Asian Pacific Journal of Environment and Cancer
Vol 4 No 1 (2021), 3-7
Original Research

Forecasting the Incidence of Breast, Colorectal and Bladder Cancers in North of Iran Using Time Series Models; Comparing Bayesian, ARIMA and Bootstrap Approaches

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Introduction: Cancers are the second cause of death worldwide. Prevalence and incidence of cancers is getting increased by aging and population growth. This study aims to predict the incidence of breast, colorectal and bladder cancers in north of Iran until 2020 using time series models.
Methods: The number of breast, colorectal and bladder cancer cases from April 2014 to March 2016 was extracted. The time variable was each month of the study years and using the number of daily registered cancers in each month, the time series of the monthly incident cases was designed. Then, three methods of time series analysis including Box Jenkins, Bayesian and Bootstrap were applied for predicting the incidence of the above cancers until March 2020.
Results: The number of bladder cancer cases in March 2014 was 6 cases. This study showed that the number of breast cancer cases in March 2020 will be increased to 15, 15 and 26 cases based on ARIMA, Bootstrap and Bayesian methods respectively. In addition, the incident cases of breast cancer, will be increased from 32 in 2014 to 65 (ARIMA method), 47 (Bootstrap method) and 364 (Bayesian method). The corresponding figure for colorectal cancer was 30, 30 and 95 respectively.
Conclusion: The increasing trend of breast, bladder and colorectal cancers will be continued which is considerable based on the Bayesian method results. Considering the limited reliable data used in a short time, it seems that the forecasting results of this model is acceptable.

Introduction

Cancers are the second cause of death worldwide [1]. The increasing trend of cancer, is associated with aging and population growth [2, 3]. Cancers significantly act in individual and social levels and cause a wide network of physical, mental, familial and social problems [4].

Breast cancer is the most common cancers among women and the second top cancers among all types of malignancies. The standardized incidence of breast cancer among Iranian women has been increased from 15.96 per 100,000 in 2003 to 28.25 per 100,000 in 2009 [5, 6]. Colorectal cancer is the third prevalent cancers worldwide with approximately 150,000 new cases annually. In Iran, during 2003- 2008, the age standardized incidence of colorectal cancer has been increased from 5.47 to 11.12 per 100,000 in women and from 5.56 to 12.7 per 100,000 in men [7, 8]. Bladder cancer is one of the other common cancers especially among men. According to the results of a meta-analysis, the standardized incidence of this cancer among Iranian men and women has been estimated as of 10.92 per 100,000 and 2.80 per 100,000 respectively [9].

Control of cancer, as one of the three man health priorities in Iran, requires designing a clear road map for all stakeholders. The present global facts show the importance of approach to this strategy. For example, the treatment costs of cancer is 19% higher than the costs of cardiovascular disorders. Meanwhile, one-third to half of the cancer associated deaths which are occurred in the low-middle income countries are preventable by early diagnosis and treatment. The growth of knowledge of public health helps policymakers plan suitable evidence based strategies. Therefore, it is better to draw the future perspective of cancer based on the present situation and associated factors such as changes in population and risk factors [10].

Time series is one of the most common used techniques applied in the futures studies including a set of observations of a specified variable sorting based on time. In general, the aim of time series studies is determination of the probable models of data generating and predicting their quantities in the future. These techniques facilitate the statistical analysis of the variables according to the time [11]. In a time series study investigating the previous behavior of the series, the best model engaged in the data generation is detected. Therefore, assuming the similar behaviors in the future, the upcoming amounts of the series is predicted. Such analyses are attributed to dependent data which are associated with each other during the time. Such dependence between the sequential observations is the basic principle of the time series analysis [12]. This study aims to forecast the incidence of breast cancer, colorectal cancer and bladder cancer in the northern part of Iran (Mazandaran province) until 2020 using different approaches of time series analysis.

Materials and Methods

This cross sectional study was carried out based on the recorded data. The monthly number of the incident cases of bladder cancer, breast cancer and colorectal cancer from April 2014 to March 2016 were extracted. Note that only the information of the recent two years were completely available, just 24 time points were established. Sampling was conducted based on consensus method.

The main source of data was the cancer registry of Mazandaran University of Medical Sciences, Sari, Iran (IR.MAZUMS.REC.96.2730). The data extraction was conducted without patients’ names.

Three methods of analysis including Box Jenkins, Bayesian and Bootstrap were applied for prediction of the breast, colorectal and bladder cancers until March 2020. The time variable in this time series analysis was each of the months of the study years. Considering the daily number of the incident cancers registered in each month, the time series model of the monthly incident cases was designed.

Modeling approaches

In the time series modeling based on the Box-Jenkins model, to investigate the nature of data, time series graphs were designed including ACF (autocorrelation function) and PACF (partial autocorrelation function). The type of these series was assessed in term of static or instability of the mean, variance and trend detection. Model making was first begun by detecting an experimental ARIMA model through real data analysis. Then, the unknown parameters of the model (p, d, q) were estimated using ACF and PACF graphs. The final model was designed using ARIMA method. Goodness of fit of the model was assessed using AIC, Box Ljung test as well as evaluation of the model residuals (Q-Q plot).

For each observation, the Q-Q plot shows the observed (X axis) and expected (Y axis when the sample data are normally distributed) values. In the case of normal distributed data, all points will be collected around a direct line.

In the Bootstrap approach, for each series, 1000 sampling was performed according to the selected rank in the ARIMA model. Then, the model goodness of fit was applied on all ranks of the sampling and finally, the number of cancer cases was predicted for the future. In the Bayesian approach, the probable trend of each series was investigated using bsts package. Then, the posterior distributions were selected using appropriate prior distributions and the forecasting was conducted for the next 48 months.

The statistical analyses were performed using R version 3.5.3 software. The tseries part of the forecast package was used for Box-Jenkins and Bootstrap modeling and the bsts part of the package was applied for the Bayesian approach modeling.

Results

All bladder cancer cases were 367 patients varied between 6 cases in April to 25 cases in August 2014 (appendix 1). The relevant distributions were 18 in March to 38 in February.

The model parameters were estimated from ACF and PACF models after differentiation. As illustrated in the graphs of appendix3&4, the p & q parameters were estimated as 1. Considering the graphs in the appendix 2-4, the ARIMA (p=1, q=1 and d=1) seems to be the best models. I.e. the model includes both autoregressive and moving average components (ARIMA [(p, q, d) (1,1,1)]). This model had also the least AIC (149.45). It should be noted that Ljung-Box test was applied for assessment the ARIMA model for forecasting the bladder cancer incidence and the statistics showed that the final selected model is appropriate (X-squared=0.015718, p-value=0.900). The residuals were normally distributed indicating the effectiveness of the model (appendix 5).

As illustrated in the graph in the appendix 6, the average monthly number of the bladder cancer incident cases in north of Iran in 2020 will be 15 per month. The graph in appendix 7 illustrates the results of forecasting following 1000 Bootstrap sampling based on the ARIMA model. The results of the bladder cancer new cases based on Bayesian approach was estimated as of 30 cases per month in 2020 (Table 1, graph appendix 8).

Id	Year	Month		Bladder cancer			Breast cancer			Colorectal cancer	
			ARIMA	Bootstrap	Bayesian	ARIMA	Bootstrap	Bayesian	ARIMA	Bootstrap	Bayesian
1	2016	Apr	17.4155	15.3452	15.22746	48.6689	46.65132	71.2487	27.76202	30.11558	35.66455
2	2016	May	15.86397	15.38567	15.43442	73.10882	47.02884	78.27944	30.33082	30.17676	37.06692
3	2016	Jun	15.43291	15.36696	15.65411	61.24121	46.86865	84.45937	30.00476	30.16285	38.06237
4	2016	Jul	15.31315	15.38314	16.15532	67.00392	46.94276	90.59722	30.04615	30.17653	39.68993
5	2016	Aug	15.27987	15.37182	16.09151	64.20565	46.90941	96.8571	30.04089	30.1757	40.89032
6	2016	Sep	15.27063	15.38183	16.87119	65.56444	46.9222	103.1941	30.04156	30.17555	42.34386
7	2016	Oct	15.26806	15.37402	17.21513	64.90463	46.9194	109.7253	30.04147	30.18029	42.73563
8	2016	Nov	15.26735	15.38058	17.50012	65.22502	46.91715	115.9209	30.04149	30.17425	44.73483
9	2016	Dec	15.26715	15.37524	17.48442	65.06945	46.92206	122.8926	30.04148	30.1825	46.10567
10	2017	Jan	15.2671	15.3797	18.01552	65.14499	46.91598	129.8191	30.04148	30.17319	46.88251
11	2017	Feb	15.26708	15.37598	18.26541	65.10831	46.92263	135.709	30.04148	30.18374	48.33736
12	2017	Mar	15.26708	15.37913	18.4448	65.12612	46.9159	141.835	30.04148	30.17244	49.29929
13	2017	Apr	15.26707	15.37645	18.73475	65.11747	46.92255	148.6321	30.04148	30.18447	50.67441
14	2017	May	15.26707	15.37874	19.02945	65.12167	46.91613	154.9006	30.04148	30.17195	51.66125
15	2017	Jun	15.26707	15.37677	19.62755	65.11963	46.92228	162.2598	30.04148	30.18492	53.09373
16	2017	Jul	15.26707	15.37848	20.13925	65.12062	46.91644	167.9198	30.04148	30.17162	53.83005

17	2017	Aug	15.26707	15.37699	19.94702	65.12014	46.92197	174.4505	30.04148	30.18519	55.342
18	2017	Sep	15.26707	15.3783	20.1321	65.12037	46.91675	180.5774	30.04148	30.17142	56.60753
19	2017	Oct	15.26707	15.37715	20.55032	65.12026	46.92168	187.4819	30.04148	30.18537	58.29652
20	2017	Nov	15.26707	15.37816	20.99356	65.12032	46.91703	193.3027	30.04148	30.17129	59.06646
21	2017	Dec	15.26707	15.37727	21.5669	65.12029	46.92141	200.0601	30.04148	30.18547	60.0318
22	2018	Jan	15.26707	15.37806	22.03783	65.1203	46.91729	205.6375	30.04148	30.1712	61.92887
23	2018	Feb	15.26707	15.37735	22.20908	65.1203	46.92117	211.9153	30.04148	30.18554	62.75577
24	2018	Mar	15.26707	15.37798	22.44532	65.1203	46.91751	217.1927	30.04148	30.17115	64.37054
25	2018	Apr	15.26707	15.37742	22.85164	65.1203	46.92096	224.5392	30.04148	30.18558	65.05909
26	2018	May	15.26707	15.37792	23.13887	65.1203	46.91771	229.8751	30.04148	30.17112	66.47356
27	2018	Jun	15.26707	15.37747	23.5565	65.1203	46.92077	235.444	30.04148	30.18561	67.51255
28	2018	Jul	15.26707	15.37787	24.20189	65.1203	46.91789	242.6142	30.04148	30.1711	69.29039
29	2018	Aug	15.26707	15.37752	19.19638	65.1203	46.92061	242.6037	30.04148	30.18562	66.43344
30	2018	Sep	15.26707	15.37784	25.00504	65.1203	46.91805	269.331	30.04148	30.17109	76.58006
31	2018	Oct	15.26707	15.37755	22.2988	65.1203	46.92046	270.681	30.04148	30.18563	74.82842
32	2018	Nov	15.26707	15.37781	28.08278	65.1203	46.91819	260.9105	30.04148	30.17109	80.27744
33	2018	Dec	15.26707	15.37758	34.27281	65.1203	46.92033	275.7888	30.04148	30.18563	73.77579
34	2019	Jan	15.26707	15.37778	32.31013	65.1203	46.91831	289.38	30.04148	30.17108	81.36997
35	2019	Feb	15.26707	15.3776	20.37637	65.1203	46.92021	279.8265	30.04148	30.18563	77.56736
36	2019	Mar	15.26707	15.37777	28.88045	65.1203	46.91842	298.304	30.04148	30.17108	81.50867
37	2019	Apr	15.26707	15.37761	32.16857	65.1203	46.9201	293.4317	30.04148	30.18563	79.81653
38	2019	May	15.26707	15.37775	27.8914	65.1203	46.91852	301.2768	30.04148	30.17108	79.10895
39	2019	Jun	15.26707	15.37763	35.1063	65.1203	46.92001	316.1611	30.04148	30.18563	87.53291
40	2019	Jul	15.26707	15.37774	27.72762	65.1203	46.91861	335.134	30.04148	30.17109	92.57104
41	2019	Aug	15.26707	15.37764	25.63614	65.1203	46.91992	307.0223	30.04148	30.18563	79.99557
42	2019	Sep	15.26707	15.37773	27.2985	65.1203	46.91869	336.092	30.04148	30.17109	94.05782
43	2019	Oct	15.26707	15.37765	30.63707	65.1203	46.91985	330.3854	30.04148	30.18563	93.62512
44	2019	Nov	15.26707	15.37772	29.51558	65.1203	46.91876	338.08	30.04148	30.17109	84.93896
45	2019	Dec	15.26707	15.37765	28.41592	65.1203	46.91978	348.0495	30.04148	30.18563	99.37787
46	2020	Jan	15.26707	15.37771	28.94071	65.1203	46.91883	357.2993	30.04148	30.17109	84.98825
47	2020	Feb	15.26707	15.37766	34.98991	65.1203	46.91972	354.7557	30.04148	30.18562	86.1083
48	2020	Mar	15.26707	15.37771	26.21888	65.1203	46.91888	363.643	30.04148	30.1711	95.24105

Table 1. The Incident Cases of Breast, Bladder and Colorectal Cancer Predicted for March 2020.

Totally 1113 breast cancer cases were investigated minimum and maximum of which were identified in April 2015 (25 cases) and March 2016 (99 cases) respectively (Appendix 9). These cases were distributed from 57 in March to 163 in February. The time series model had instable pattern converted to stable model by one step differentiation (appendix 10). Autoregressive and moving average parameters were estimated as of 1 (appendix 11& 12). Therefore, the ARIMA (p,d,q) (1,1,1) was selected as the best model.

Moreover, the AIC of the model was estimated as of 196.13. The results of Ljung-Box test for the assessment of the ARIMA model showed that the model was appropriate (X-squared=0.014429, p-value=0.9044). According to the graph appendix 13, the residuals were normally distributed.

Graph of the appendix 14 shows the average number of breast cancer cases based on the ARIMA model in 2020 as of 65 cases per month. The corresponding figures for Bootstrap approach (appendix 15) and Bayesian approach (appendix 16) were predicted as of 47 and 358 cases respectively per month (Table 1).

The total number of colorectal cancer cases was 722 minimum and maximum of which were observed in September-October 2015 (21 cases) and April 2014 (86 cases) respectively (appendix

17). These cases were distributed from March (44 cases) to February (86 cases). Note that the time series had instability, one step differentiation was performed (appendix 18). Autoregressive parameter was estimated from the ACF graph (appendix 19) and moving average was estimated from PACF graph (appendix 20), both of which were estimated as of 1 and ARIMA (p,q,d) (1,1,1) was selected as the best model with AIC as of 160.34. Based on the results of the Ljung-Box test (X-squared=0.0063381, p-value=0.936), the selected model was appropriate. In addition, the residuals had normal distribution (appendix 21).

The number of colorectal cancer cases in north of Iran based on the ARIMA model (appendix 22) was estimated as of 30 cases per month. Corresponding incidences for Bootstrap (appendix 23) and Bayesian models (appendix 24) were 30 and 89 cases respectively (Table 1).

Discussion

In this study, the incidence of breast, colorectal and bladder cancers until March 2020 was predicted using time series analysis based on three modeling approaches (ARIMA, Bootstrap and Bayesian). The results showed that the number of bladder cancer incident cases will be increased from six cases in 2014 to 15, 15 and 26 cases in March 2020 based on ARIMA, Bootstrap and Bayesian approaches. The number of patients diagnose as breast cancer will be increased from 32 to 65, 47 and 364 cases in 2020 based on the above three approaches respectively. In addition, the corresponding incidences for colorectal cancers will be 30, 30 and 95 cases respectively.

Time series models are used in different fields of medical sciences such as forecasting the number of patients, deaths … . In the study conducted by Nikbakht et al, trend of colon cancer in Southeast of Iran until 206 was predicted and showed an increasing trend [13].

Alvaro-Meca et al applied time series models to forecast the mortality of breast cancer in Spain during 1981-2007 and obtained an ARIMA (0,2,0) which was used for 15 years forecasting. Based on the results of that study, an increasing trend of breast cancer mortality for all age groups until 1995 was observed which was then reduced so that the total pattern of death during the 15-year study period was a decreasing trend [14].

Bae et al in 2002 found an increasing trend for all cancers mortality during 1983-2000 based on time series models [15].

Fazeli et al investigated the mortality of breast cancer among four age groups of Iranian women during 1995-2004. They found an increasing trend from 2005 to 2002 and a reducing trend during 2002-2004 [16].

Time series models are widely used in forecasting the cancers [17-18]. Similar to the current study, results of the other forecasting studies are in keeping with the fact that the rate of cancers is increasing. One of the main characteristics of the time series analysis is that such studies are suitable for short time durations so that in the case of long periods, there are more uncertainties [18].

Bayesian theory which has been suggested by Tomas Bayes for the first time, is being used widely in the field of medical sciences [19]. Using Bayesian method during time series analysis has a lot of benefits. When modeling is performed on data with short time period, over fitting may be occurred. Therefore, the designed model can be fit with the current data but cannot precisely predict the new data.

One of the methods for solution of the over fitting is using Bayesian method and prior distribution as a model parameter. In the Bayesian approach, these parameters are considered as random variables and are applied to detect the posterior distribution and more precise estimates [20-24]. In the case of low prior data, the Bayesian approach is an appropriate method for prediction [25]. Ribes et al predicted the cancer incidence until 2020 using Bayesian approach. They reported that the incidence of cancer in 2020 will reach to 26455 in men and 18345 in women indicating 22.5% and 24.5% increase among men and women respectively [26]. That is similar to the results of the present study.

One of the limitations of the current study is that the information of just 24 months (2014-2015) was completely available. It should be noted that at least 50 time points are required for a precise time series analysis. To overcome this limitation in the ARIMA model, 1000 sampling was performed using Bootstrap approach before forecasting. As another limitation of our study, the time of cancer onset is ignored by the Bootstrapping while time series are time dependent. Moreover, the ARIMA model has a short forecasting domain and in the long time predictions, the confidence intervals will be wide. Such limitation can be resolved by the Byesian method.

In conclusion, our study predicted an increasing trend for breast, bladder and colorectal cancers in northern part of Iran. We also found higher estimations based on the Bayesian approach.

Acknowledgments

This study was financially supported by Mazandaran University of Medical Sciences, Sari, Iran. The authors thank to the research deputy as well as cancer research and registry centers of the university by their kindly cooperation.

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