Original Articles

Trends in cancer incidence in Chennai city (1982–2006) and statewide predictions of future burden in Tamil Nadu (2007–16)

R. SWAMINATHAN, V. SHANTA, J. FERLAY, S. BALASUBRAMANIAN, F. BRAY, R. SANKARANARAYANAN

ABSTRACT

Background. This paper investigates cancer trends in Chennai and predicts the future cancer burden in Chennai and Tamil Nadu state, India, using data on 89 357 incident cancers from the Chennai registry during 1982–2006, published incidence rates from the Dindigul Ambilikkai Cancer Registry during 2003–06 and population statistics during 1982–2016.

Methods. Age-specific incidence rates were modelled as a function of age, period and birth cohort using the NORDPRED software to predict future cancer incidence rates and numbers of cancer cases for the period 2007–11 and 2012–16 in Chennai. Predictions for Tamil Nadu state were computed using a weighted average of the predicted incidence rates of the Chennai registry and current rates in Dindigul district.

Results. In Chennai, the total cancer burden is predicted to increase by 32% by 2012–16 compared with 2002–06, with 19% due to changes in cancer risk and a further 13% due to the impact of demographic changes. The incidence of cervical cancer is projected to drop by 46% in 2015 compared with current levels, while a 100% increase in future thyroid cancer incidence is predicted. Among men, a 21% decline in the incidence of oesophageal cancer by 2016 contrasts with the 42% predicted increase in prostate cancer. The annual cancer burden predicted for 2012–16 is 6100 for Chennai, translating to 55 000 new cases per year statewide (in Tamil Nadu). Breast cancer would dislodge cervical cancer as the top-ranking cancer in the state, while lung, stomach and large bowel cancers would surpass cervical cancer in ranking in Chennai by 2016.

Conclusion. In order to tackle the predicted increases in cancer burden in Tamil Nadu, concerted efforts are required to assess and plan the infrastructure for cancer control and care, and ensure sufficient allocation of resources.

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INTRODUCTION

Population-based cancer registration in India dates back to the establishment of the Bombay (now Mumbai) Cancer Registry in 1963. The systematic registration of invasive cancers in different parts of the country commenced in 1982 with the formation of the National Cancer Registry Programme.[1] The Chennai Cancer Registry, also known as the Madras Metropolitan Tumour Registry, is one of the earliest registries in the Indian network (since 1981), and is based at the Cancer Institute (WIA), Chennai, Tamil Nadu.[2]

Most descriptive studies reporting incidence trends of various cancers in India have presented trends in crude or age-standardized rates based on a restricted span of available data.[3–7] Other than a report based on the older Bombay Cancer Registry data,[8] few studies have attempted to extrapolate the age-specific incidence patterns from Indian registries to predict the future cancer burden, as is customarily done in more developed countries.[9–11] Such trend and prediction analyses in India serve as surveillance tools in measuring and evaluating the introduction of targeted screening or early cancer detection programmes for cancer control as well as the provision of health services including curative and palliative care for cancer. This paper has two objectives; first, to evaluate the changing cancer incidence patterns and trends in urban Chennai in southern India, based on data collected from the Cancer Registry over 25 years (1982–2006) and second, to provide estimates of the future cancer burden both in Chennai city and in the state of Tamil Nadu, based on the projected incidence rates according to age, calendar period and birth cohort.

METHODS

Incident cancer cases were extracted from the Chennai Cancer Registry during the period 1982–2006 and from the Dindigul Ambilikkai Cancer Registry in the state of Tamil Nadu during the period 2003–06.[12]

Cancer registration in Chennai city, 1982–2006

The Chennai Cancer Registry includes all invasive cancers occurring among the resident population of Chennai city via active case-finding procedures and principles advocated by the International Agency for Research on Cancer, the International Association of Cancer Registries[13] and the National Cancer Registry Programme of the Indian Council of Medical Research,[1,2] based

on multiple sources of data. The data sources comprise public and private hospitals, consultants/clinics, hospices, imaging centres and pathology laboratories in and around the city of Chennai since 1982. Disease coding was undertaken using the International Classification of Diseases, Tenth Revision (ICD-10).[14] The registration procedures have been described in detail elsewhere.[2] The catchment population of the Chennai Cancer Registry is entirely urban, with an estimated 4.8 million inhabitants within the metropolitan limits of the city in 2009.[15] The estimated annual populations between the years 1982 and 2016 obtained from National Cancer Registry Programme[15] were used to represent the corresponding person-years over time.

Cancer registration in Dindigul district, 2003–06

The Dindigul Ambilikkai Cancer Registry includes all invasive cancers occurring among the resident population of Dindigul district in the state of Tamil Nadu. Data were first collected by visiting more than 100 sources of cancer information in and around Dindigul district and then completed by house visits for each of the cases registered. The registration procedures are described in detail elsewhere.[12]

Estimates of the population in the state of Tamil Nadu

Population statistics for each district in Tamil Nadu are available by 5-year age group and urban–rural areas from census data. The population of Tamil Nadu in 2009, estimated on similar lines as for Chennai city,[15] is 68.4 millions, of which 70% live in rural and 30% in urban areas.

Organization of data

The observed cancer cases were grouped into five 5-year calendar periods (1982–1986, 1987–1991, …, 2002–2006), sixteen 5-year age-groups (0–4, 5–9, …, 70–74, 75+ years) and 21 single or grouped cancer sites/types by sex. The details of single or grouped cancer sites/types with ICD–10 codes are as follows: tongue (C01–02), mouth (C03–06), other oral or pharynx (C00; C07–14), oesophagus (C15), stomach (C16), large bowel (C18–20), other gastrointestinal tract (C17; C21–26), larynx (C32), lung (C33–34), female breast (C50), cervix uteri (C53), ovary (C56), other female genital tract (C51–52; C54–55; C58), prostate (C61), other male genital (C60; C62–63), bladder (C67), other urinary (C64–66; C68), thyroid (C73), lymphomas (C81–85; C96), leukaemias (C91–95) and others or unknown (codes C00–96 not listed above).

Methods for prediction

The person-years for the calculation of incidence rates and predictions were grouped into corresponding 5-year calendar periods as above. The predicted number of cases for all cancer sites together is represented by the sum of 21 site-specific predictions. These have been made for two 5-year periods (2007–11 and 2012–16).

Chennai

The predicted number of cases in Chennai were calculated by first predicting the age-specific incidence rates for these periods based on observed rates up to 2002–2006 and then multiplying these predicted rates by the respective person-years for the corresponding future periods.

Incidence rates were modelled as a function of age at diagnosis, calendar period of diagnosis and birth cohort or generation. The central value of birth cohort is calculated by subtracting the mid-point of each age group from the mid-point of the period. Since the data are aggregated into 5-year age groups and 5-year calendar periods, the birth cohorts are synthetic and cases alternate between two birth cohorts during their lifetime. The model used for predicting incidence rates for a given cancer in this study is a modified version of the standard age–period–cohort model used in the prediction software NORDPRED[16] written in R, which incorporates the power link function instead of the logarithmic link function and is specified as follows:

$$R_{ap} = (A_a + D \cdot p + P_p + C_c)^5$$

where R_{ap} is the incidence rate in age group a during calendar period p, A_a is the age component for age group a, D is the common drift parameter, P_p is the non-linear period component of period p and C_c is the non-linear component of cohort c.[10] Since current trends extrapolate reliably close into the future, the drift parameter was held constant rather than gradually attenuated, as is the common practice for longer-term predictions.[10] The prediction base covered the entire period of 1982–2006; when a significant non-linear change in the recent trend was observed, the linear trend in the past 10 years was used rather than the average change over the entire observation period

Age-standardized rates using the world standard population[17] were computed to describe the observed and future trends. The predicted changes in the average annual numbers of cases were further partitioned into two components: those due to changes in cancer risk (rates) and those due to changes in demographics (population growth and ageing).[18]

Tamil Nadu

In the absence of systematic cancer registration covering the entire state, the future average annual cancer burden for the whole of Tamil Nadu in 2007–2011 and 2012–2016 was calculated using data on incidence rates from two population-based cancer registries in the state: (i) the recent incidence rates of 2003–2006 from the Dindigul Ambilikkai Cancer Registry covering the entire rural district of Dindigul[12] were used to represent the rural population of the state (assuming incidence rates remain constant in the next 10 years) and (ii) the predicted incidence rates of the Chennai registry as obtained from this study for 2007–11 and 2012–16 were utilized to represent the urban population of the state. The predicted incidence rates for the whole of Tamil Nadu were calculated as the weighted average of the Dindigul and Chennai rates in a ratio of 7:3, reflecting the 70% rural or semi-urban population and 30% metropolitan or municipal/corporation city/town population distribution within the state. The predicted rates were then multiplied by the corresponding person-years obtained from population projections for Tamil Nadu to obtain the number of incident cancers in the respective 5-year calendar periods.

RESULTS

Table I presents the observed numbers of cases and age-standardized rates for 1982–2006 in Chennai city and indicates the steadily increasing trend in overall cancer burden among both sexes in consecutive 5-year calendar periods.

Table II indicates that the current cancer incidence profile in Chennai (2002–06) is quite different from that observed 20 years ago (1982–86). The incidence of lung cancer has exceeded that of stomach cancer, while rates of large bowel cancer and leukaemia have increased to emerge ahead in ranking among men in 2002–06 compared with 1982–86. Among women, a key finding is the decreasing rates of cervix cancer offset by the increasing incidence of breast cancer. The incidence rates of ovary and large bowel

TABLE I. Trend of average annual number of cases and age-standardized rates of all cancer sites together by sex in consecutive 5-year calendar periods in Chennai

Period	Men		Women	
	Average number of cases/year	Average annual ASR	Average number of cases/year	Average annual ASR
1982–1986	1114	86.7	1492	118.6
1987–1991	1487	104.4	1701	121.2
1992–1996	1657	104.0	1784	112.9
1997–2001	1925	106.6	2094	116.8
2002–2006	2219	109.8	2398	118.3

ASR age-standardized rate per 100 000 population

cancers and leukaemia have also risen in the past two decades and have higher relative rankings in 2002–06. Cancers of the prostate in men and thyroid in women are among the top ten cancers in 2002–06.

The observed and predicted trends in age-standardized rates of all cancers together as well as common cancers within Chennai during 1982–2016 are depicted in Fig. 1. Predicted rates of all cancers combined, as well as cancers of the female breast, lung, large bowel, prostate and tongue, and leukaemia and lymphomas showed an increasing trend, while cancers of the stomach and oesophagus declined. Predicted rates indicate that thyroid cancer incidence in women would approach that of ovarian cancer by 2016, while rates of oral cancer would continue to increase in men but decrease in women during the next decade (Fig. 1).

Table III gives the observed and predicted average annual number of cases for all cancers combined alongside common specific cancers among men and women in Chennai, and relates the predicted overall 10-year percentage change in burden in 2012–16 to changes in cancer risk and changes in population size and ageing, relative to the observed new cases of cancer in 2002–06. The overall increase in the average annual number of incident cases of all cancers combined is predicted to be similar among women (33%) and men (30%), with approximately 2200 and 2400 new cases in men and women, respectively, in Chennai. These rates are predicted to increase to about 2900 and 3200 new cases by 2016. The increase attributable to changes in cancer risk (19%) was similar for both sexes while the increase attributable to changes in population was slightly greater among women (14%) compared to men (12%). The burden of common cancers (with the exception of cancers of the oesophagus and cervix) is predicted to increase for all specific cancer sites, with the extent of rise ranging from 15% (stomach) to 55% (prostate) among men, and between 5% (mouth) and 100% (thyroid) among women. The percentage increase in the number of cases due to changes in site-specific cancer risks among men was the highest for prostate and leukaemia (42%) followed by large bowel (40%); the order was thyroid (100%), breast (58%) and lung (52%) for women. The number of oesophageal cancer cases in both sexes and cervical cancer cases are predicted to fall in 2012–16, with the decrease due to a change in respective cancer risks being greater than the increase due to a corresponding change in population. Oral cancer risk decreased among women (–9%) but increased among men (19%) with the overall number of cases predicted to increase both for men (31%) and women (5%) in Chennai.

Table IV gives the predicted burden of all cancers together by sex, age-group and site in Chennai and Tamil Nadu for the periods 2007–11 and 2012–16. The average annual number of incident cases predicted for 2012–16 would be 6100 in Chennai and 55 000 in Tamil Nadu. The bulk of predicted cancer cases are among the age group of 35–64 years, both in Chennai and Tamil Nadu. By 2016, the incidence of breast cancer will rank higher than that for cervix cancer as the most frequent cancer in Tamil Nadu, while the number of lung, stomach and large bowel cancers occurring among both sexes together would surpass the number of cervix cancers in Chennai.

DISCUSSION

The effective delivery of cancer-related services requires reliable predictions of the future cancer burden. Such statistics help ensure rational allocation of resources to develop the infrastructure for cancer control and care. This study has used empirically evaluated methods to predict the future cancer burden in Chennai. Predicted rates from the urban catchment population of the Chennai Cancer Registry were combined with the currently available rates from rural Dindigul to provide statewide predictions of site-specific future cancer estimates for Tamil Nadu. The incidence data from Chennai and Dindigul have been demonstrated to be of reasonable quality and have been used as such for research purposes.[12,17,19,20]

Studies in India have modelled age-standardized or crude rates using linear extrapolation in trend and prediction analyses.[3,21] Variations due to non-linear components were not considered in

TABLE II. Changing incidence and pattern of common cancers in Chennai, India, in 1982–86 and 2002–06 (ranking is based on absolute number of cases)

Men				Women			
1982–86		2002–06		1982–86		2002–06	
Top 10 cancers	ASR (%)	Top 10 cancers	ASR (%)	Top 10 cancers	ASR (%)	Top 10 cancers	ASR (%)
Stomach	13.9 (15.3)	Lung	11.8 (10.3)	Cervix	44.5 (37.7)	Breast	31.6 (27.4)
Lung	7.4 (8.3)	Stomach	11.3 (10.2)	Breast	18.9 (15.9)	Cervix	22.1 (18.5)
Oesophagus	6.6 (7.2)	Oesophagus	7.9 (7.0)	Mouth	7.8 (6.1)	Ovary	6.0 (5.0)
Mouth	6.2 (6.8)	Mouth	6.1 (5.6)	Stomach	6.2 (5.0)	Stomach	5.6 (4.7)
Lymphomas	4.2 (6.2)	Lymphomas	5.8 (5.6)	Ovary	5.1 (4.4)	Mouth	4.9 (3.9)
Hypopharynx	4.4 (5.0)	Large bowel	5.8 (5.5)	Oesophagus	5.4 (4.2)	Oesophagus	4.7 (3.8)
Tongue	4.2 (4.7)	Tongue	5.6 (5.4)	Large bowel	2.6 (2.1)	Large bowel	4.1 (3.5)
Larynx	4.2 (4.5)	Leukaemias	4.6 (4.3)	Lymphomas	1.9 (1.9)	Leukaemias	3.5 (2.9)
Leukaemias	2.8 (4.1)	Prostate	4.7 (4.0)	Leukaemias	1.7 (1.8)	Thyroid	3.0 (2.7)
Large bowel	3.5 (3.9)	Larynx	4.5 (3.9)	Hypopharynx	1.7 (1.6)	Lymphomas	3.0 (2.7)

ASR average annual age-standardized rate per 100 000 person-years

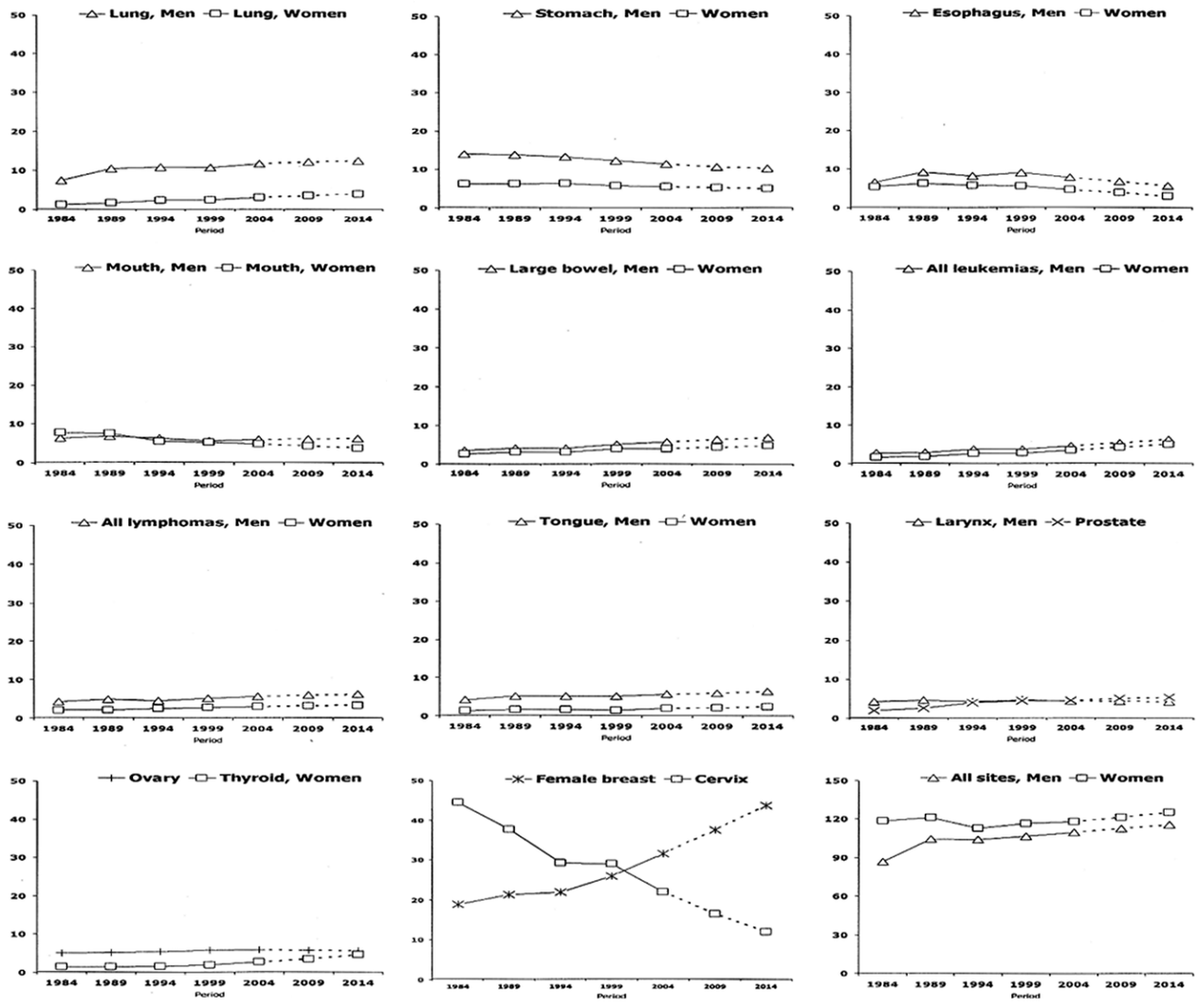

FIG 1. Observed and predicted trend of age-standardized rates of common and all cancers in Chennai in 1982–2016. The 12 panels show observed trend (in smoothed line) and predicted trend (in dashed line) of average annual age-standardized rates of common and all cancers by sex in Chennai during 1982–2016 in 5-year calendar periods represented by mid-year on X-axis and rates per 100 000 on Y-axis (scale not uniform across panels) with separate legends for each panel.

these studies. Our paper took into consideration the marked changes in the age-specific trends for the most common cancers in Chennai over time and modelled them to establish the predictions. In this context, by adding birth cohort as the third dimension in trend analysis, and incorporating non-linear components in measuring the change, we believe that site-specific predictions will be more precise than those that would be attained by linear extrapolation. In any case, the predictions are provided for a period that is only 10 years ahead, and the problems associated with providing long term forecasts are thus less in this study.

The predicted increase in all-cancer age-standardized rates in Chennai echoes the findings of many national and international studies in the past two decades.[21–23] Although the overall increase in the rates will be small, the actual burden will be much larger due to increase in and ageing of the population and changing rural–urban divide. In our study, the increase predicted in Chennai could be attributed more to changes in the site-specific cancer risk rather than demographic effect.

Breast cancer has been the most common cancer in Chennai since 2002 and its burden is predicted to increase by 73% in the next 10 years. It is also predicted that it would dislodge cervix cancer to emerge as the most common cancer in Tamil Nadu in 2016. Changes in socioeconomic factors among women, even in rural areas, with respect to education, age at first childbirth and parity suggest that the risk of breast cancer may continue to increase.[19] In contrast, the cervical cancer incidence and burden has been predicted to fall in Chennai but its predicted burden in Tamil Nadu would remain the same. Breast and cervical cancers together constitute almost half of the total cancer burden among women in Chennai and Dindigul. Hence, organizing intervention programmes at the population level aimed at controlling both these cancers would significantly reduce the overall cancer burden among women in Tamil Nadu.

Tobacco-related cancers accounted for 40%–45% of all cancers in men and 15%–20% of all cancers in women in Chennai and Dindigul.[12] The incidence of these cancers in Chennai is showing

TABLE III. Observed incident cases in 2002–06, predicted incident cases/rate in 2012–16 and 10-year per cent change in incident cases of common cancers in Chennai by sex

Predicted common cancers in 2012–16	Average number of incident cases/year		Predicted average annual ASR in 2012–16	Overall % change in predicted number	% change due to change in cancer risk	% change due to change in population
	Observed in 2002–06	Predicted for 2012–16				
Men						
Lung	230	306	12.5	+33.0	+21.3	+11.7
Stomach	227	260	10.3	+14.5	+3.0	+11.5
Large bowel	121	184	7.0	+52.1	+40.5	+11.6
Mouth	124	162	6.3	+30.6	+18.5	+12.1
Tongue	119	166	6.5	+39.5	+27.7	+11.8
Lymphomas	124	157	6.3	+26.6	+15.3	+11.3
Leukaemias	94	144	6.4	+53.2	+41.5	+11.7
Oesophagus	155	140	5.7	–9.7	–21.3	+11.6
Prostate	88	136	5.4	+54.5	+42.0	+12.5
Larynx	87	105	4.3	+20.7	+9.2	+11.5
All sites	2219	2894	115.8	+30.4	+18.7	+11.7
Women						
Breast	656	1135	43.8	+73.0	+58.4	+14.6
Cervix	443	304	12.0	–31.4	–45.8	+14.4
Ovary	121	146	5.7	+20.7	+6.7	+14.0
Stomach	112	131	5.1	+17.0	+2.7	+14.3
Thyroid	64	128	4.7	+100.0	+85.9	+14.1
Large bowel	82	121	4.8	+47.6	+33.0	+14.6
Leukaemias	70	112	5.1	+60.0	+45.7	+14.3
Lung	62	103	4.1	+66.1	+51.6	+14.5
Oesophagus	91	80	3.1	–12.1	–26.4	+14.3
Mouth	93	98	3.9	+5.4	–8.6	+14.0
All sites	2398	3200	125.5	+33.4	+18.9	+14.5

ASR age-standardized rate per 100 000 person-years

TABLE IV. Future incident cancer burden in Chennai and Tamil Nadu

Item	Chennai				Tamil Nadu			
	2007–11		2012–16		2007–11		2012–16	
	*n**	%	*n**	%	*n**	%	*n**	%
All cancer site/type	5316		6094		49 910		54 634	
By sex								
Men	2549	47.9	2894	47.5	22 717	45.5	24 771	45.3
Women	2767	52.1	3200	52.5	27 193	54.5	29 863	54.7
By age group (years)								
0–14	140	2.6	158	2.6	1249	2.5	1320	2.4
15–34	410	7.7	476	7.8	4001	8.0	4346	8.0
35–64	3157	59.4	3547	58.2	32 209	64.5	34 809	63.7
65–98	1609	30.3	1913	31.4	12 451	24.9	14 159	25.9
By cancer site/type								
Tongue	188	3.5	227	3.7	1571	3.1	1771	3.2
Mouth	240	4.5	260	4.3	2652	5.3	2825	5.2
Other oral/pharynx	284	5.3	304	5.0	2891	5.8	3064	5.6
Oesophagus	236	4.4	220	3.6	2253	4.5	2250	4.1
Stomach	365	6.9	391	6.4	3474	7.0	3683	6.7
Large bowel	250	4.7	305	5.0	1787	3.6	2055	3.8
Other gastrointestinal tract	243	4.6	294	4.8	2137	4.3	2413	4.4
Larynx	112	2.1	122	2.0	1053	2.1	1126	2.1
Lung	350	6.6	409	6.7	2450	4.9	2749	5.0
Female breast	875	16.5	1135	18.6	6480	13.0	7724	14.1
Cervix uteri	372	7.0	304	5.0	7136	14.3	7169	13.1
Ovary	133	2.5	146	2.4	1390	2.8	1490	2.7
Other female genital tract	90	1.7	94	1.5	868	1.7	909	1.7
Prostate	115	2.2	136	2.2	583	1.2	674	1.2
Other male genital tract	61	1.1	66	1.1	739	1.5	784	1.4
Bladder	95	1.8	112	1.8	739	1.5	831	1.5
Other urinary tract	54	1.0	63	1.0	471	0.9	519	0.9
Thyroid	123	2.3	175	2.9	907	1.8	1148	2.1
Lymphomas	217	4.1	246	4.0	1597	3.2	1751	3.2
Leukaemias	207	3.9	256	4.2	1697	3.4	1948	3.6
Others and unknown	706	13.3	829	13.6	7035	14.1	7751	14.2

* Average annual number of cases

a rising trend, particularly among men, and the trend in Tamil Nadu may be similar as statistics on the prevalence of tobacco habits reveal little difference between urban and rural areas in Tamil Nadu.[24] Lung cancer incidence is increasing in both sexes in Chennai as observed in other registries in India.[3,21] Curiously, oral cancer incidence in Chennai is falling among women but rising among men, with no let-up in the number of cases predicted for both sexes. This may be related to the new wave of increased tobacco use in urban areas of India and the high prevalence of the use of smokeless tobacco among younger adult men than women.[25] A reduction in prevalence of smoking has been cited as the single most important factor for the decreasing trend of age-standardized rates of cancer among men in England.[11] If the use of tobacco in any form in India is not controlled, it will translate into many more cancer cases, particularly among men. Hence, those involved in tobacco control in India should study the reasons behind the differentials in the prevalence of smokeless tobacco use among younger women and men, and devise appropriate strategies for tobacco cessation, including public education campaigns.

The rise in incidence of large bowel cancer and fall in oesophagus and stomach cancer in Chennai are consistent with global and national experiences.[3,17,21] Such trends may relate in part to improved aspects of diet and nutrition in India, in turn brought about by socioeconomic changes. Food-based dietary guidelines need to be formulated and general awareness increased at the population level, including the benefits of physical exercise for control of diet-related cancers.

Ovarian cancer, leukaemia and lymphomas are also showing an increasing trend, as in other registries in India.[3,21] The continuing increase in incidence of prostate cancer correlated well with the increase in the proportion of cases registered from private hospitals in the Chennai Cancer Registry. This merits a study to ascertain the extent of incidental diagnosis due to opportunistic screening by prostate-specific antigen testing and its implications. The reasons for the sharp increase in the incidence of thyroid cancer among young women in the recent calendar period in Chennai are unknown and need to be monitored. In general, the advent of more state-of-the-art imaging centres in Chennai has enhanced the cancer diagnostic capability, especially for cancers with unknown environmental risk factors.

We believe that the predictions for Chennai are suitable for cancer planning purposes for the state of Tamil Nadu, but may err on either side due to lack of availability of data on cancer trends in rural areas. The representativeness of the two cancer registries is also subject to caution, particularly with respect to the rural component. We also predict that cancer would continue to affect more women than men and more people between 35 and 64 years of age than any other age group in Chennai and Tamil Nadu. In the presence of an increasing future cancer burden, concerted efforts across the cancer control spectrum are required. The priorities are strengthening of cancer information systems and surveillance, launching of public education campaigns on tobacco cessation, targeted screening programmes for cervix and breast cancer and, in the tertiary prevention domain, resources for curative and palliative care for locally advanced cancers.

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Conflict of interest. None declared

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