Changing cancer survival in China during 2003–15: a pooled analysis of 17 population-based cancer registries

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Summary

Background From 2003 to 2005, standardised 5-year cancer survival in China was much lower than in developed countries and varied substantially by geographical area. Monitoring population-level cancer survival is crucial to the understanding of the overall effectiveness of cancer care. We therefore aimed to investigate survival statistics for people with cancer in China between 2003 and 2015.

Methods We used population-based data from 17 cancer registries in China. Data for the study population was submitted by the end of July 31, 2016, with follow-up data on vital status obtained on Dec 31, 2015. We used anonymised, individual cancer registration records of patients (aged 0–99 years) diagnosed with primary, invasive cancers from 2003 to 2013. Patients eligible for inclusion had data for demographic characteristics, date of diagnosis, anatomical site, morphology, behaviour code, vital status, and last date of contact. We analysed 5-year relative survival by sex, age, and geographical area, for all cancers combined and 26 different cancer types, between 2003 and 2015. We stratified survival estimates by calendar period (2003–05, 2006–08, 2009–11, and 2012–15).

Findings There were 678 842 records of patients with invasive cancer who were diagnosed between 2003 and 2013. Of these records, 659 732 (97·2%) were eligible for inclusion in the final analyses. From 2003–05 to 2012–15, age-standardised 5-year relative survival increased substantially for all cancers combined, for both male and female patients, from 30·9% (95% CI 30·6–31·2) to 40·5% (40·3–40·7). Age-standardised 5-year relative survival also increased for most cancer types, including cancers of the uterus (average change per calendar period 5·5% [95% CI 2·5–8·5]), thyroid (5·4% [3·2–7·6]), cervix (4·5% [2·9–6·2]), and bone (3·2% [2·1–4·4]). In 2012–15, age-standardised 5-year survival for all patients with cancer was higher in urban areas (46·7%, 95% CI 46·5–47·0) than in rural areas (33·6%, 33·3–33·9), except for patients with oesophageal or cervical cancer; but improvements in survival were greater for patients residing in rural areas than in urban areas. Relative survival decreased with increasing age. The increasing trends in survival were consistent with the upward trends of medical expenditure of the country during the period studied.

Interpretation There was a marked overall increase in cancer survival from 2003 to 2015 in the population covered by these cancer registries in China, possibly reflecting advances in the quality of cancer care in these areas. The survival gap between urban and rural areas narrowed over time, although geographical differences in cancer survival remained. Insight into these trends will help prioritise areas that need increased cancer care.

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Introduction

With the world's largest population, about a fifth of all global cancer cases occur in China,[1,2] and cancer has become the leading cause of death in the country in recent years.[3,4] Along with cancer incidence and mortality data, population-based survival estimates provide further insight to assess the effectiveness of cancer care. In 2015, we published the first collaborative report[5] to pool results of population-based cancer survival in China from 17 cancer registries. We previously reported that overall standardised 5-year relative survival in China was 30·9% for the cohort of patients diagnosed during 2003–05, much lower than in developed countries,[5,6] and that survival varied substantially by geographical area. These findings have informed the design of China's national cancer control plans and motivated a series of cancer control and prevention actions in the past few years.[7–9] Examples of these include implementing cancer screening programmes in areas with an identified high cancer risk,[10] alongside the integration of improvements in cancer diagnosis and treatment.[11] Given the potential of these initiatives to affect the short-term survival of people diagnosed with cancer, we used the most up-to-date cancer survival information for China to investigate

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Research in context

Evidence before this study

Population-based survival trends provide a key insight into the overall effectiveness of a cancer care system. We searched PubMed, Google Scholar, and China National Knowledge Infrastructure, without language restrictions, for articles published before Dec 16, 2017, using the terms "cancer survival", "population-based", and "trend". We found that many studies reported increasing survival trends for many individual cancers as well as all cancers combined in several countries during the past 20 years. In 2015, the first pooled analysis was published of population-level cancer survival data for Chinese patients who were diagnosed between 2003 and 2005, providing a benchmark for a series of national health plans, including the Mid-term and Long-term Plan for Prevention and Treatment of Chronic Diseases in China (2017–25) and Healthy China 2030. During the past decade, major changes in cancer care and treatment occurred in China; however, no updated population-based cancer survival statistics and trend analyses were reported in the country. To assess the extent of survival improvement in China, we extended coverage to patients diagnosed with cancer during 2003–13, and followed up to the end of 2015, to report updated cancer survival statistics using data from 17 cancer registries.

Added value of this study

We found a substantial improvement in survival over time for all cancers combined. There was also an improvement in age-standardised 5-year relative survival for eight cancers: oesophagus, stomach, larynx, bone, cervix, uterus, bladder, and thyroid. Relative survival varied widely for different cancers and was generally lower for old patients than for young patients, and lower for male patients than for female patients. Geographical disparities still existed between urban and rural areas in the specific regions of this study, although the gap narrowed during the 13 years of follow-up.

Implications of all the available evidence

This study provides the most comprehensive and up-to-date assessment of the prognosis of cancer survival in China over time. The comparison of estimates of survival between urban and rural areas should provide an insight into national health challenges and priority areas for cancer care.

how survival has changed between 2003 and 2015 and whether these changes are consistent across geographical areas. We also used national data to examine the trends in medical resources and expenditures, and how these might relate to survival rates.

Methods

Study population and data collection

The National Central Cancer Registry is the only national agency with the mandate to oversee national population-based cancer statistics in China. It is responsible for collecting, investigating, and publishing cancer data from subnational population-based cancer registries of the country.[12] The National Central Cancer Registry instigated 21 population-based cancer registries to follow up registered patients with cancer who were diagnosed since 2003.[5] Through a study protocol, the National Central Cancer Registry trained cancer registrars to collect survival information through a series of training programmes.[13] All cancer registries collected data according to a standardised protocol, and submitted their local data at the end of July 31, 2016. Data from four cancer registries (Donghai, Guanyun, Lianyungang, and Yangzhong) were considered incomplete in terms of registration or follow-up, while the remaining 17 cancer registries (with their geographical distribution being presented previously[5]) submitted data for all cancer types. Thus, the study population was patients with cancer who were diagnosed between 2003 and 2013, aged 0–99 years, from 17 geographical areas covered by population-based cancer registries. For survival trend analysis, we also obtained follow-up data (for patients diagnosed in 2006–13) on vital status, updated on Dec 31, 2015, as well as previously published survival data from 2003–05.[5] All registries, except for the registry in Dalian, used both passive and active follow-up methods to ascertain the vital status of patients with cancer. The staff of local registries linked the cancer records and death records on the basis of identifiable information. Unlinked patients were further followed up by registry staff through direct contact or via family members. Registry staff anonymised the records before we received them.

We used the tenth edition of International Classification of Diseases (ICD-10) and the third edition of the International Classification of Diseases for Oncology (ICD-O-3) to classify all cancer cases, which were anonymised. The detailed cancer dictionary and their corresponding ICD-10 codes are shown in the appendix (p 1). The final dataset included variables describing demographic characteristics, date of diagnosis, anatomical site, morphology, behaviour code, vital status, and last date of contact. We used data from the National Bureau of Statistics of China to analyse trends in medical resources and health expenditures.

Quality control and exclusions

We standardised the format of the variables and applied automatic checking procedures to assess the data quality of each registry. Adherence to these variables was required for a record to be eligible. However, records without morphology were also considered eligible. Also, multiple primary data were included in the datasets. First, we verified adherence to each variable. We classified values that were out of range as errors. We checked the consistency of combinations of date of birth, diagnosis, and follow-up. We used International Agency for Research on Cancer guidelines to check the combinations of site and morphology.[14] We also classified impossible combinations as errors, with erroneous records sent back to the registries for correction or clarification. We re-checked resubmitted data using the same procedures. Using standardised data registration and a centralised follow-up data collection and quality control system, we could estimate and report time trends in survival for Chinese populations residing in different areas of the country.

Statistical analysis

We included records that passed quality control checks in the survival analysis. We used relative survival as the main survival indicator, which was calculated as the ratio of the observed survival in the group of patients with cancer and the expected survival from a comparable group of the general population. We estimated expected survival according to the Ederer II method, using life tables stratified by registry, age, sex, 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.[15,16] We categorised patients into five major age groups (0–44, 45–54, 55–64, 65–74, and 75–99 years) following the International Cancer Survival Standards for age standardisation of survival. We used standard weights to calculate age-standardised relative survival: 7% (0–44 years), 12% (45–54 years), 23% (55–64 years), 29% (65–74 years), and 29% (75–99 years).[17] The same age weights were used for male and female patients, for all cancers combined, and for each area and cancer, enabling direct comparison of age-standardised relative survival between patient groups. We calculated standard errors by the Greenwood formula, assuming a normal distribution, and derived 95% CIs accordingly.[18]

We stratified survival estimations by calendar period (2003–05, 2006–08, 2009–11, and 2012–15). We analysed relative survival during 2003–05 and 2006–08 using the cohort method. We used period analysis to calculate relative survival for the period 2009–11, because 5-year survival for patients diagnosed during this period was not available for all patients.[19] We used a hybrid analysis to predict the 5-year relative survival for the period 2012–15, because we did not have enough data to use cohort or period approaches for the latest years of follow-up (2014–15; appendix p 5).[20] To assess changes in between-area survival differences, we compared data from rural registries and urban registries using the area classification of the National Bureau of Statistics of China. The improvement in cancer survival was quantified as the absolute average change between successive calendar periods. We tested differences between survival in different calendar periods for statistical significance by a weighted least squares regression, assuming a linear trend.[21–23] We used variance of each survival estimate as a weight. The slope of the linear regression provides an estimate of the average change between successive periods of diagnosis, with a 95% CI derived from its standard error.

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See Online for appendix

Registry	Area	Number of people	Number of records	Exclusions		Records available for analysis	Multiple primary	Morphological verification
				Death certificate only	Unknown vital status			
Beijing	Urban	8 169 176	243 103	2012 (0·8%)	7367 (3·0%)	233 724 (96·1%)	3753 (1·6%)	175 416 (75·1%)
Changle	Rural	704 060	15 526	126 (0·8%)	148 (1·0%)	15 252 (98·2%)	28 (0·2%)	9594 (62·9%)
Cixian	Rural	643 751	19 256	463 (2·4%)	0	18 793 (97·6%)	118 (0·6%)	15 117 (80·4%)
Dafeng	Rural	725 369	20 075	56 (0·3%)	0	20 019 (99·7%)	0	13 276 (66·3%)
Dalian	Urban	2 234 063	86 906	4795 (5·5%)	0	82 111 (94·5%)	46 (0·1%)	64 290 (78·3%)
Feicheng	Rural	985 512	25 281	82 (0·3%)	521 (2·1%)	24 678 (97·6%)	0	16 866 (68·3%)
Ganyu	Rural	1 155 800	18 803	44 (0·2%)	1 (0·0%)	18 758 (99·8%)	2 (0·0%)	7365 (39·3%)
Haimen	Rural	1 004 707	38 529	357 (0·9%)	82 (0·2%)	38 090 (98·9%)	46 (0·1%)	20 081 (52·7%)
Haining	Rural	667 617	17 330	155 (0·9%)	96 (0·6%)	17 079 (98·6%)	18 (0·1%)	11 253 (65·9%)
Jianhu	Rural	802 536	26 824	0	701 (2·6%)	26 123 (97·4%)	3 (0·0%)	18 120 (69·4%)
Jiashan	Rural	386 171	14 371	37 (0·3%)	46 (0·3%)	14 288 (99·4%)	76 (0·5%)	10 067 (70·5%)
Jintan	Rural	548 011	15 432	191 (1·2%)	0	15 241 (98·8%)	3 (0·0%)	8330 (54·7%)
Linzhou	Rural	1 084 493	28 105	370 (1·3%)	0	27 735 (98·7%)	0	21 614 (77·9%)
Qidong	Rural	1 123 683	39 797	22 (0·1%)	336 (0·8%)	39 439 (99·1%)	0	19 738 (50·0%)
Sihui	Rural	415 731	8550	366 (4·2%)	222 (2·6%)	7962 (93·1%)	16 (0·2%)	3983 (50·0%)
Taixing	Rural	1 197 200	24 326	48 (0·2%)	439 (1·8%)	23 839 (98·0%)	0	14 331 (60·1%)
Zhongshan	Urban	1 528 005	36 628	0	27 (0·1%)	36 601 (99·9%)	487 (1·3%)	27 785 (75·9%)
All	Rural and urban	23 375 885	678 842	9124 (1·3%)	9986 (1·5%)	65 9732 (97·2%)	4596 (0·7%)	457 226 (69·3%)

Data are n or n (%). Patients were diagnosed during 2003–13, and followed up to 2015.

Table 1: **Characteristics of study population**

To exclude the temporal factors related to changing proportions of cancers with varying prognosis, we further constructed an all-cancers survival index as a weighted average of the survival for every combination of age group at diagnosis (0–44, 45–54, 55–64, 65–74, and 75–99 years), sex (male and female), and type of cancer (n=26). We used SAS (version 9.3) for descriptive and trend analyses, and *strs* in Stata (version 12.1) for survival analyses.

Role of the funding source

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The first author and corresponding authors had full access to all the data in the study and were responsible for the decision to submit for publication.

Results

Table 1 summarises the demographic characteristics and quality of the 17 included registries, representing a total population of 23·4 million inhabitants in 2013. Of these people, there were 678 842 records of patients with invasive cancer who were diagnosed between 2003 and 2013, accounting for 2·2% of all patients diagnosed with cancer in China during that period. We excluded 9124 (1·3%) records of patients registered from death certificate only, and 9986 (1·5%) with unknown vital status. We therefore included 659 732 (97·2%) records in all analyses. The percentage of morphologically verified cancers for all patients was 69·3%. The numbers of patients with each cancer overall, and by sex, are shown in table 2.

	ICD-10	All patients (n=659 732)	Male patients (n=371 471)	Female patients (n=288 261)
Oral cavity and pharynx	C00–10, C12–14	7627	4938 (1·3%)	2689 (0·9%)
Nasopharynx	C11	7966	5694 (1·5%)	2272 (0·8%)
Oesophagus	C15	63 506	43 299 (11·7%)	20 207 (7·0%)
Stomach	C16	82 065	56 846 (15·3%)	25 219 (8·7%)
Colon–rectum	C18–21	61 736	34 104 (9·2%)	27 632 (9·6%)
Liver	C22	66 575	49 542 (13·3%)	17 033 (5·9%)
Gallbladder	C23–24	10 550	5167 (1·4%)	5383 (1·9%)
Pancreas	C25	17 823	9960 (2·7%)	7863 (2·7%)
Larynx	C32	4029	3617 (1·0%)	412 (0·1%)
Lung	C33–34	122 870	79 771 (21·5%)	43 099 (15·0%)
Other thoracic organs	C37–38	1880	1128 (0·3%)	752 (0·3%)
Bone	C40–41	3430	1925 (0·5%)	1505 (0·5%)
Melanoma of skin	C43	1305	668 (0·2%)	637 (0·2%)
Breast	C50	49 176	469 (0·1%)	48 707 (16·9%)
Cervix	C53	11 496	NA	11 496 (4·0%)
Uterus	C54–55	11 531	NA	11 531 (4·0%)
Ovary	C56	8576	NA	8576 (3·0%)
Prostate	C61	11 690	11 690 (3·1%)	NA
Testis	C62	579	579 (0·2%)	NA
Kidney	C64–66, C68	15 671	9640 (2·6%)	6031 (2·1%)
Bladder	C67	16 727	12 657 (3·4%)	4070 (1·4%)
Brain	C70–72	10 391	5509 (1·5%)	4882 (1·7%)
Thyroid	C73	18 470	4421 (1·2%)	14 049 (4·9%)
Lymphoma	C81–85, C88, C90, C96	16 903	9764 (2·6%)	7139 (2·5%)
Leukaemia	C91–C95	13 190	7547 (2·0%)	5643 (2·0%)
All others	NA	23 970	12 536 (3·4%)	11 434 (4·0%)
All sites	C00–97, D32–33, D42–43, D45–47	659 732	371 471 (100%)	288 261 (100%)

Including data for patients aged 0–99 years. ICD-10=International Classification of Diseases, tenth revision. NA=not applicable.

Table 2: **Number of patients included in analyses, by sex and type of cancer**

Age-standardised 5-year relative survival varied considerably according to cancer type, ranging from 7·2% (95% CI 6·6–7·9) for pancreatic cancer to 84·3% (81·8–86·8) for thyroid cancer in 2012–15 (table 3). Cancers with high survival (>60%) in 2012–15 included cancers of the thyroid, breast, bladder, uterus, kidney, and prostate (table 3). However, about half of cancer types had low 5-year survival (below 40%) in this calendar period (table 3).

For all cancers combined, 5-year relative survival increased from 30·9% (95% CI 30·6–31·2) in 2003–05 to 40·5% (40·3–40·7) in 2012–15 (table 3). For about half of cancer types, age-standardised 5-year relative survival increased steadily over time with the largest improvements for cancers of the uterus (average change per calendar period 5·5% [95% CI 2·5–8·5]), thyroid (5·4% [3·2–7·6]), cervix (4·5% [2·9–6·2]), and bone (3·2% [2·1–4·4]). Other cancers with a significant survival increase over the decade were cancers of the oesophagus (2·9% [0·7–5·2]), stomach (2·5% [1·3–3·6]), larynx (2·0 [0·2–3·8]), and bladder (1·8% [1·0–2·5]). No improvements were observed for the more lethal cancer types, including pancreatic and gallbladder cancer (table 3).

To further examine the survival profiles, we analysed trends in age-standardised 5-year survival by sex for all cancers combined and 26 individual cancers (figure 1; appendix pp 2,3). For all cancers combined, survival was 10·0–13·9% higher for female patients than for male patients in every calendar period. Female patients had better survival than did male patients for almost all cancer types, other than for cancers of the kidney, bladder, and larynx. The rate of increase in survival for all cancers combined was more pronounced in female patients than in male patients (average change 3·5% *vs* 2·3%). Although colorectal cancer survival in male patients did not substantively increase, a significant rise (3·5%; 95% CI 0·9–6·0) was seen in female patients. For both sexes, there were survival increments for all cancers combined, and for cancers of the stomach, oesophagus, and bladder. There were notable increases in survival after diagnoses of cancers of the uterus and cervix (figure 1; appendix p 3).

In 2012–15, the age-standardised 5-year survival rate for all patients with cancer was higher in urban areas (46·7%, 95% CI 46·5–47·0) than in rural areas (33·6%, 33·3–33·9). For most individual cancers, survival tended to be higher in urban areas, the exceptions being oesophageal and cervical cancer (figure 2, table 4). Relative to 2003–05, patients with cancer in rural parts of China showed greater survival

	Number of patients	Age-standardised 5-year relative survival				Average change per calendar period
		2003–05	2006–08	2009–11	2012–15	
Oral cavity and pharynx	7627	42·2% (38·9 to 45·5)	50·0% (47·3 to 52·8)	50·6% (47·8 to 53·3)	50·4% (48·4 to 52·5)	2·0% (–3·4 to 7·4)
Nasopharynx	7966	43·8% (39·6 to 48·0)	44·2% (40·4 to 48·0)	43·8% (40·3 to 47·4)	45·5% (42·6 to 48·4)	0·5% (–0·7 to 1·8)
Oesophagus	63 506	20·9% (20·1 to 21·6)	25·0% (24·3 to 25·8)	25·6% (24·9 to 26·4)	30·3% (29·6 to 31·0)	2·9% (0·7 to 5·2)
Stomach	82 065	27·4% (26·7 to 28·1)	30·5% (29·8 to 31·2)	31·8% (31·1 to 32·5)	35·1% (34·5 to 35·7)	2·5% (1·3 to 3·6)
Colon–rectum	61 736	47·2% (46·1 to 48·3)	52·7% (51·8 to 53·6)	52·7% (51·9 to 53·6)	56·9% (56·2 to 57·5)	2·9% (0 to 5·7)
Liver	66 575	10·1% (9·5 to 10·7)	10·1% (9·6 to 10·7)	9·8% (9·3 to 10·3)	12·1% (11·7 to 12·6)	0·7% (–1·2 to 2·6)
Gallbladder	10 550	20·1% (18·1 to 22·1)	16·2% (14·6 to 17·8)	15·1% (13·6 to 16·5)	16·4% (15·1 to 17·6)	–0·9% (–4·4 to 2·6)
Pancreas	17 823	11·7% (10·5 to 12·9)	8·6% (7·7 to 9·6)	7·4% (6·6 to 8·2)	7·2% (6·6 to 7·9)	–1·2% (–3·1 to 0·7)
Larynx	4029	51·7% (47·3 to 56·1)	53·1% (49·4 to 56·9)	54·1% (50·4 to 57·8)	57·7% (54·8 to 60·7)	2·0% (0·2 to 3·8)
Lung	122 870	16·1% (15·6 to 16·6)	15·8% (15·3 to 16·2)	16·8% (16·4 to 17·3)	19·7% (19·3 to 20·1)	1·3% (–0·8 to 3·5)
Other thoracic organs	1880	30·5% (25·0 to 36·0)	29·9% (25·0 to 34·8)	30·2% (25·7 to 34·8)	36·7% (32·7 to 40·7)	2·2% (–3·0 to 7·5)
Bone	3430	17·1% (13·8 to 20·5)	19·1% (15·9 to 22·2)	22·8% (19·5 to 26·2)	26·5% (23·9 to 29·1)	3·2% (2·1 to 4·4)
Melanoma of skin	1305	38·8% (30·8 to 46·7)	41·9% (35·3 to 48·6)	41·6% (35·5 to 47·8)	45·1% (40·1 to 50·1)	1·9% (–0·3 to 4·1)
Breast	49 176	73·1% (71·2 to 75·0)	78·9% (77·4 to 80·3)	79·7% (78·3 to 81·1)	82·0% (81·0 to 83·0)	2·5% (–0·3 to 5·2)
Cervix	11 496	45·4% (40·7 to 50·2)	51·7% (47·9 to 55·6)	54·8% (50·9 to 58·7)	59·8% (57·1 to 62·5)	4·5% (2·9 to 6·2)
Uterus	11 531	55·1% (51·6 to 58·5)	64·0% (60·9 to 67·1)	67·0% (64·1 to 70·0)	72·8% (70·5 to 75·0)	5·5% (2·5 to 8·5)
Ovary	8576	38·9% (35·4 to 42·3)	37·0% (34·6 to 39·3)	38·0% (35·6 to 40·4)	39·1% (37·2 to 41·0)	0·4% (–1·6 to 2·5)
Prostate	11 690	53·8% (49·5 to 58·2)	60·8% (56·5 to 65·0)	59·2% (55·2 to 63·2)	66·4% (63·7 to 69·0)	3·8% (–0·8 to 8·4)
Testis	579	48·0% (31·8 to 64·2)	59·4% (44·2 to 74·7)	66·7% (44·7 to 88·8)	55·2% (42·5 to 67·8)	1·8% (–11·6 to 15·1)
Kidney	15 671	62·0% (59·6 to 64·4)	65·0% (63·2 to 66·8)	64·7% (63·0 to 66·4)	69·8% (68·5 to 71·1)	2·5% (–0·7 to 5·7)
Bladder	16 727	67·3% (65·3 to 69·4)	69·8% (68·1 to 71·4)	70·9% (69·3 to 72·5)	72·9% (71·6 to 74·1)	1·8% (1·0 to 2·5)
Brain	10 391	18·2% (16·0 to 20·4)	18·9% (17·1 to 20·6)	21·1% (19·3 to 22·9)	26·7% (25·1 to 28·2)	3·0% (–0·4 to 6·5)
Thyroid	18 470	67·5% (63·3 to 71·8)	73·9% (70·6 to 77·2)	77·2% (73·9 to 80·5)	84·3% (81·8 to 86·8)	5·4% (3·2 to 7·6)
Lymphoma	16 903	32·6% (30·6 to 34·6)	32·9% (31·4 to 34·5)	33·8% (32·2 to 35·3)	37·2% (36·0 to 38·4)	1·7% (–0·5 to 3·9)
Leukaemia	13 190	19·6% (17·6 to 21·7)	21·0% (19·2 to 22·8)	19·2% (17·7 to 20·6)	25·4% (24·1 to 26·8)	1·9% (–3·5 to 7·2)
All others	23 970	44·9% (43·2 to 46·7)	50·3% (48·7 to 51·8)	48·5% (47·0 to 49·9)	53·3% (52·2 to 54·4)	2·4% (–1·7 to 6·4)
All	659 732	30·9% (30·6 to 31·2)	34·9% (34·6 to 35·1)	35·8% (35·5 to 36·0)	40·5% (40·3 to 40·7)	3·0% (0·9 to 5·2)

Data are n or % (95% CI).

***Table 3*: Trends in age-standardised 5-year relative survival, by cancer site**

increases than those in urban areas over the same calendar periods; the survival gap narrowed between urban and rural areas from 17·7% in 2003–05, to 13·1% in 2012–15, for all cancers combined (table 4). Survival increased more rapidly in rural areas for patients diagnosed with cancers of the stomach, oesophagus, colon–rectum, breast (female patients only), bladder, uterus, and cervix (table 4).

Considering that the profiles of cancer types might affect the comparison of trends in survival for all cancers combined, we found that the weighted all-cancers survival analysis still showed a significant increase during 2003–15 (table 5). In this analysis, the survival gaps between urban and rural areas decreased from 10·2% in 2003–05 to 3·6% in 2012–15.

Relative survival was generally lower for older patients than for younger ones (figure 3). For all cancers combined, 5-year relative survival decreased with age across all calendar periods of diagnosis. By 2012–15, 5-year relative survival for patients younger than 45 years was 67·6%, whereas for patients aged 75 years and older, 5-year survival was 24·3%, with a 43·3% absolute difference between these two groups. By cancer types, we observed the largest 5-year survival difference (47·0%) for cervical cancer, with survival of 83·4% in the youngest and 36·4% in the oldest age group (figure 3).

We used data from the National Bureau of Statistics of China to analyse trends in medical resources and health expenditures (figure 4). Between 1980 and 2014, medical expenditure increased over time, as indicated by the increase in hospital beds and registered doctors, as well as overall health expenditure. Notably, the rates of expenditure specific to cancer increased more quickly (almost nine times from 2003 to 2015) than those of total health expenditure in China (figure 4).

Discussion

This study provides up-to-date geographical and temporal comparisons of cancer survival with data from 17 population-based cancer registries in China. The results offer insight into the survival status of patients

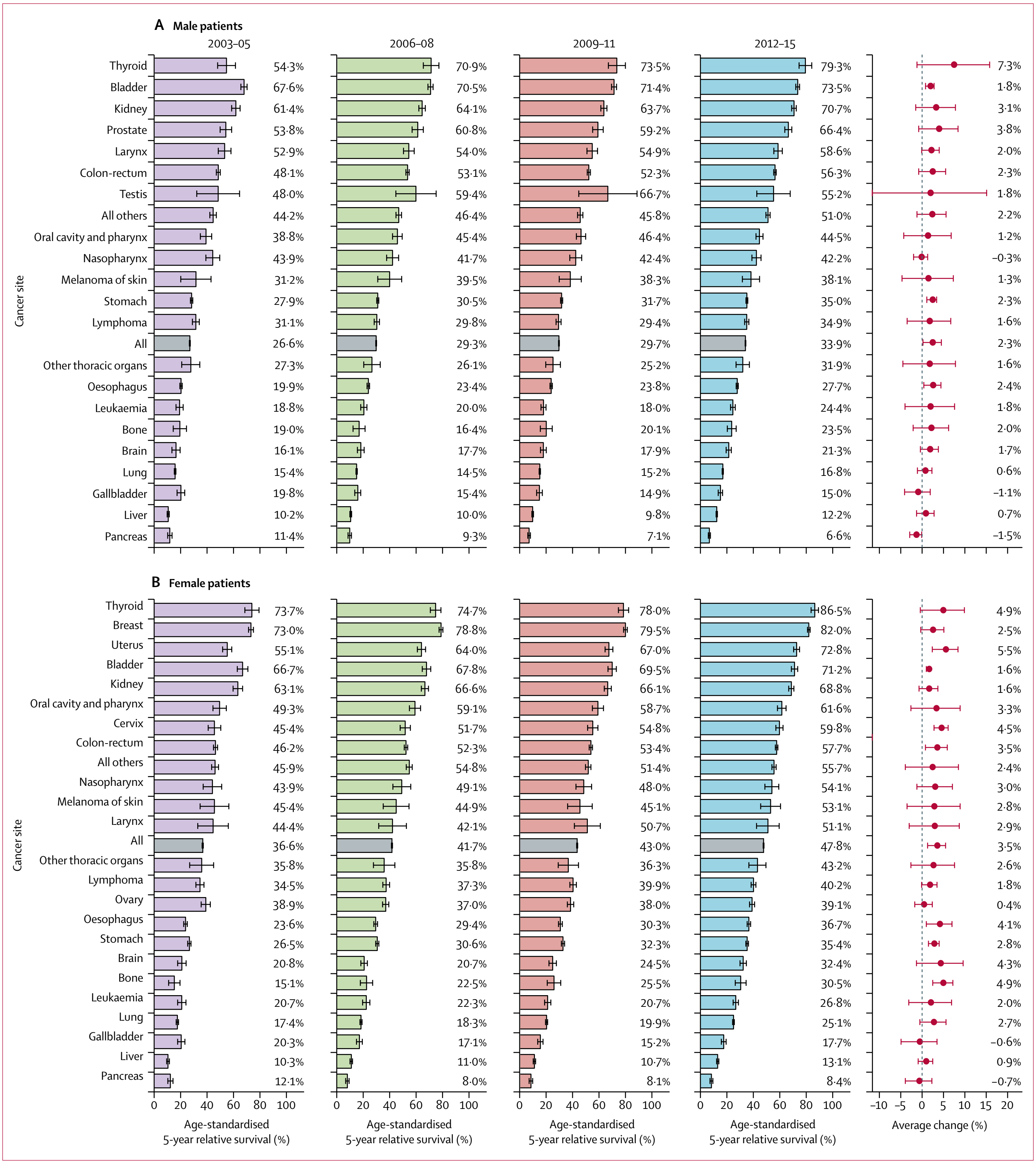

Figure 1: **Age-standardised 5-year relative survival, by sex**
95% CI values are provided in the appendix (pp 2,3).

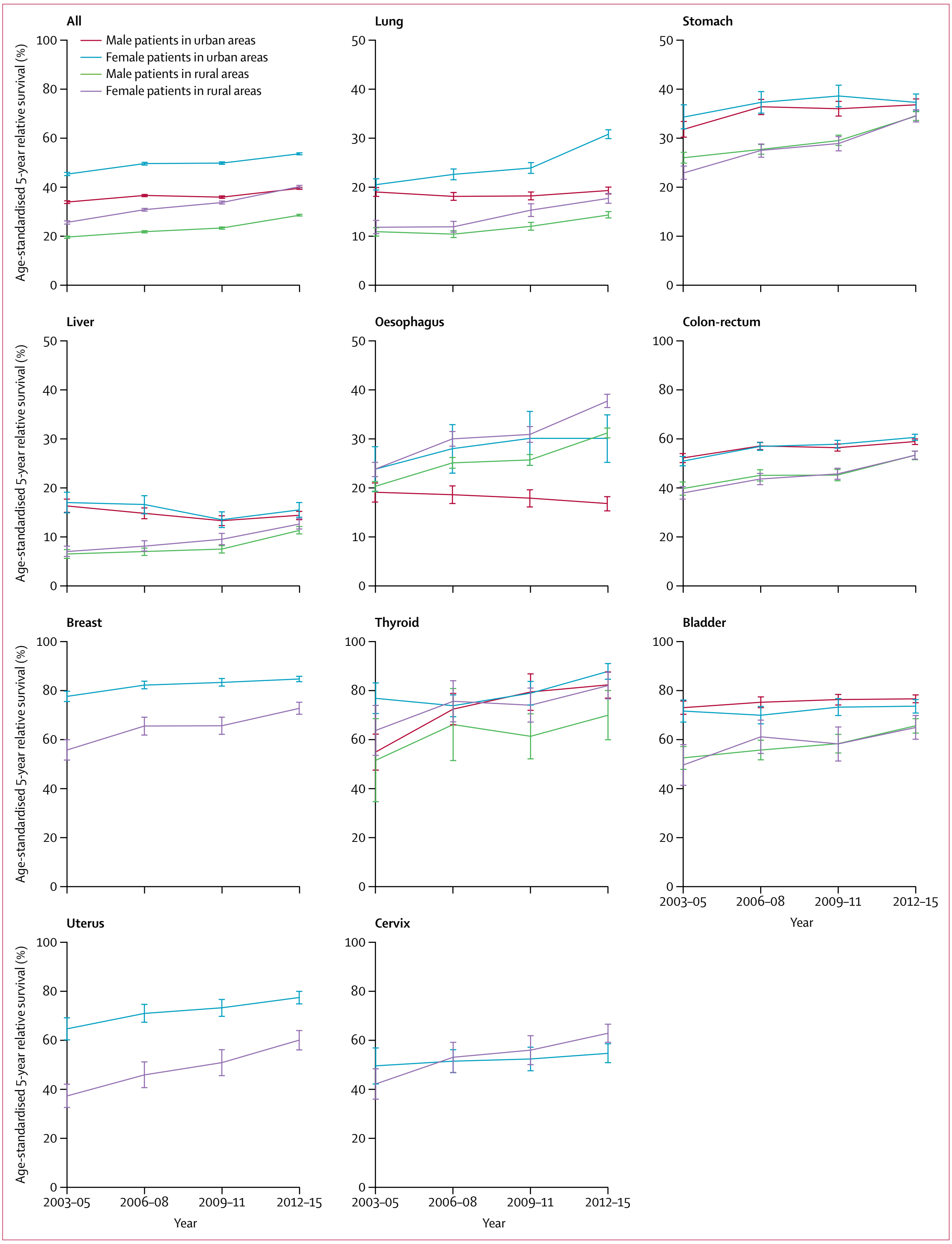

Figure 2: **Trends in age-standardised 5-year relative survival for all cancers combined and the ten most prevalent cancers**
Error bars show 95% CIs.

	Urban areas					Rural areas				
	2003–05	2006–08	2009–11	2012–15	Average change	2003–05	2006–08	2009–11	2012–15	Average change
All cancers	39·5% (39·1 to 39·9)	43·1% (42·8 to 43·5)	42·9% (42·6 to 43·3)	46·7% (46·5 to 47·0)	2·2% (–0·2 to 4·5)	21·8% (21·4 to 22·2)	25·4% (25·1 to 25·8)	27·6% (27·2 to 28·0)	33·6% (33·3 to 33·9)	3·9% (1·7 to 6·1)
Male patients	33·9% (33·3 to 34·4)	36·6% (36·1 to 37·0)	35·9% (35·4 to 36·4)	39·5% (39·1 to 39·9)	1·7% (–0·8 to 4·1)	19·6% (19·1 to 20·0)	21·8% (21·3 to 22·2)	23·3% (22·8 to 23·7)	28·5% (28·2 to 28·9)	2·9% (0·5 to 5·4)
Female patients	45·3% (44·7 to 46·0)	49·6% (49·0 to 50·1)	49·8% (49·3 to 50·3)	53·6% (53·2 to 54·0)	2·5% (0·2 to 4·8)	25·6% (24·9 to 26·2)	30·8% (30·2 to 31·3)	33·7% (33·1 to 34·3)	40·2% (39·7 to 40·7)	4·8% (2·9 to 6·6)
Lung	19·5% (18·8 to 20·3)	19·7% (19·1 to 20·4)	20·3% (19·6 to 20·9)	23·8% (23·2 to 24·3)	1·5% (–0·9 to 3·9)	11·2% (10·5 to 11·9)	10·8% (10·2 to 11·4)	13·0% (12·3 to 13·7)	15·4% (14·9 to 15·9)	1·6% (–0·4 to 3·6)
Male patients	19·0% (18·1 to 19·9)	18·1% (17·3 to 18·9)	18·2% (17·4 to 19·0)	19·3% (18·6 to 20·0)	0·2% (–1·1 to 1·5)	10·9% (10·0 to 11·7)	10·4% (9·7 to 11·1)	12·0% (11·2 to 12·8)	14·3% (13·7 to 15·0)	1·3% (–0·6 to 3·2)
Female patients	20·5% (19·4 to 21·7)	22·6% (21·5 to 23·7)	23·9% (22·8 to 25·0)	30·8% (29·9 to 31·7)	3·4% (–0·3 to 7·2)	11·8% (10·5 to 13·2)	11·9% (10·8 to 13·0)	15·3% (14·0 to 16·6)	17·7% (16·7 to 18·7)	2·2% (0·2 to 4·2)
Stomach	32·5% (31·1 to 33·8)	36·6% (35·4 to 37·9)	36·7% (35·5 to 38·0)	36·9% (35·9 to 37·9)	1·2% (–1·6 to 3·9)	24·9% (24·1 to 25·8)	27·6% (26·8 to 28·4)	29·3% (28·4 to 30·1)	34·4% (33·7 to 35·1)	3·1% (1·0 to 5·1)
Male patients	31·8% (30·2 to 33·4)	36·4% (34·8 to 37·9)	36·0% (34·5 to 37·5)	36·8% (35·5 to 38·0)	1·3% (–1·6 to 4·3)	26% (24·9 to 27·1)	27·7% (26·7 to 28·7)	29·5% (28·5 to 30·6)	34·5% (33·6 to 35·4)	2·8% (0·4 to 5·2)
Female patients	34·3% (31·9 to 36·8)	37·3% (35·1 to 39·5)	38·6% (36·4 to 40·8)	37·3% (35·5 to 39·0)	0·8% (–2·0 to 3·7)	22·9% (21·6 to 24·3)	27·5% (26·1 to 28·8)	28·9% (27·4 to 30·3)	34·6% (33·3 to 35·8)	3·7% (1·5 to 5·9)
Liver	16·1% (14·9 to 17·2)	14·8% (13·9 to 15·7)	12·7% (11·9 to 13·5)	14·0% (13·3 to 14·7)	–0·7% (–3·1 to 1·8)	6·3% (5·6 to 7·0)	7·0% (6·4 to 7·6)	7·8% (7·1 to 8·4)	11·2% (10·6 to 11·8)	1·6% (–0·4 to 3·6)
Male patients	16·1% (14·8 to 17·5)	14·6% (13·5 to 15·7)	13·1% (12·1 to 14·1)	14·2% (13·3 to 15·0)	–0·5% (–2·6 to 1·5)	6·3% (5·4 to 7·2)	6·8% (6·0 to 7·5)	7·3% (6·5 to 8·0)	11·1% (10·4 to 11·9)	1·6% (–1·0 to 4·1)
Female patients	16·8% (14·7 to 18·9)	16·4% (14·5 to 18·2)	13·3% (11·7 to 14·9)	15·3% (13·8 to 16·8)	–0·6% (–3·9 to 2·6)	6·8% (5·8 to 7·9)	7·9% (6·9 to 9·0)	9·3% (8·2 to 10·5)	12·4% (11·4 to 13·5)	1·8% (0·5 to 3·2)
Oesophagus	19·1% (17·4 to 20·8)	19·4% (17·8 to 21·0)	18·6% (17·0 to 20·2)	18·1% (16·7 to 19·5)	–0·4% (–1·1 to 0·3)	21·2% (20·3 to 22·0)	26·4% (25·6 to 27·3)	27·1% (26·2 to 28·0)	33·2% (32·4 to 34·0)	3·7% (0·8 to 6·6)
Male patients	18·9% (16·9 to 20·8)	18·4% (16·6 to 20·2)	17·7% (15·9 to 19·4)	16·6% (15·1 to 18·0)	–0·8% (–1·2 to –0·4)	20·1% (19·0 to 21·1)	24·9% (23·8 to 26·0)	25·5% (24·4 to 26·6)	31·0% (30·0 to 32·0)	3·4% (0·7 to 6)
Female patients	23·6% (19·1 to 28·2)	27·8% (22·8 to 32·7)	29·9% (24·4 to 35·4)	29·9% (25·0 to 34·7)	2·1% (–0·6 to 4·9)	23·6% (22·1 to 25·0)	29·8% (28·3 to 31·3)	30·7% (29·1 to 32·3)	37·5% (36·2 to 38·9)	4·3% (1·1 to 7·5)
Colon–rectum	51·2% (49·9 to 52·6)	56·6% (55·5 to 57·7)	56·6% (55·6 to 57·7)	59·3% (58·4 to 60·1)	2·3% (–0·6 to 5·1)	38·4% (36·5 to 40·2)	43·9% (42·3 to 45·5)	44·9% (43·3 to 46·5)	52·6% (51·4 to 53·8)	4·5% (0·9 to 8·2)
Male patients	51·8% (49·9 to 53·6)	56·7% (55·2 to 58·2)	56·0% (54·6 to 57·5)	58·5% (57·3 to 59·6)	1·8% (–1·1 to 4·7)	39·3% (36·6 to 42·0)	44·7% (42·4 to 47·0)	44·8% (42·5 to 47·1)	52·9% (51·1 to 54·6)	4·3% (–0·1 to 8·7)
Female patients	50·5% (48·6 to 52·4)	56·5% (54·9 to 58·1)	57·4% (55·8 to 59·0)	60·2% (59·0 to 61·5)	2·8% (0 to 5·6)	37·5% (35·0 to 40·1)	43·2% (40·9 to 45·5)	45·3% (43·1 to 47·6)	52·9% (51·3 to 54·6)	5·0% (2·0 to 7·9)
Breast*	77·8% (75·7 to 79·9)	82·4% (80·9 to 84·0)	83·5% (82·0 to 85·1)	84·9% (83·8 to 86·0)	2·0% (–0·3 to 4·2)	55·9% (51·8 to 60·1)	65·7% (62·0 to 69·3)	65·8% (62·3 to 69·3)	72·9% (70·5 to 75·4)	5·0% (0·3 to 9·8)
Thyroid	69·6% (64·7 to 74·4)	74·1% (70·6 to 77·7)	79·9% (75·9 to 83·9)	86·2% (83·3 to 89·0)	5·7% (4·5 to 6·9)	61·3% (52·4 to 70·3)	73·4% (66·0 to 80·7)	71·0% (65·2 to 76·8)	79·0% (73·9 to 84·1)	4·9% (–2·9 to 12·6)
Male patients	55·1% (47·7 to 62·4)	72·6% (66·2 to 79·0)	79·6% (72·1 to 87·0)	82·5% (77·1 to 87·8)	8·2% (–1·4 to 17·8)	51·7% (34·8 to 68·7)	66·3% (51·6 to 81·0)	61·5% (52·3 to 70·7)	70·1% (60·1 to 80·2)	4·8% (–5·9 to 15·4)
Female patients	77·0% (70·8 to 83·3)	74·0% (69·5 to 78·4)	79·1% (74·3 to 83·9)	88·0% (84·8 to 91·2)	5·0% (–2·6 to 12·5)	63·9% (53·7 to 74·1)	75·8% (67·4 to 84·2)	74·2% (67·3 to 81·2)	82·2% (76·8 to 87·6)	5·2% (–1·7 to 12·1)
Bladder	72·9% (70·5 to 75·2)	74·1% (72·2 to 75·9)	75·7% (73·9 to 77·5)	76·0% (74·6 to 77·4)	1·0% (0·2 to 1·9)	52·2% (48·2 to 56·2)	56·7% (53·2 to 60·2)	58·4% (55·1 to 61·8)	65·5% (63·0 to 68·0)	4·4% (1·3 to 7·4)
Male patients	73·2% (70·5 to 75·9)	75·4% (73·2 to 77·6)	76·5% (74·3 to 78·6)	76·8% (75·2 to 78·4)	1·1% (–0·2 to 2·3)	52·7% (48·0 to 57·3)	55·9% (51·9 to 59·9)	58·5% (54·7 to 62·3)	65·8% (62·8 to 68·7)	4·5% (1·2 to 7·7)
Female patients	71·8% (67·3 to 76·3)	70·1% (66·6 to 73·7)	73·4% (70·0 to 76·9)	73·8% (71·0 to 76·5)	1·1% (–1·6 to 3·7)	49·8% (41·5 to 58·1)	61·3% (54·5 to 68·1)	58·4% (51·4 to 65·3)	65·1% (60·3 to 70·0)	4·0% (–3·2 to 11·3)
Uterus*	64·7% (60·2 to 69·2)	71·0% (67·4 to 74·7)	73·3% (69·8 to 76·7)	77·5% (74·9 to 80·0)	3·9% (1·9 to 6·0)	37·3% (32·6 to 42·1)	45·9% (40·7 to 51·2)	50·9% (45·6 to 56·2)	60·1% (56·1 to 64·0)	7·4% (5·4 to 9·5)
Cervix*	49·6% (42·2 to 56·9)	51·5% (46·8 to 56·2)	52·4% (47·6 to 57·2)	54·7% (50·9 to 58·6)	1·6% (0·8 to 2·5)	42·2% (36·0 to 48·4)	53·1% (46·9 to 59·2)	56·0% (50·1 to 61·9)	62·9% (59·2 to 66·6)	6·4% (2·7 to 10·1)

Data are % (95% CI). *Data are for female patients only.

Table 4: **Trends in age-standardised 5-year relative survival, by sex and area**

with cancer living in these areas and how prognosis has changed in the most recent decade. Most notable is that the 5-year survival for all cancers combined increased significantly, from 30·9% in 2003–05 to 40·5% in 2012–15 in these Chinese registries. Even after adjustment for sex and case mix, to exclude temporal factors related to changing proportions of cancers with varying prognosis, the increase in 5-year survival was significant for all cancers combined. Relative survival improved steadily over time for all cancers combined, suggesting an overall improvement in the quality of cancer care in the population covered by these cancer registries in China. We also observed significant improvement in 5-year survival for eight individual cancers: oesophagus, stomach, larynx, bone, cervix, uterus, bladder, and thyroid.

Population-based cancer survival is a key indicator of the quality of cancer services, including early detection and appropriate management of cancer. Survival of patients with cancer at the population level is closely related to access to and quality of cancer care, and funding of such services.[26] In keeping up with the rapid economic development of the country, the Chinese government has allocated more resources to health care.[25] It is likely that the substantial investment in health care by the Chinese Government, since 2003, has contributed to these survival improvements.

Results of temporal trends in survival must be interpreted with care.[27] For example, increases in cancer survival could be attributed to many real factors, including improved access to primary health care, greater availability of diagnostic facilities, and improved effectiveness of the treatment. They can also be due to statistical artifacts such as lead-time bias and overdiagnosis.[28,29] The noteworthy increase in 5-year relative survival for thyroid cancer observed in our study might reflect overdiagnosis, in which a greater proportion of cases with small and slow-growing thyroid nodules caused by increased use of new imaging technologies in the assessment of thyroid gland are diagnosed. This proportion increased from approximately 10% in 2000 to nearly 60% in 2013.[30] In the absence of large-scale screening programmes, the improved survival for cancers of the oesophagus, stomach, cervix, and uterus could be mainly due to increased access to effective treatment over time. This access has been made possible by the greater insurance coverage of the whole population since 2003. Coincident with the improving survival trends, mortality from stomach and oesophageal cancers has also decreased.

In 2005, the National Health and Family Planning Commission of China initiated cancer screening and early detection programmes (including cancers of the oesophagus, stomach, liver, nasopharynx, female breast, and cervix), initially in rural areas associated with a high risk of specific cancer types. By 2015, a cancer screening and early detection network had expanded to 31 provinces.[10] The screening effects on survival remain to be seen because most of these programmes started from 2010 onwards with only a small number of cases being detected (appendix p 4). In this study, we found cancer survival to have shown the greatest improvement in the rural areas of China, which might be the result of lead-time bias.[28] However, declining age-standardised mortality rates for cancers with poor prognosis, including those of the oesophagus and stomach, were observed in parallel,[12] implying that earlier cancer diagnosis and quality of treatment contributed at least partly to increasing survival, especially in rural areas of China. For breast cancer, the increase in mortality was not as rapid as the increase in incidence.[12] Because less than 1% of breast cancer cases in our study were identified via breast screening, the effect of screening on survival could be minimal. However, the improving willingness of the Chinese population to have active medical examinations, better access to cancer care, and improved treatment might have led to the improved breast cancer survival observed in our study.

	All	Urban	Rural
2003–05	30·9% (30·6–31·2)	34·8% (34·4–35·3)	24·6% (24·1–25·1)
2006–08	33·3% (33·0–33·6)	36·5% (36·1–36·9)	28·0% (27·5–28·4)
2009–11	33·9% (33·6–34·1)	36·4% (36·0–36·8)	29·4% (28·9–29·8)
2012–15	37·2% (37·0–37·4)	38·1% (37·8–38·4)	34·5% (34·2–34·9)

Data are % (95% CI). Adjusted by age, sex, and cancer type.

Table 5: **Adjusted 5-year relative survival for all cancers combined**

Although we observed a marked increase in cancer survival over time, a survival gap between urban and rural areas persisted in the registries included. However, the size of this gap decreased over time. Government initiatives to proportionally allocate more health-care resources to rural areas for cancer care improvement[31] have the potential to reduce survival disparities between areas. Socioeconomic status, health-care-seeking behaviours, and treatment effectiveness can all affect cancer outcome. For example, in 2003, China began addressing the financial burden faced by rural families incurring catastrophic health expenditure through the New Rural Cooperative Medical System, and the reimbursement rates have since progressively increased.[32] By the end of 2014, 736 million rural residents in China (98·9% of the rural population) had joined the Rural Cooperative Medical System.[24,33] This improving insurance coverage for patients with cancer, especially for those in rural and remote areas in China, has the potential to lead to further improvement in overall survival. Additionally, screening might be partly responsible for urban and rural contrasts in survival for oesophageal cancer, because cancer screening programmes were only located in rural areas of China before 2012.

The survival disparity by age is an important public health issue that requires further attention. In our study, we observed a survival disadvantage in the elderly population (>65 years), similar to that observed in many

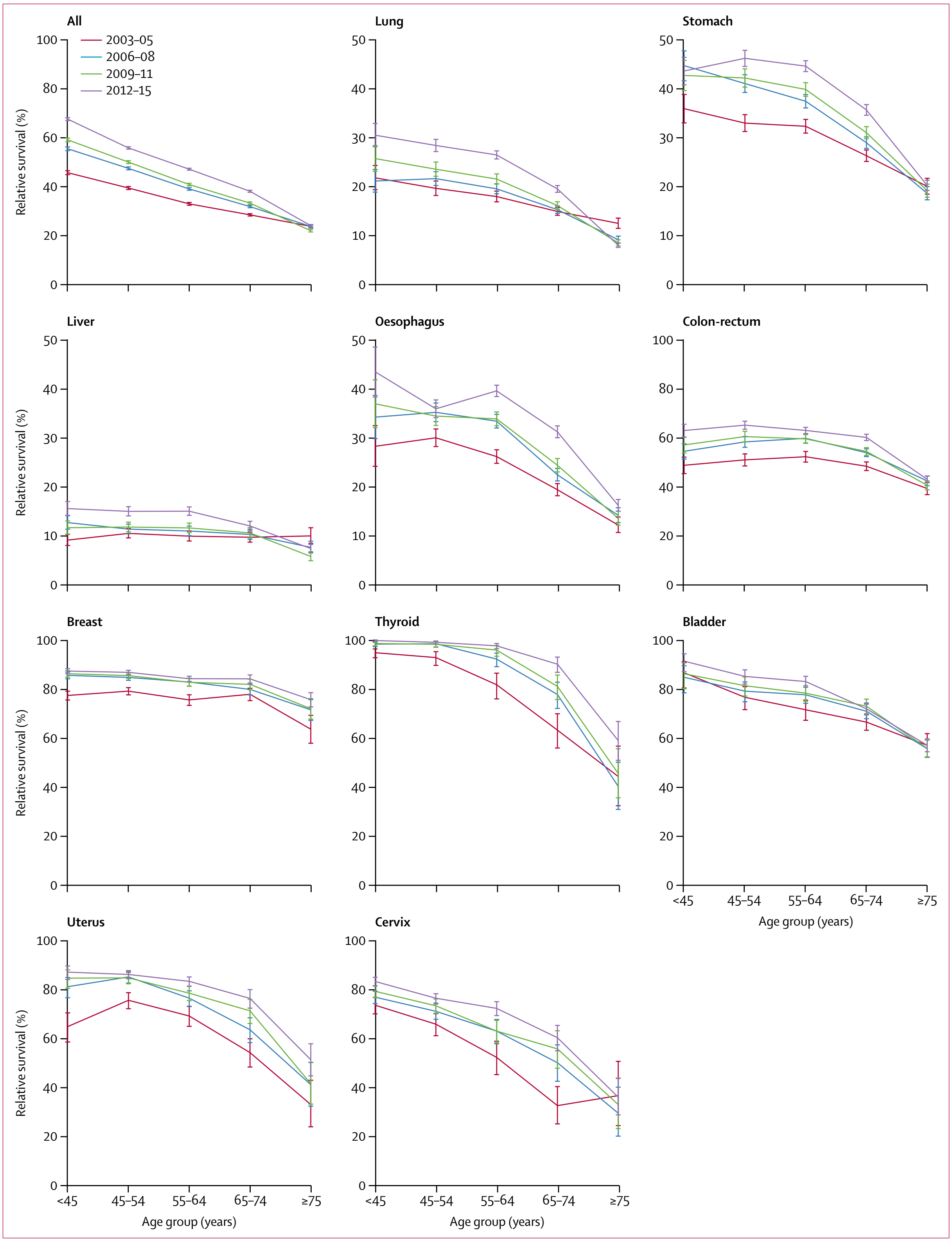

***Figure 3:* 5-year relative survival for all cancers combined and ten major cancers by age in 2003–15**
Error bars show 95% CIs.

other countries.[34–36] The fact that older patients are more likely to be diagnosed at a late stage, have more comorbidity, are less likely to get curative intent treatment, and have socioeconomic inequalities could be important explanatory factors.[21,37] We also observed a survival difference between male and female patients of 10·0–13·9% for all cancers combined for all calendar periods, with female patients generally having better survival than male patients. Such gaps should be further investigated by use of data about clinical factors that might explain these differences.

Incomplete follow-up and failure to capture all incident cases can bias survival comparisons.[38] Although most cancer registries included in this study used both passive and active follow-up methods to assess the vital status of patients with cancer, our study used passive follow-up in one urban cancer registry (Dalian). Because the death surveillance system was not complete enough to catch all deaths from cancer, the survival estimates might be over-estimated, particularly for the more lethal cancers in urban areas.[39] This outcome could be more relevant to the early period (2003–05), since the system linking cancer registry data with death surveillance improved over time. This finding could at least partly explain the decreasing trend in survival from oesophageal cancer observed for male patients living in urban areas.

We provide a survival estimate derived from pooled data for 17 population-based registries, covering a population of 23·4 million people. Because registration coverage is not national, these results are not representative of survival in China as a whole. Considering the registries in our study were mostly located in areas in better economic shape than average, the true survival proportions in China could be lower than our pooled results. Nevertheless, the survival data used in this study remain the best available nationwide data in China, and can be generalised in the population covered by these 17 cancer registries. Moreover, we used the same methods and collected data covering the same population over a 13-year period so that the cancer survival statistics should be comparable to our previous findings.[5]

Cancer survival statistics are essential in providing scientific evidence for policy formulation on health care and health insurance. Since 2015, the Chinese Government has implemented a series of plans and policies on cancer control. In the Mid-term and Long-term Plan for Prevention and Treatment of Chronic Diseases in China (2017–25) and the Healthy China 2030 strategy, cancer survival is considered a key indicator of the effectiveness of the health-care system.[7,8] The finding of persisting disparity in survival between rural and urban areas in China has important implications for cancer control in the future. Further studies are needed to identify the underlying reasons for the rural–urban survival disparity so that policy makers can appropriately implement targeted interventions to reduce or eliminate the disparity.

Despite a marked increase in 5-year survival from all cancers combined and several major cancers over the last decade in China, survival for many major cancers in the most recent period studied remained lower than in many developed countries.[40,41] We found that age-standardised 5-year relative survival from breast cancer in China had increased from 73·1% in 2003–05 to 82·0% in 2012–15. However, this increase was still more than 8% lower than the most recent survival estimates calculated with the same method (the Ederer II) for the USA (91%) in 2007–13 and for Australia (90%) in 2009–13.[42,43] Similar or larger survival gaps were also found between China and these developed countries for several other major cancers, including liver and colorectal cancers. Thus, much remains to be done to reduce the survival gap between China and developed countries. For example, China needs to increase further investment in infrastructure and health technology and needs more government-funded health resources and health services, especially in rural areas and western provinces. It is also important to set up best practice guidelines for management of major cancers in China at different levels according to local situations, and to establish a national body to coordinate the implementation of these guidelines.

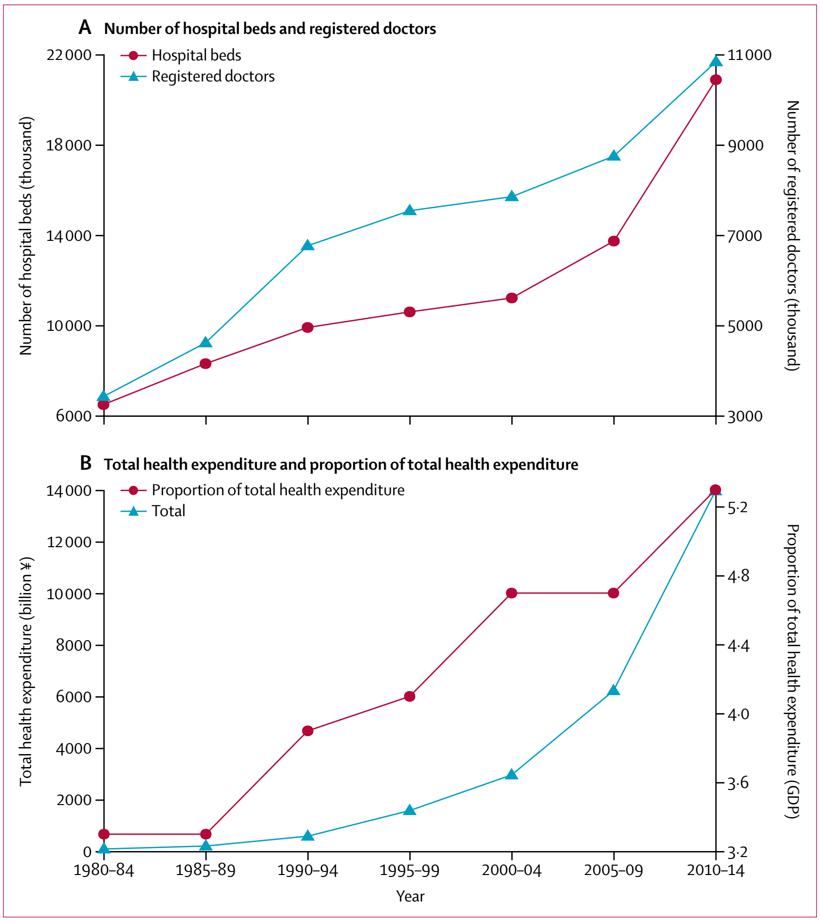

Figure 4: Trends in medical resources and health expenditures
Data are from the National Bureau of Statistics of China.[24,25]

A nationally representative cancer registry system with improved data quality and wider population coverage will help to identify priorities for improvement in the quality of cancer care and to track progress in cancer care over time. Since 2015, the central Government of China has invested stable funding in population-based survival investigations annually, and more than 300 registries have collected population-based survival data across the country. Thus, future survival studies should have wider population coverage and use more representative data, while high-resolution studies are being considered to identify the exact effects of cancer screening and stage distribution on changes in survival among different areas and populations. Registries will record more detailed information, including sociodemographic, staging, and treatment data to further the potential of population-based cancer registries to better inform cancer prevention and control and improve quality of cancer care.

In summary, the areas served by these cancer registries in China observed marked improvements in overall cancer survival during 2003–15, in both rural and urban areas. However, disparity in survival between cancers and geographical areas remains, and progress in improving survival for some major cancers is minimal, underscoring the need for renewed efforts to improve cancer outcomes and the equity of cancer care for all populations.[44] Continuous surveillance of population-based cancer survival, with high-resolution data and an expanded population coverage, will provide further insight into progress in cancer control in China.

Contributors

HZ, RZ, SZ, WC, XiaZ, and JH drafted the study protocol. HZ, JSJ, XQY, PB, AJ, FB, WC, and JH contributed to the conception and design of the study. HZ, RZ, and CX did the data analysis. KS, ZY, and HeL contributed to the data quality control. NW, RH, SL, HuL, HM, YH, YX, ZF, YZ, JJ, YY, JiansC, KW, DF, JW, FF DZ, GS, JiangC, CJ, XinZ, XG, FJ, QL, YL, TW, CY, JD, and ZH contributed to the data collection, data transmission, and data correction after quality control, and checking of the results. HZ, JSJ, PB, XQY, FB, AJ, CW, and JH drafted the paper and interpreted the results. All authors contributed to data interpretation and rewriting the paper, and reviewed and approved the final version. HZ, RZ, WC, and HJ had access to the all raw data.

Declaration of interests

We declare no competing interests.

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