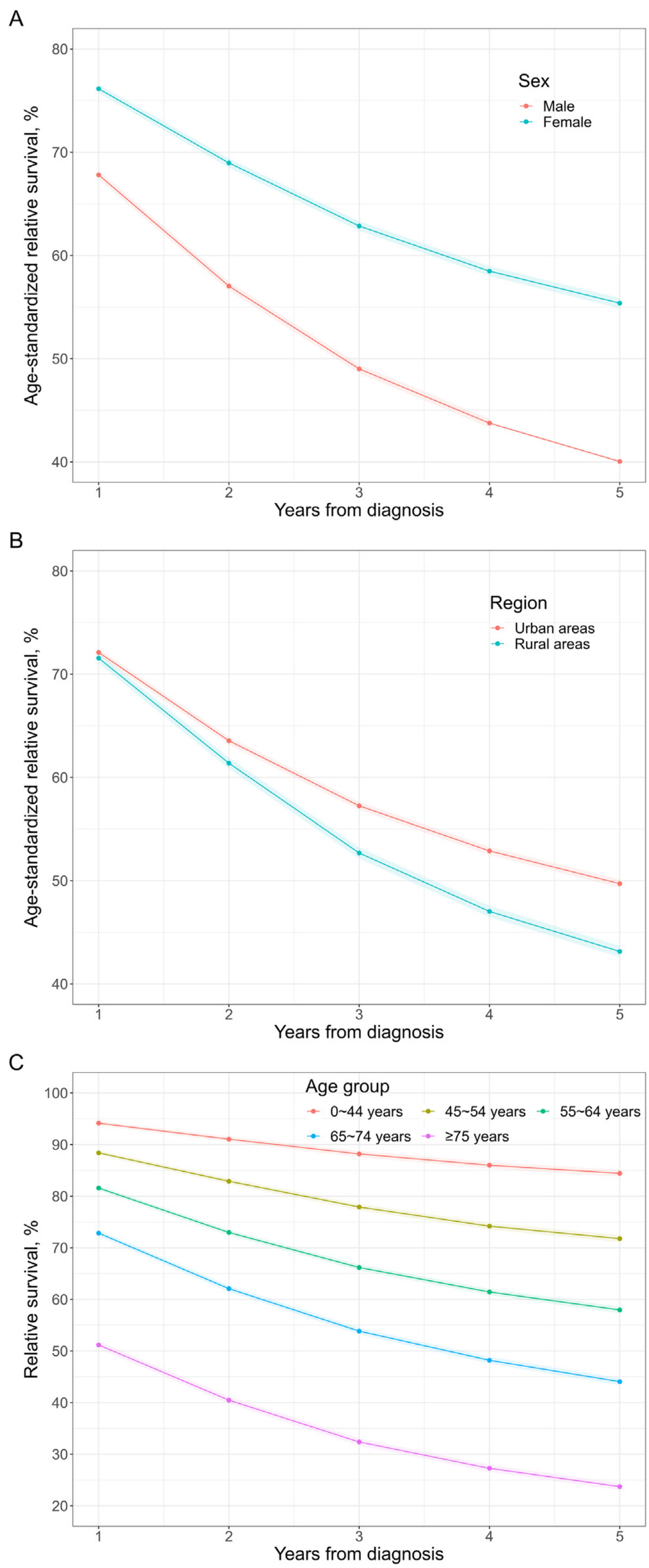


**Fig. 2.** Comparison of age-standardized relative survival by sex (A), region (B), and age group (C) in Zhejiang Province, China.

### 3.3. Five-year relative survival of by cancer type

The 5-year survival rates varied greatly by cancer type. As shown in Table 3, the cancer types with high 5-y ASRS were thyroid cancer (96.0%), breast cancer (84.3%), testicular cancer (79.9%), prostate cancer (77.2%), and bladder cancer (70.6%). The 5-y ASRS was lower for pancreatic cancer (6.0%), liver cancer (15.6%), gallbladder cancer (17.1%), esophageal cancer (22.7%), leukemia (31.0%), and lung cancer (32.00%). The estimates of 5-year NS were similar to the results of 5-year RS, for both crude rates and age-standardized rates.

To further explore the survival status, the 5-year RS for all the cancer types was analyzed by sex and by urban/rural area (Fig. 3). Survival was relatively lower in male patients than in female patients, both for all cancers combined and for most individual cancers (Fig. 3A and Fig. 4). As shown in Supplementary Table 2, after age-standardization, the top 5 cancer types in male patients were thyroid cancer (96.4%), testicular cancer (79.9%), prostate cancer (77.2%), bladder cancer (70.1%), and larynx cancer (65.2%); the 5 cancer types with the worst prognosis in male patients were pancreatic cancer (5.5%), liver cancer (15.6%), gallbladder cancer (16.2%), esophageal cancer (20.7%), and lung cancer (25.0%). The top 5 cancer types in female patients were thyroid cancer (95.9%), breast cancer (84.3%), larynx cancer (74.6%), oral cavity and pharynx cancer (73.0%), and bladder cancer (72.1%). The 5 cancer types with the worst prognosis in female patients were pancreatic cancer (6.9%), liver cancer (16.8%), gallbladder cancer (18.0%), leukemia (34.6%), and esophageal cancer (36.6%). The 5-year RS of most cancer types in urban areas was markedly higher than that in rural areas, and the exceptions were esophageal cancer, oral cavity and pharynx cancer, and melanoma of skin—the only cancer for which survival for rural patients was higher than for urban patients (Fig. 3B). We also found a clear age gradient for the 5-year RS, which of common cancers decreased with the increment of age. Meanwhile, the 5-year RS curves of bladder cancer, kidney cancer, colorectal cancer, liver cancer, pancreatic cancer, stomach cancer, and thyroid cancer showed no significant difference between males and females (Fig. 5).

## 4. Discussion

This is a comprehensive overview of long-term cancer survival in Zhejiang Province, China using population-based registry data and hybrid analysis. A total of 255,725 patients diagnosed during 2013–2017 and followed up to 2019 were included. We provided the most up-to-date 5-year RS, as well as 5-year NS for cancer patients during 2018–2019, aiming to measure the overall effectiveness of cancer prevention and control strategies, which can provide useful information to healthcare professionals and policy-makers.

In our study, the 5-y ASRS for all cancers combined in Zhejiang Province, China was 47.5%, which was relatively higher than the result of 40.2% during 2018–2020 in Shandong Province, China,[15] and higher than the report of 40.5% during 2012–2015 for the whole country,[6] indicating the superiority of the early detection or treatment management for common cancers in Zhejiang over national average. In recent years, China has increased its investment in health resources, and practical factors such as the improvement of primary health care, the applicability of diagnostic facilities, and the improvement of treatment levels have directly contributed to the improvement of cancer survival. From a decade

**Table 3**
The 5-year relative survival and net survival of different cancer types in Zhejiang Province, China (2018–2019).

| Cancer site | 5-year RS, % (95% CI) | Age-standardized 5-year RS, % (95% CI) | 5-year NS, % (95% CI) | Age-standardized 5-year NS, % (95% CI) |
|---|---|---|---|---|
| Thyroid | 99.3 (99.0–99.6) | 96.0 (94.0–97.4) | 99.3 (99.0–99.5) | 96.2 (93.8–97.6) |
| Breast | 88.8 (88.0–89.6) | 84.3 (82.3–86.1) | 88.9 (88.0–89.7) | 85.0 (82.7–86.9) |
| Testis | 90.5 (79.6–96.4) | 79.9 (70.6–86.5) | 90.6 (78.2–96.1) | 81.6 (67.4–90.0) |
| Prostate | 74.2 (72.1–76.2) | 77.2 (75.0–79.2) | 74.2 (71.9–76.3) | 77.7 (75.5–79.7) |
| Bladder | 67.4 (64.8–69.9) | 70.6 (68.2–72.7) | 65.6 (61.8–69.2) | 70.3 (67.4–73.0) |
| Cervix | 77.6 (75.9–79.2) | 70.4 (68.4–72.3) | 77.3 (75.6–79.0) | 70.6 (68.5–72.5) |
| Uterus | 83.2 (80.9–85.2) | 68.2 (64.0–72.0) | 82.9 (80.6–85.0) | 68.6 (64.3–72.6) |
| Kidney | 69.8 (67.4–72.1) | 64.9 (62.4–67.4) | 69.6 (67.1–71.9) | 65.5 (62.8–68.0) |
| Larynx | 68.2 (63.5–72.5) | 64.9 (59.2–70.0) | 67.7 (62.5–72.4) | 64.6 (58.5–70.1) |
| Brain | 63.4 (61.4–65.3) | 63.1 (61.1–64.9) | 63.7 (61.7–65.7) | 63.9 (62.0–65.8) |
| Oral cavity and pharynx | 49.9 (46.9–52.9) | 57.4 (54.1–60.6) | 49.4 (46.1–52.6) | 57.6 (54.2–60.8) |
| Colorectum | 56.7 (55.7–57.7) | 56.1 (55.0–57.1) | 56.6 (55.5–57.7) | 56.7 (55.6–57.7) |
| Nasopharynx | 64.6 (61.5–67.5) | 53.3 (48.7–57.7) | 64.7 (61.6–67.6) | 54.8 (49.8–59.5) |
| Melanoma of skin | 42.9 (36.1–49.7) | 46.1 (38.2–53.5) | 45.7 (38.3–52.7) | 48.0 (40.1–55.4) |
| Stomach | 40.7 (39.6–41.8) | 40.4 (39.4–41.4) | 40.8 (39.7–41.9) | 41.2 (40.1–42.2) |
| Bone | 36.6 (31.0–42.2) | 39.9 (34.4–45.3) | 39.1 (32.9–45.2) | 41.6 (36.0–47.2) |
| Lymphoma | 43.8 (41.9–45.7) | 39.6 (37.8–41.4) | 43.9 (41.9–45.8) | 40.5 (38.6–42.4) |
| Ovary | 50.3 (47.3–53.2) | 37.4 (33.9–41.0) | 50.6 (47.6–53.5) | 38.9 (35.0–42.7) |
| Lung | 32.6 (31.9–33.3) | 32.0 (31.4–32.6) | 32.9 (32.2–33.6) | 33.1 (32.4–33.7) |
| Leukemia | 39.9 (37.7–42.1) | 31.0 (28.9–33.1) | 41.1 (38.8–43.4) | 33.1 (30.9–35.4) |
| Esophagus | 20.6 (19.2–22.0) | 22.7 (20.6–24.8) | 21.4 (19.9–22.9) | 23.7 (21.6–25.9) |
| Gallbladder | 14.5 (12.8–16.2) | 17.08 (15.1–19.2) | 17.1 (15.2–19.1) | 19.4 (17.3–21.7) |
| Liver | 17.1 (16.2–18.0) | 15.6 (14.8–16.5) | 19.2 (18.3–20.2) | 17.9 (16.9–18.9) |
| Pancreas | 4.5 (3.8–5.2) | 6.0 (5.0–7.2) | 6.3 (5.3–7.4) | 7.8 (6.6–9.2) |
| All others | 56.7 (54.9–58.5) | 56.3 (54.5–58.1) | 57.7 (55.7–59.7) | 57.5 (55.6–59.4) |

Abbreviations: CI, confidence interval; NS, net survival; RS, relative survival.

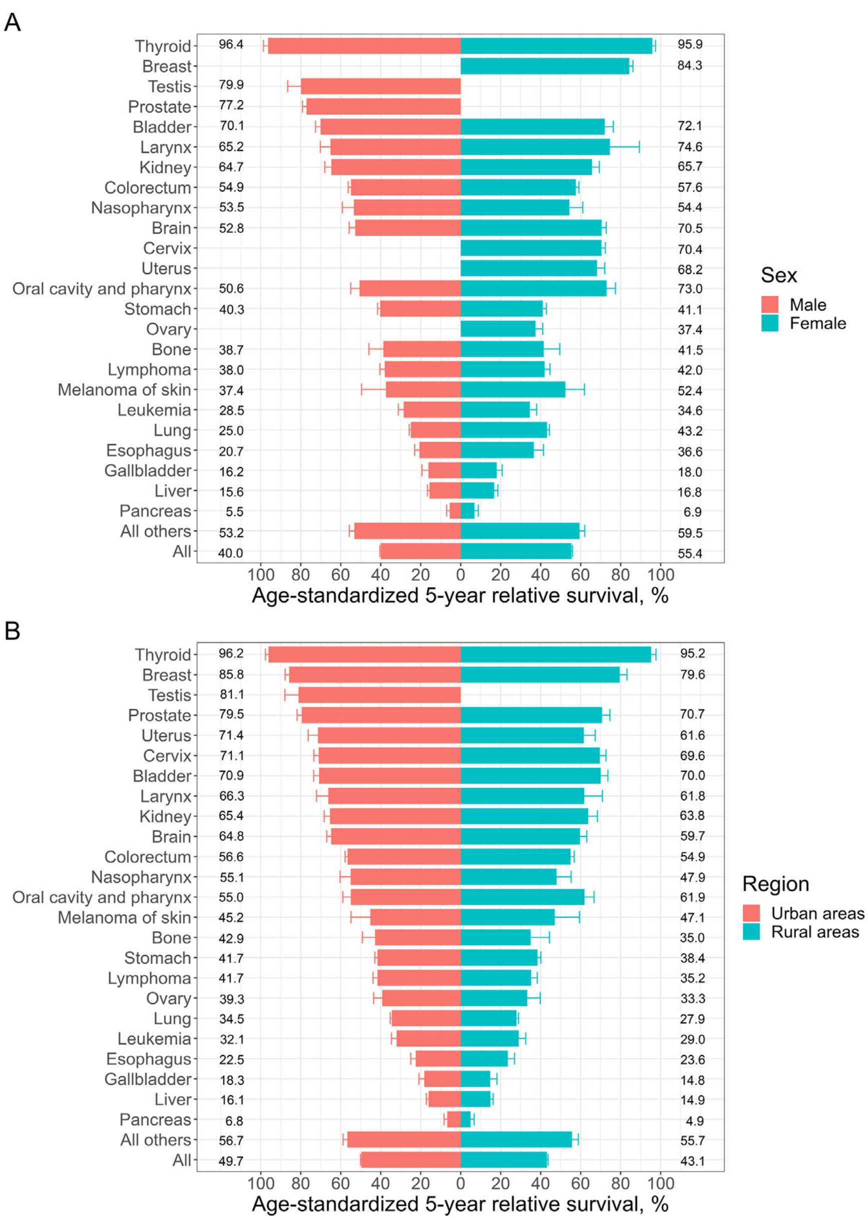


**Fig. 3.** Age-standardized 5-year relative survival by cancer site in Zhejiang Province, China. (A) Males and females. (B) Urban and rural areas.

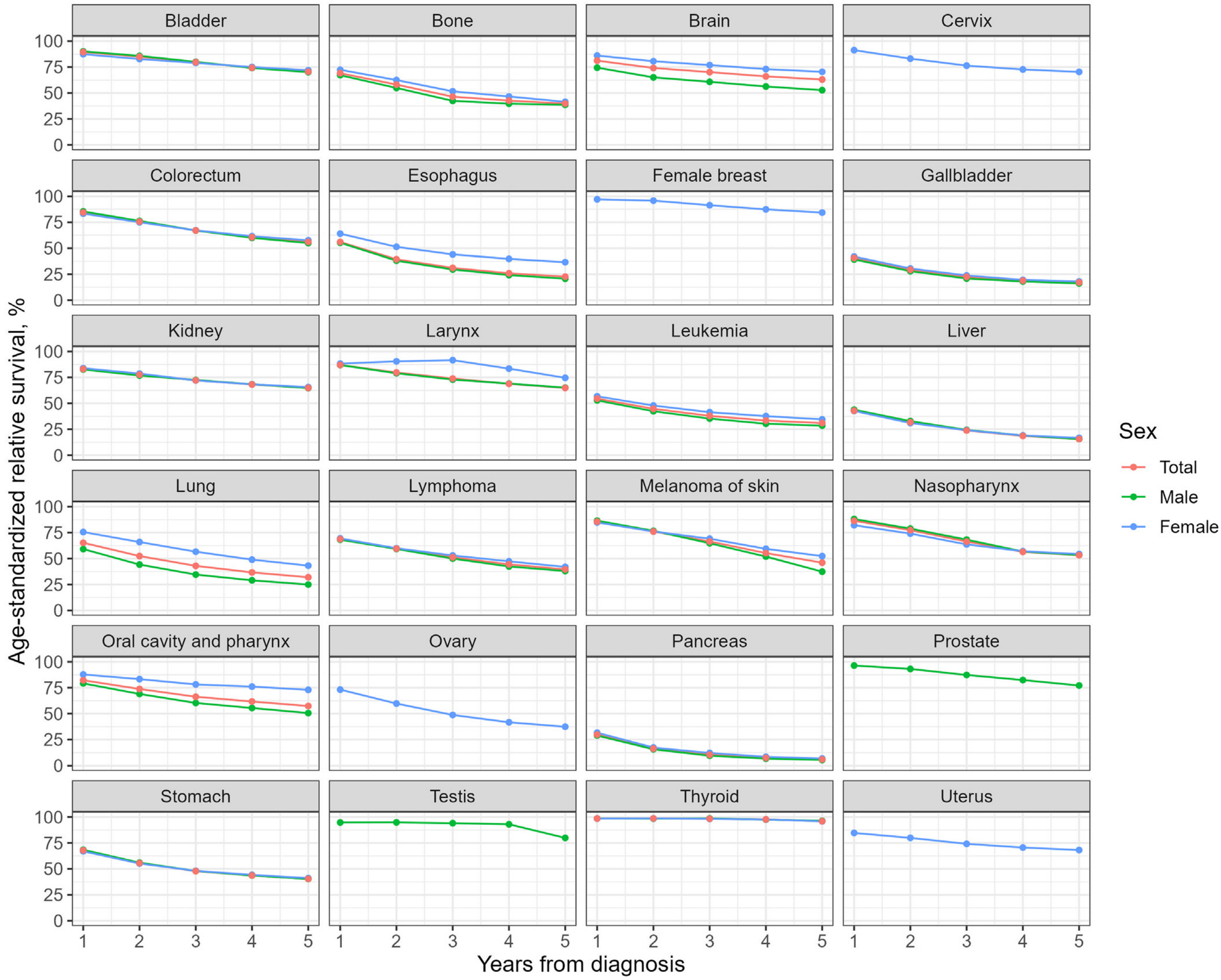


**Fig. 4.** Comparison of age-standardized relative survival curves among common cancer sites in Zhejiang Province, China.

ago, Zhejiang has successively carried out colorectal cancer screening, breast cancer screening, upper gastrointestinal cancer screening, lung cancer screening, and liver cancer screening. Through screening, a large number of cancer cases at early stages have been found and effectively treated, and thus extending the survival time and improving the quality of life of patients.

However, our estimate was still lower than the 5-year RS for all cancers combined in developed countries, such as the United States (US) (67.2%) in 2004 and Australia (66%) during 2006–2010.[16,17] The inconsistence in cancer survival between Zhejiang Province and western developed countries may be due to the different cancer spectra. We found survival estimates varied widely among diverse cancer types. The best prognosis was observed for thyroid cancer, breast cancer, testicular cancer, and prostate cancer. However, pancreatic cancer, liver cancer, and gallbladder cancer showed the worst prognosis. In developed countries, breast cancer, prostate cancer, and colorectal cancer were three of the most common cancers, all with high 5-year RS. According to the incidence estimates, cancers of the lung, liver, stomach, esophagus, and pancreas were high-incidence cancers with much poorer prognosis in Zhejiang. Together, according to the 2020 statistics, these five typical cancers accounted for 64% of all cancer cases in Zhejiang,[13] while their counterparts accounted for only 16.3% in the US and 20.3% in Europe.[18] Our results of the RS and NS showed no significant difference for both crude rates and age-standardized rates. The gaps between 5-year RS and NS were a little larger for cancers that tend to occur among older patients (≥75 years) than for those cancers occurring in younger patients, which could be explained by less competing risks for death at a younger age.[19]

We found the survival of all cancers combined for men was lower than for that for women in Zhejiang, which is consistent with national figures and other researches.[19–22] And this could largely be explained by the different distribution of cancer types between men and women, as has been mentioned above. Thyroid cancer and breast cancer accounted for a large proportion (34.57%) of all cancers in women, while the corresponding cancers made up only 5.35% in men. Moreover, women showed better survival than men for every non-specific cancer types only except for thyroid cancer, which could be attributed to biological superiority mediated by estrogens.[23–26] Better survival was observed in urban areas than in rural areas. The low level of treatment in rural areas and the limited access to healthcare may have contributed to the low survival rates in rural areas. The uneven distribution of healthcare resources in rural areas may be exacerbated by the small number of medical experts and antiquated equipment there.[27] Age-related declines in cancer survival were typically observed, which is consistent with other population-based studies,[1,28–30], implying a survival disadvantage for older adults (≥65 years). Older cancer patients are more likely to be in the middle or late stages at the time of di-

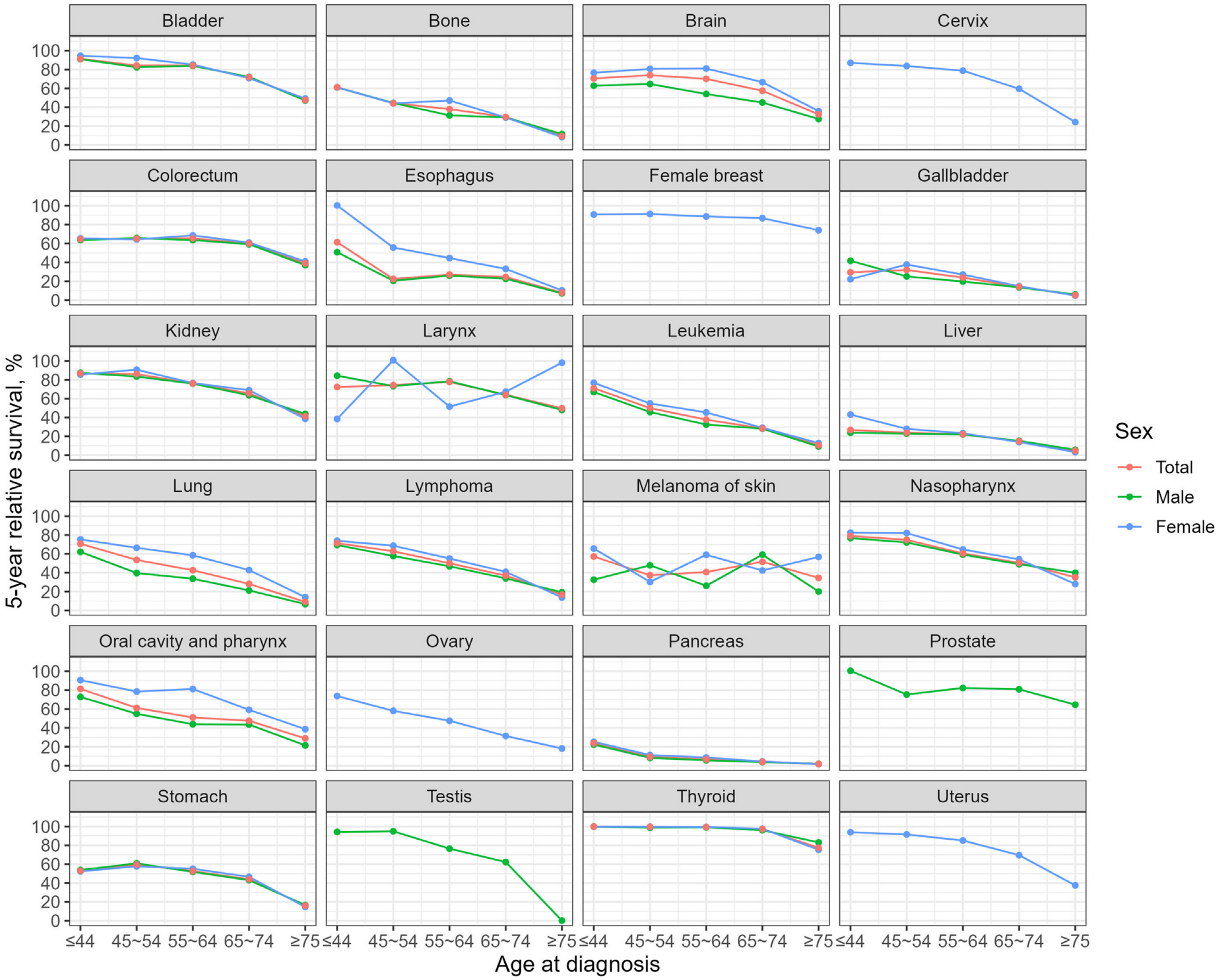


**Fig. 5.** Five-year relative survival among common cancer sites by age group and cancer type in Zhejiang Province, China.

agnosis, and they have relatively less strong intentions for treatment compared to young and middle-aged patients. Additionally, our findings of age-related disparities in cancer survival may be caused by a number of factors, such as comorbidity, frailty, socioeconomic level, inadequate cancer management, and patient preferences for treatment options.[31–33]

Comparing with the major cancer types nationwide, the 5-y ASRS of esophageal cancer, colorectal cancer, pancreatic cancer, uterus cancer, ovary cancer, kidney cancer, and bladder cancer in Zhejiang during 2018–2019 were lower than the national level (30.3%, 56.9%, 7.2%, 72.8%, 39.1%, 69.8%, and 72.9%) during 2012–2015, respectively.[6] Notably, the 5-y ASRS of lung cancer, cervical cancer, brain tumor, and thyroid cancer were significantly higher than national levels (19.7%, 59.8%, 26.7%, and 84.3%).[6] The CONCORD-3 study reported worldwide NS estimates for 15 cancer types up to the period 2010–2014.[4] Globally, the highest 5y-ASNSs for stomach cancer were in Korea (69%) and Japan (60%), with our figure being merely 41.2%. The 3 countries with the highest 5y-ASNSs for esophageal cancer were Japan (36%), China (34%) and South Korea (31%), much higher than the estimate in Zhejiang Province (23.70%). Canada and the US had 5y-ASNSs for colorectal cancer of 67% and 65%, respectively; meanwhile the 5y-ASNS in our study was lower, being 56.7%. The 5y-ASNS for prostate cancer was over 90% in the US, Canada, Japan, Korea, and several European countries, obviously higher than our survival estimate (77.7%). The 5y-ASNS for lung cancer was the highest in Japan (33%), which was similar to our figure (33.1%), and was approximately 21% in both the US and Canada. The 5y-ASNS for pancreatic cancer ranged from 5% to 15% worldwide, and our result was within this range (7.8%). The 5y-ASNS for liver cancer was the highest in Japan (30%); and it was 19% in the US and 17% in Canada, similar to our result (17.9%). The 5y-ASNSs for female breast cancer in Europe and the US were around 85%, which was pretty close to our result (85.0%). The highest 5y-ASNS for cervical cancer was in Japan (more than 70%), while it ranged from 60% to 69% in Europe, the US, and China; notably, in Zhejiang, the 5y-ASNS for cervical cancer was as high as 70.6%. The 5y-ASNS for ovarian cancer ranged within 30%-50% worldwide, and our figure also fell into this range (38.9%). Compared with the cancer survival in the developed countries mentioned above, the 5y-ASNSs of stomach, esophageal, colorectal, and prostate cancers in Zhejiang Province of China were significantly lower than the estimates in Japan, Korea, the US, and Canada. And the 5y-ASNS of lung, female breast, and cervical cancers in Zhejiang Province of China have reached or were very close to the levels of developed countries. This may be due to the implementation of chest CT examination and the promotion of women's screening for "two cancers", namely, breast cancer and cervical cancer. Population-based cancer survival rates are mainly related to factors such as access to and quality of cancer services and their financial investment.[4] Cancer type, screening program, economy, and quality of cancer registries also greatly influence cancer survival rates, and differences in population-based cancer survival across time and countries/regions are mainly related to these factors. Improving cancer services, such as developing cancer prevention and control programs, improving access to primary health care and diagnostic equipment, taking physical examination regularly, improving treatment outcomes, and investing sufficient funds, can improve the cancer survival rates. Zhejiang Province has a more developed economy, richer medical resources, higher medical standards, wider medical insurance coverage, and more accurate cancer registry data, and thus the population here should have a better cancer survival.

The main strengths of our study include using hybrid analysis to derive the most up-to-date (during 2018–2019) survival estimates in Zhejiang, China, which could extend the applicability of the period approach to commonly encountered situations with different cut-off dates for inclusion of incident cases and for mortality follow-up[12]; providing both RS and NS estimates for the first time, which are the widely used long-term survival indicators, and thus making it convenient to compare with other cancer survival studies; using the standardized registration procedures, the high-quality cancer registry data, and the reliable follow-up of vital status, which all contributed to the reliability of our results. Nevertheless, there are limitations in this study. On one hand, the 14 cancer registries covered only about 29.03% of the Zhejiang population, which cannot represent the cancer survival level in the whole China, and the next step will be to sort and analyze all the follow-up data in eastern China to obtain a more comprehensive and accurate overview of cancer survival status. On the other hand, the population-based cancer registry has not yet been able to obtain some important explanatory factors, such as stage at diagnosis and pathological types or treatments, for further subgroup analysis. Nevertheless, this is the most complete and accurate information available on the cancer survival in eastern China. We will further improve the information collection on clinical staging and pathology, and conduct on-site surveys in conjunction with hospitals and communities to collect information on lifestyle behaviors, aiming to further explore the factors affecting patients' prognosis.

## 5. Conclusions

In this study, we reported the most up-to-date 5-year RS and NS in Zhejiang Province, China for the first time, and found that the 5-year survival for cancer patients in Zhejiang during 2018–2019 was relatively high. These findings could be the results of a number of factors, such as earlier diagnosis and better available treatment. Women had better cancer survival than men did, and the cancer survival in urban areas was higher than that in rural areas. We also found a clear age gradient for cancer survival, declining along with age. However, the dismal prognosis shown for some cancer types highlights the need to strengthen efforts taken at every stage of the cancer continuum, starting with primary prevention and continuing with early detection, the best possible therapy, and supportive care. Population-based cancer registries are acknowledged as important policy tools that may be used to assess both the performance of healthcare systems and the effectiveness of cancer preventive strategies.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Acknowledgements

The authors are grateful to all the staff of the 14 cancer registries in Zhejiang Province, China, for their support in data collection, sorting, verification, and database creation. The authors also thank the National Central Cancer Registry, National Cancer Center for their technical guidance on data cleaning and statistical analysis. This study was funded by Healthy Zhejiang One Million People Cohort (grant number: K-20230085).

## Author contributions

L.D. and X.C. were responsible for the study concept and design. X.C. obtained funding. H.L., W.G. and Y.C. acquired data. H.L. and Y.W. analyzed and interpreted data. Y.W. and H.L. drafted the manuscript, and all authors revised it for important intellectual content. The authors take full responsibility for data analysis and result interpretation of this article.

## Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jncc.2023.12.003.

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