RESEARCH ARTICLE

A Model Approach to Calculate Cancer Prevalence From 5 Year Survival Data for Selected Cancer Sites in India

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Abstract

Background: Prevalence is a statistic of primary interest in public health. In the absence of good follow-up facilities, it is difficult to assess the complete prevalence of cancer for a given registry area. Objective: An attempt was here made to arrive at complete prevalence including limited duration prevalence with respect to selected sites of cancer for India by fitting appropriate models to 1, 3 and 5 years cancer survival data available for selected population-based registries. Materials and Methods: Survival data, available for the registries of Bhopal, Chennai, Karunagappally, and Mumbai was pooled to generate survival for breast, cervix, ovary, lung, stomach and mouth cancers. With the available data on survival for 1, 3 and 5 years, a model was fitted and the survival curve was extended beyond 5 years (up to 35 years) for each of the selected sites. This helped in generation of survival proportions by single year and thereby survival of cancer cases. With the help of survival proportions available year-wise and the incidence, prevalence figures were arrived for selected cancer sites and for selected periods. Results: The prevalence to incidence ratio (PI ratio) stabilized after a certain duration for all the cancer sites showing that from the knowledge of incidence, the prevalence can be calculated. The stabilized P/I ratios for the cancer sites of breast, cervix, ovary, stomach, lung, mouth and for life time was observed to be 4.90, 5.33, 2.75, 1.40, 1.37, 4.04 and 3.42 respectively. Conclusions: The validity of the model approach to calculate prevalence could be demonstrated with the help of survival data of Barshi registry for cervix cancer, available for the period 1988-2006.

Keywords: Survival - model - prevalence - breast cancer - cervix cancer - lung cancer

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Introduction

Prevalence is a statistic of primary interest in public health because it identifies the level of burden of disease or health-related events on the population and health care system. Prevalence represents new and pre-existing cases alive on a certain date, in contrast to incidence which reflects new cases of a condition diagnosed during a given period of time. Prevalence is a function of both the incidence of the disease and survival. The prevalence for cancer is calculated in two major ways: Tumor based and person based. Whenever the interest of investigator lies in finding out the prevalence of certain tumor like breast cancer, cancer of cervix or lung cancer then actually the tumor based prevalence is calculated. But, when the interest is to find out the number of person suffering from cancer regardless of the tumor from which they are suffering then the calculation of person based prevalence is required.

Cancer is still a relatively a rare disease in India (incidence≈0.1%) and no good follow-up facilities are available, at present, with many of the Indian cancer registries. The complete survival data of cancer cases can be of great help in this regard. But, the survival data which is available with our country is only for a limited duration (1 year, 3 years and 5 years) and that too for selected cancer sites only which at most may facilitate estimating of cancer cases for limited duration only. Estimation of prevalence for complete duration for various cancer sites including all-sites cancer still remains a challenge. An attempt is therefore made to develop a model approach to estimate the prevalence of cancer cases using Indian cancer Incidence and limited survival data.

The objectives of the present study were: *i*) Using the available cancer survival data of 1 year, 3 years and 5 years for selected cancer sites including all-sites of cancer, to identify a best fit model for each site; *ii*) The best fit model equation to be used to extend the cancer survival curve beyond 5 years say up to 30 years or till such period that survival becomes zero; *iii*) From the extended survival curve, to generate the proportion of survivals by single years say for 1-30 years duration; *iv*) The survival proportions as obtained above by single years are helpful in determining the limited duration prevalence or complete prevalence; *v*) To show the validity of extending survival curve beyond 5 years with the help of a live data; and *vi*) To calculate the prevalence of cancer cases for selected cancer sites using the results of the study.

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Materials and Methods

The prevalence is calculated in two major ways: *i*) Tumor based; and *ii*) Person based. In Tumor Based Cancer, an attempt is made to find out the number of primary cancers diagnosed among individuals living on a specified date while in Person Based Cancer, an attempt is made to find out the number of individuals living with cancer on a specified date. Since the person-based approach counts the number of individuals with cancer rather than the number of diagnosed tumors, it can underestimate the true burden of cancer. The person based prevalence is again categorized in two ways: *i*) Complete prevalence; and *ii*) Limited duration prevalence. The Complete Prevalence represents the proportion of people alive on a certain day who previously had a diagnosis of the disease, regardless of how long ago the diagnosis was, or if the patient is still under treatment or is considered cured. The registries with long duration of working (more than 30 years) and good follow-up facilities could only give the complete prevalence. The registries with short duration of working say 15-20 years can at-most provide the information on Limited Duration Prevalence. It represents the proportion of people alive on a certain day who had a diagnosis of the disease, within the past 'X' years. Prevalence can be examined over various durations of time say 5 years, 10 years or 15 years.

In a Scientific Report (N0. 162) of IARC, the registries of Bhopal, Chennai, Karunagappally and Mumbai provided their survival rates for three selected periods (1, 3 and 5 years) and for 16, 20, 22 and 28 sites, respectively. Three sites each were identified for males (Stomach, Lung and Mouth) and females (Breast, Cervix and Ovary) separately. In addition, cancer as a whole (All-sites) is also considered. The survival data was pooled separately for each selected site by periods for all the registries. Using the pooled-survival data of 1 year, 3 years and 5 years of selected cancer sites an attempt was made to identify a best fit model to describe the 1 year, 3 years and 5 years survival data. Then the best fit model equation was utilized to extend the survival curve beyond 5 years say up to 30 years or till such period that the survival becomes zero. From the extended survival curve, the proportion of survivals by single years say for 1-30 years duration is determined. The survival proportions so obtained by single years in combination with the knowledge of prevailing incidence rates of cancers are helpful in determining the life time prevalence or complete prevalence.

For calculation of prevalence, for the selected cancer site, it is assumed that the cancer incidence rate for the registry remains constant over the years and the incidence cases of the registry are 100,000 for the base year 2001. Further, the incidence cases are expected to grow proportionately to the population growth rate (16.34% decadal growth rate). Then, applying the survival proportions and the incidence estimates for the years say 2001-2030, the prevalence figures are estimated. The prevalence to incidence ratio is also calculated for each single year till such time that it almost become constant. Such a P/I ratio is termed as stabilized P/I ratio. Then stabilized P/I ratio can be utilized to multiply the latest incidence cases to arrive at the point prevalence.

An attempt is also made to predict prevalence cases of selected cancer sites, utilizing the published data of incidence cases at India level for selected cancer sites and for selected periods (Takiar et al., 2009).

There are two points in the model approach which needs to be highlighted. First, it looks like a simulation technique used for calculation of prevalence. Second, the use of survival equation to estimate the survival proportions outside the actual range ie., beyond 5 years. It is therefore desirable to show that the model fitted in such a way is good and can be used to derive the prevalence of cancer for any given cancer site. To prove the point, it is essential that the model approach is to be applied to a long term follow up data of a certain cancer site and then its validity to be established. Fortunately, 18 years follow up data on incidence and mortality of cervix cancer was available from Barshi cancer registry. From the incidence and mortality data, the actual survival data will be generated for the period 1988-2006 and thus the actual prevalence cases will be determined for each single year. Then, using the first five year survival data and best fitted model equation a survival curve will be generated for the period 1988-2006 and prevalence will be determined for the entire period by single years and will be compared with that of actual prevalence at each point. A non-significant chi-square, derived from actual and fitted values, will prove that the model fitted is good and can be used to predict survival and thereby prevalence for the desired period.

Results

The absolute percentage survival by different years and by different cancer registries is provided in Table 1. The survival for 1 year varied between 55.2% in the registry of Mumbai to 62.3% in the registry of Bhopal. The 3 years survival did not show much variation between the registries (34.0-36.1%). However, the 5 years survival varied between 25.4% in Karunagappally to 28.1% in the registry of Mumbai. The pooled absolute % survival was observed to be 55.5%, 35.4% and 27.8% for the duration of 1 year, 3 years and 5 years, respectively. With the help of SPSS, a suitable curve was fitted and shown in Figure 1. The type of equation and the respective constants are also shown in Figure. The equation is termed as the best fit equation. It can be seen that the observed and fitted values are quite close to each other suggesting the fit is good.

With the help of the best fit equation, the survival proportions are estimated for 1 year to 26 years and shown in Table 2. The estimated survival proportion is 0.553 for first year, 0.432 for second year, 0.362 for third year and so on. The survival proportion became zero for the year 24.

An approach used for calculation of prevalence is shown in Table 3. The first row in the table, show the cancer incidence cases which are assumed for the years 2001-2005. The selected years are shown in second row. The years for which prevalence is to be calculated is

shown in second column. The corresponding survival proportions are shown in first column. Considering the incidence cases for the year 2001 are 100000 and using the survived proportions, the survived cases for the years 2001-2005 can be estimated to be 55259, 43209, 36361, 31160 and 27281, respectively. Similarly, for the year 2002, the incidence cases are 101634 and the survived from this for the years 2002-2005 are 56162, 43915, 36752 and 31669, respectively. The prevalence for the year 2001 will be 55259 while for year 2002, it will be 43209+56162=99371; for the year 2003, it will be 36161+43915+57080=137156. Finally, the prevalence for the year 2005 will be 200627.

In Table 3, the incidence as well as the demonstration of calculation of prevalence of cancer for the year 2001-2005 is shown. The similar calculations for the year 2006-2024 are extended and complete calculations are shown in Table 4.

The prevalence (P) to incidence (I) ratio calculated for 2001-2024 for India is shown separately in Table 5. The ratio appears to stabilizing to 3.42 after the year 2022.

Based on the follow-up data of Barshi registry on the incidence and mortality cases of cervix for the period 1988-2006, the prevalence figures were calculated for each year and shown in second and sixth columns (Table 6). Following the survival of 1 year, 3 years and 5 years from the above data, as described earlier, a survival curve was generated and estimated prevalence figures were arrived for selected years and shown in third and seventh columns. The actual and estimated prevalence figures showed no significant variation from each other. The overall non-significant chi-square value suggests that the fit is good.

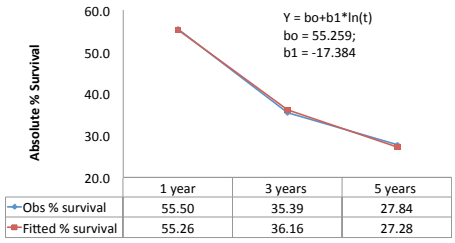

Figure 1. Observed and Fitted Absolute % Survival, All Sites Cancers

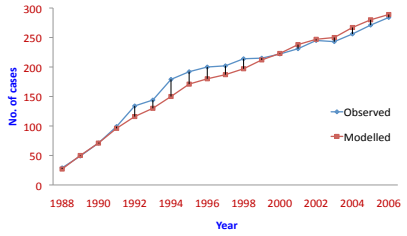

Figure 2. Observed and Fitted Values-cervix Data, Barshi (1988-2006)

The actual and fitted prevalence figures are also shown in Figure 2.

The percentage absolute survival of selected cancer sites, pooled for all selected cancer registries, is shown for 1 year, 3 years and 5 years period in Table 7. The 5 years pooled survival for the cancer sites of Breast, Cervix, Ovary, Lung, Stomach and Mouth was 41.6%, 43,7%, 23.6%, 7.0%, 8.2%, 31.4% respectively.

Following the procedure described earlier, the incidence and prevalence figures were generated for selected cancer sites with the help of suitable survival curves and prevalence to Incidence ratios are calculated for different years but shown for years which are multiple of five (5, 10, 15, 20, 25, 30, 35) in Table 8. The P/I ratio for the cancer sites of breast, cervix, ovary, stomach, lung and mouth for 5 years duration was 2.87, 2.89, 1.84, 0.77, 0.69 and 2.12 respectively. Similarly, the respective life time figures for above sites were 4.90, 5.33, 2.75, 1.40, 1.37 and 4.04 respectively. For All sites, the ratio for 5 year, 10 years, 15 years and life time was 1.88, 2.75, 3.19 and 3.42, respectively.

Considering the above stabilized P/I ratios for selected cancer sites and with the knowledge of cancer incidence cases for India, the prevalent cancer cases are calculated for India for selected three periods and shown in Table 9. In India, by the year 2020, the prevalent cancer cases of breast, cervix and ovary are estimated to be 605.1, 657.1

Table 1. Percentage Survival of Cases by Different Registries and Different Years (1990-1999)

Registry	Period of study	No. of sites	Cases	1 year	3 years	5 years
Bhopal	1991-1995	16	1863	62.3	35.6	27.9
Chennai	1990-1999	20	22598	55.3	34.0	27.4
Karunagpally	1993-2001	22	1601	59.3	34.3	25.4
Mumbai	1992-1999	28	46162	55.2	36.1	28.1
Pooled over all Registries			72224	55.5	35.4	27.8

*Sankarnarayan R and Swaminathan R (2011): Cancer Survival in Africa, Asia, the Caribbean and Central America, IARC Scientific Publications No. 162

Table 2. Estimated Survival Proportions by Different years-All Sites Cancers

Year	Absolute % Survival	Year	Absolute % Survival
1	0.553	14	0.094
2	0.432	15	0.082
3	0.362	16	0.071
4	0.312	17	0.060
5	0.273	18	0.050
6	0.241	19	0.041
7	0.214	20	0.032
8	0.191	21	0.023
9	0.171	22	0.015
10	0.152	23	0.008
11	0.136	24	0.000
12	0.121	25	-0.007
13	0.107	26	

Table 3. Calculation of Prevalence Based on Survival Pattern* Seen in India

Survival proportion	Incidence® Year	100000 2001	101634 2002	103296 2003	104984 2004	106700 2005	Prev (P)	Inc (I)	P/I
0.553	2001	55259[a]					55259	100000	0.55
0.432	2002	43209[b]	561621				99371	101634	0.98
0.362	2003	36161[c]	439152	570801			137156	103296	1.33
0.312	2004	31160[d]	367523	446342	580131		170559	104984	1.62
0.273	2005	27281[e]	316694	373533	453632	589611	200627	106700	1.88

[a]Incidence*0.553; [b]Incidence*0.432; [c]Incidence*0.362; [d]Incidence*0.312; [e]Incidence*0.273

Table 4. Calculation of Prevalence based on Survival pattern* seen in India

Survival Proportion	Incidence Year	100000 2001	101634 2002	103296 2003	104984 2004	106700 2005	108444 2006	110216 2007	112017 2008	113848 2009	115709 2010	117600 2011	119522 2012	121476 2013	123461 2014	125479 2015	127530 2016	129614 2017	131732 2018	133885 2019	136074 2020	138298 2021	140558 2022	142855 2023	145190 2024	Prev (P)	Inc (I)	P/I
0.55259	2001	55259																								55259	100000	0.553
0.43209	2002	43209	56162																							99371	101634	0.978
0.36161	2003	36161	43915	57080																						137156	103296	1.328
0.31160	2004	31160	36752	44634	58013																					170559	104984	1.625
0.27281	2005	27281	31669	37353	45363	58961																				200627	106700	1.880
0.24111	2006	24111	27726	32187	37963	46104	59925																			228016	108444	2.103
0.21431	2007	21431	24505	28180	32713	38583	46858	60904																		253174	110216	2.297
0.19110	2008	19110	21781	24906	28640	33247	39214	47624	61899																	276421	112017	2.468
0.17062	2009	17062	19422	22138	25313	29108	33791	39855	48402	62911																298002	113848	2.618
0.15231	2010	15231	17341	19740	22499	25726	29584	34343	40506	49193	63940															318103	115709	2.749
0.13574	2011	13574	15480	17625	20062	22867	26147	30068	34904	41168	49997	64985														336877	117600	2.865
0.12061	2012	12061	13796	15733	17913	20390	23241	26574	30559	35475	41841	50814	66047													354444	119522	2.966
0.10670	2013	10670	12258	14021	15990	18206	20724	23621	27008	31058	36055	42525	51645	67126												370907	121476	3.053
0.09382	2014	9382	10844	12459	14251	16251	18503	21062	24007	27450	31566	36644	43220	52489	68223											386351	123461	3.129
0.08182	2015	8182	9535	11022	12663	14483	16517	18806	21406	24399	27899	32082	37243	43927	53347	69338										400849	125479	3.195
0.07060	2016	7060	8316	9691	11202	12869	14720	16787	19113	21756	24798	28355	32606	37852	44644	54219	70472									414460	127530	3.250
0.06006	2017	6006	7176	8452	9849	11385	13080	14961	17061	19425	22112	25203	28818	33139	38470	45374	55105	71623								427239	129614	3.296
0.05013	2018	5013	6105	7293	8590	10010	11571	13294	15205	17340	19743	22473	25615	29289	33681	39099	46116	56005	72794							439236	131732	3.334
0.04073	2019	4073	5095	6204	7412	8730	10174	11760	13511	15454	17623	20065	22841	26034	29768	34231	39738	46869	56921	73984						450487	133885	3.365
0.03181	2020	3181	4139	5178	6306	7533	8873	10340	11952	13732	15706	17911	20393	23214	26459	30254	34791	40387	47635	57851	75193					461028	136074	3.388
0.02333	2021	2333	3233	4207	5263	6409	7656	9018	10509	12147	13956	15963	18204	20727	23593	26892	30749	35359	41047	48414	58797	76422				470898	138298	3.405
0.01524	2022	1524	2371	3286	4276	5349	6514	7782	9166	10681	12346	14184	16224	18502	21065	23979	27331	31251	35937	41718	49205	59758	77671			480120	140558	3.416
0.00752	2023	752	1549	2410	3340	4346	5436	6620	7909	9315	10855	12548	14416	16489	18804	21410	24371	27778	31762	36525	42400	50010	60734	78940		488719	142855	3.421
0.00012	2024	12	764	1575	2449	3394	4417	5525	6728	8038	9468	11033	12753	14652	16759	19112	21760	24769	28232	32281	37122	43093	50827	61727	80231	496721	145190	3.421

Table 5. Prevalence to Incidence Ratio by Different Years

Year	P/I	Year	P/I	Year	P/I	Year	P/I
2001	0.55	2007	2.3	2013	3.05	2019	3.36
2002	0.98	2008	2.47	2014	3.13	2020	3.39
2003	1.33	2009	2.62	2015	3.19	2021	3.4
2004	1.62	2010	2.75	2016	3.25	2022	3.42
2005	1.88	2011	2.86	2017	3.3	2023	3.42
2006	2.1	2012	2.97	2018	3.33	2024	3.42

Table 6. Validation of Calculation of Prevalence by Fitting the Apropriate Model

Year	Actual Prevalence	Prevalence by model	Chi-sqaure	Year	Actual Prevalence	Prevalence by model	Chi-sqaure
1988	29	27	0.14	1998	214	197	1.35
1989	49	50	0.02	1999	215	212	0.04
1990	71	71	0	2000	222	223	0
1991	99	96	0.09	2001	231	238	0.21
1992	134	116	2.42	2002	245	247	0.02
1993	144	130	1.36	2003	243	250	0.2
1994	179	150	4.7	2004	256	267	0.47
1995	192	171	2.3	2005	271	280	0.3
1996	200	180	2	2006	284	289	0.09
1997	202	187	1.11	Total X^2=16.82, p value=0.54			

Table 7. Percentage Survival of Cases of Selected Cancer Sites by Different Years-Pooled for five Registries (1990-1999)

Site	Cases	1 years	3 years	5 years
Breast	10812	78.5	58.2	41.6
Cervix	9376	76.2	59.5	43.7
Ovary	2941	53.3	37.8	23.6
Lung	5693	29.5	10.4	7.0
Stomach	5038	33.6	10.5	8.2
Mouth	4063	61.6	40.5	31.4

*Source: Sankaranarayanan R and Swaminathan R (2011)

Table 8. Prevalence to Incidence Ratio by Different Cancer Sites and Periods (5-30 years)

Year	All sites	Breast	Cervix	Ovary	Stomach	Lung	Mouth
5	1.88	2.87	2.89	1.84	0.77	0.69	2.12
10	2.75	4.06	4.22	2.45	0.99	0.91	3.13
15	3.19	4.56	4.83	2.65	1.12	1.05	3.68
20	3.39	4.77	5.12	2.72	1.21	1.15	3.95
25	3.42	4.85	5.25	2.74	1.29	1.24	4.04
30	-	4.89	5.31	2.75	1.35	1.31	-
35	-	4.9	5.33	2.75	1.4	1.37	-
Life time	3.42	4.9	5.33	2.75	1.4	1.37	4.04

Table 9. Estimated Prevalence Cases for Selected Cancer Sites Utilzing Stabilized Ratio for India (2010-2020)

Site of cancer	Incidence cases* 2010	2015	2020	P/I ratio	Prevalence 2010	2015	2020
Breast	90,659	106,124	123,634	4.90	444,229	520,008	605,807
Cervix	103,821	113,138	123,291	5.33	553,366	603,026	657,141
Ovary etc.	30,482	33,218	36,199	2.75	83,826	91,350	99,547
Males							
Lung	44,301	47,622	51,193	1.40	62,021	66,671	71,670
Stomach	25,831	27,767	29,850	1.37	35,388	38,041	40,895
Mouth	30,920	38,380	46,784	4.04	124,917	155,055	189,007
All sites**	979,787	1,060,889	1,148,758	3.42	3,350,872	3,628,240	3,928,752

*Takiar R et al. (2010), **ICMR Bulletin (2010)

and 99.5 thousand respectively. Similarly, the prevalent cancer cases of lung, stomach and mouth among males by the year 2020 will be 71.7, 40.9 and 189.0 thousand respectively. By the year 2020, the overall prevalent cancer cases in India are estimated to be rising to 3.9 millions.

Discussion

Prevalence of cancer is a statistic of primary interest in public health. It identifies the level of burden of cancer on the population and health care system. It is taken as a function of both the incidence of the disease and survival. In India, while reasonably good incidence data is available, still mortality data is far from being reliable and satisfactory. The variation seen in MI ratio of various Indian registries further substantiates this fact: NCRP, (2010). In the absence of good follow up facilities at the registry level, the correct assessment of prevalence of cancer is a distant dream.

The use of models in assessment of different diseases under different conditions is well documented (Merrill et al., 2000; Kruijshaar et al., 2002; Kruijshaar et al., 2003; Nacul et al., 2007). Incidence–prevalence–mortality (IPM) models have been used for improving estimates of disease epidemiology. The discrepancies between model estimates and observations are sometimes caused both by the data inaccuracies and change in the trends of incidence or mortality Kruijshaar et al. (2002). In SEER data, also, models are used to estimate the Cancer prevalence Merrill et al. (2000). Disease models describing the relationship between incidence, prevalence and mortality are also used to detect data problems or to supplement missing data Kruijshaar et al. (2003). The model can be used to estimate population prevalence of COPD from large general practices to national level, and as a tool to identify areas of high levels of unmet needs for COPD priority health actions Nacul et al. (2007). A robust and well-researched disease prevalence model can help Health Planners to assess the true needs of their community, calculate the level of services needed and invest the appropriate level of resources for prevention, early detection, treatment and care.

The model approach used in the paper allow us to estimate the prevalence for different cancer sites and for different time periods say for multiples of 5 years like 5, 10, 15, 20, 25, 30 and 35 years. The exercise carried out in the present paper further showed that for all the cancer sites, a year comes in a period (up to 35 years) when prevalence to incidence ratio become constant or do not show appreciable changes. The fact that PI ratio becomes almost constant or stabilizes after certain duration for all the cancer sites shows that from the knowledge of incidence, the prevalence can be calculated. The stabilized P/I ratio for the cancer sites of breast, cervix, ovary, stomach, lung and mouth for life time was observed to be 4.90, 5.33, 2.75, 1.40, 1.37 and 4.04 respectively. The variation in PI ratio by different sites is logical as they have different survival rates. The higher the survival rate, the higher the PI ratio. Since, the stomach and lung cancer are known to have low survival rates so their PI ratios are also shown to be lower as compared to other sites.

The exercise based on Barshi cervix data proved the following points beyond doubt that: *i*) From the best fit survival curve to 1, 3 and 5 years survival data, the curve can be extended beyond 5 years; *ii*) From the survival curve, the survival proportions can be decided for each single year between 1-18 years; *iii*) In combination of knowledge of incidence and mortality the prevalence figures can be calculated for each single year; *iv*) The model generated prevalence figures beyond 5 years and for life time were found to be comparable with actual prevalence figures; *v*) The model approach used in the present paper is validated for its prediction power, adequately with the support of actual data. Since the requirement of the model approach to estimate the prevalence figures for limited duration as well as for life time prevalence is only the knowledge of continuous incidence data and five year survival data, the approach will be cost-effective.

Realizing the fact that most of the Indian cancer registries are able to generate good incidence data but however are not having good follow up facilities, we advocate the use of PI ratio values provided by us to be used for generating of prevalence figures at their registry levels. Further the approach advocated in the present paper can be replicated anywhere in the world with the knowledge of current incidence, population figures and 1-5 years survival data to generate prevalence figures for their country level or at registry level.

In conclusion, the validity of the model approach to calculate prevalence is demonstrated with the help of survival data of Barshi registry for Cervix cancer, available for the period 1988-2006. Given the incidence of cancer at India level or at the registry level, the overall prevalence can be obtained simply by multiplying the incidence by a factor of 3.42. Similarly, for the cancer of breast, cervix and ovary, the multiplying factor to get lifetime prevalence from the knowledge of incidence will be 4.9, 5.33 and 2.75, respectively. In the case of males, for the cancer of lung, mouth and stomach, the multiplying factor will be 1.4, 1.37 and 4.04, respectively.

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