Bayesian adjustment for trend of colorectal cancer incidence in misclassified registering across Iranian provinces

Sajad Shojaee1, Nastaran Hajizadeh2, Hadis Najafimehr3, Luca Busani4, Mohamad Amin Pourhoseingholi3*, Ahmad Reza Baghestani2, Maryam Nasserinejad2, Sara Ashtari1, Mohammad Reza Zali3

1 Basic and Molecular Epidemiology of Gastrointestinal Disorders Research Center, Research Institute for Gastroenterology and Liver Diseases, Shahid Beheshti University of Medical Sciences, Tehran, Iran, 2 Physiotherapy Research Center, Department of Biostatistics, Faculty of Paramedical Sciences, Shahid Beheshti University of Medical Sciences, Tehran, Iran, 3 Gastroenterology and Liver Diseases Research Center, Research Institute for Gastroenterology and Liver Diseases, Shahid Beheshti University of Medical Sciences, Tehran, Iran, 4 Department of Infectious Diseases, Istituto Superiore di Sanità, Roma, Italy

* Aminphg@gmail.com

Abstract

Misclassification error is a common problem of cancer registries in developing countries that leads to biased cancer rates. The purpose of this research is to use Bayesian method for correcting misclassification in registered cancer incidence of eighteen provinces in Iran. Incidence data of patients with colorectal cancer were extracted from Iranian annual of national cancer registration reports from 2005 to 2008. A province with proper medical facilities can always be compared to its neighbors. Almost 28% of the misclassification was estimated between the province of East Azarbaijan and West Azarbaijan, 56% between Fars and Hormozgan, 43% between Isfahan and Chaharmahal and Bakhtyari, 46% between Isfahan and Lorestan, 58% between Razavi Khorasan and North Khorasan, 50% between Razavi Khorasan and South Khorasan, 74% between Razavi Khorasan and Sistan and Balochestan, 43% between Mazandaran and Golestan, 37% between Tehran and Qazvin, 45% between Tehran and Markazi, 42% between Tehran and Qom, 47% between Tehran and Zanjan. Correcting the regional misclassification and obtaining the correct rates of cancer incidence in different regions is necessary for making cancer control and prevention programs and in healthcare resource allocation.

Introduction

Colorectal cancer (CRC) is the third most common cancer among men (10.0% of the total) and the second in women (9.2% of the total) worldwide. Mortality is lower (694,000 deaths, 8.5% of the total) with more deaths (52%) in the less developed regions of the world, reflecting a poorer survival in these regions [1]. In Iran, CRC is the fourth most common type of cancer (the third most common cancer among females and the fifth among males), which accounts for 8.4% of total cancers in the country [2,3].
There is wide geographical variation in incidence across the world; the highest estimated rates is in Australia/New Zealand, and the lowest is in Western Africa. About 55% of the cases take place in more developed regions. Clearly, it is partly because of their advanced diagnostic and registration capabilities [1].

Inflammatory bowel disease, family history of CRC, obesity, dietary habits, smoking, physical inactivity [2,4], and diabetes [5] are well-known risk factors for CRC. Furthermore, environmental risk factors are found to play an important role in the incidence and development of CRC [4]. Therefore, people who live in the same or adjacent areas which are imposed on the same environmental risk factors are expected to have similar cancer incidence rates.

The population-based and accurate information on the occurrence of the cancer is extremely valuable as the foundation for identifying risk factors and making purposeful cancer prevention policies, because it is a leading cause of morbidity and mortality worldwide [6–8]. Cancer registries as the main sources of epidemiological data, collect information regarding the burden of cancers by recording the incidence, prevalence, survival and mortality of different cancers in a systematic manner [9–11]. Nowadays, their role has expanded into detecting the impact of interventions for cancer control, evaluation of screening programs, and specifying future needs for materials and manpower resources. However the existence of deficiencies in registering individual’s information including patient’s permanent residence, primary site of tumor, date of diagnosis, and date of death [8], makes the recorded data inaccurate to use in future studies.

In many developing countries like Iran, most cancer patients prefer to get diagnostic and medical treatment services in the capital or in their neighboring provinces, since health facilities are not distributed evenly throughout the country. [12]. Some patients never mention their permanent residence and are registered in those provinces. It causes misclassification error in cancer registry data. Misclassification error is the disagreement between the observed value and the true value in categorical data. The expected coverage of new cancer cases in different provinces can be mentioned as the evidence of existence of misclassification error in registering cancer incidence. The observed number of incidence is more than the expected number in some provinces, and on the other hand, it is less than expected in a neighboring province [13]. It occurs while it is expected that the rate of cancer incidence to be about the same in adjacent provinces; since people adopt very similar lifestyle and traditions and are exposed to same environmental conditions.

There are two approaches in correcting the misclassification error; the first approach is validating a small sample of data with rechecking medical records and extending the results to the target population [14]. The second approach is employing the Bayesian method. Bayesian method is a statistical approach that let us take our prior evidence into account [15] with determining prior information for some of the parameters [16–18].

The aim of this study is to investigate the trend of colorectal cancer provinces in Iran after estimating the misclassification rate in registering cancer incidence by using Bayesian method and re-estimating the incidence rate in each province.

Material and methods

Registering of cancer reports is obtainable from different references such as pathologies, hospitals, death certificates and etc. National registration programming of cancer cases from Iranian annual of national cancer registration report is extracted during 2005 to 2008 with software which was created by health ministry, until cancer cases are collected, registered and centralized for the past couple of years and is used for data analyses. Hence all new diagnosed cancer cases in temporary information bank are sent from medical universities to ministry of health.
periodically. After process of duplicating and coding the recorded cancers based on 10th revision of international coding of disease, this information is registered in permanent information bank and all changes are sent to medical universities on specific duration, until permanent information bank of medical universities is equalized with permanent information bank of health ministry. So each medical university has an observed number of cancer cases and also has an expected coverage of cancer cases that are considered to be 100 per 100000 except 2008 that was 113 per 100000. By dividing the observed number to the expected number of cancer cases, the percent of expected coverage for each province is calculated [13].

Earlier this year, the national population-based cancer registry of the Islamic Republic of Iran was established, the International Agency for Research on Cancer (IARC) accepted Iran as a new Participating State and these registry data have been submitted to IARC to contribute to the next publications of GLOBOCAN and Cancer Incidence in Five Continents [19].

Since comparison of simple crude rate i.e. comparison of all cancer cases could make false images in total population regardless of age groups, age standardized rates (ASR) is calculated for all provinces of Iran using direct standardization method. The direct method for all provinces of Iran is based on, first selecting a criterion for the population and then calculating the desired outcome rate of this population using age specified rates at each of the two societies. At first, age groups were considered at level of 5 years. World standard population is the most common used standard population (\(W\)). By dividing number of incident cases to person-years of observations, ASR is calculated per 100000 (\(a_i = \frac{n_i}{N_i}\)). Finally for 4 age groups(0–14 years, 15–49 years, 50–69 years and over than70 years old) and for both genders, ASR is calculated in order to compare statistics on cancer internationally(\(ASR = \Sigma(W_i\times a_i)\)) [20–22].

For entering the data to the Bayesian model two vectors \(Y_1\) and \(Y_2\) were used. Vector \(Y_1 = \{y_{11}, \ldots, y_{11}\}\) for the province that has an expected coverage less than 100% with exact ASR and vector \(Y_2 = \{y_{12}, \ldots, y_{12}\}\) for a neighboring province with a more than 100% expected coverage with ASR from the first group incorrectly labeled as being in the misclassified group. Subscript \(r\) is the number of covariate patterns for age and sex group combinations. A Poisson distribution was considered for count data \(Y_1\) and \(Y_2\) which first introduced by Stamey et al [20], then developed by Pourhoseingholi et al for mortality of cancer and also adopted by Hajizadeh et al for Iranian cancer incidence [22–24].

\(Y_1 = Poisson(\mu_{1i})\) and \(Y_2 = Poisson(\mu_{2i})\) in which \(\mu_{1i} = \lambda_{1i}(1-\theta)\) and \(\mu_{2i} = \lambda_{1i}\theta + \lambda_{2i}\) and the joint distribution of the count data \(Y_1\) and \(Y_2\) is proportional to:

\[
\prod_{i=1}^{r} \left[\lambda_{1i}(1-\theta)\right]^{y_{1i}} \left[\lambda_{1i}\theta + \lambda_{2i}\right]^{y_{2i}} \exp\left\{-P_i\left[\lambda_{1i}(1-\theta)\right] - P_i[\lambda_{1i}\theta + \lambda_{2i}]\right\}
\]

An informative beta prior distribution was assumed for \(\theta\) as the probability of a data from the first group incorrectly registered in the misclassified group; so \(\theta ~ Beta(a,b)\). For selecting prior value for the parameters of beta distribution, the calculated expected coverage for the medical university which has a less than 100% expected coverage was used as \(b\) and \(a\) was calculated with subtracting \(b\) from 100. Thus \(a/(a+b)\) which is the expectation of beta distribution converges to the misclassified rate. Variable \(U\) with binomial distribution, i.e. \(U(Y_1, Y_2, \theta, \lambda_1, \lambda_2)\) that \(P_i = \frac{\lambda_{1i}\theta}{\lambda_{1i}\theta + \lambda_{2i}}\) was considered as the number of events from the first group that are incorrectly registered in the misclassified group. Now if \(\theta, Y_1, Y_2\) to be unknown; we have:

\[
\pi(\theta|U, Y_1, Y_2, \lambda_1, \lambda_2) = \pi(U|Y_1, Y_2, \theta, \lambda_1, \lambda_2) \pi(Y_1, Y_2|\theta, \lambda_1, \lambda_2) \pi(\theta)
\]
But since $Y_1$, $Y_2$ have known values of ASR on two neighboring provinces, then just theta is unknown and with employing a latent variable approach to correct the misclassification effect according to Paulino et al. [25,26], Liu et al. [27] and Stamey et al. [20] using a Gibbs sampling algorithm, the posterior appears in the following form:

$$\theta | Y_1, Y_2, \lambda_1, \lambda_2 \sim Beta \left( \sum_i U_i + a, \sum_i Y_{i1} + b \right) [22, 24 - 28]$$

To determine the low facilitated provinces and the one to adjusted, a province with low-facility provinces (usually adjacent) with a coverage of less than 100 is considered, so that the province with a coverage of over 100 (almost in neighborhood) is adjusted. The low-facility was based on the local annual statistic report of unemployment, average income, etc.

After estimating the misclassification rate between each two neighboring provinces, the rates of colorectal cancer incidence for each province were re-estimated and the trend of colorectal cancer were carried out during 2005 to 2008. In order to perform the analyses the R software version 3.3.1 was used.

**Results**

Registered cases of colorectal cancer have been included in the study for all provinces in Iran from 2005 to 2008. ASR of CRC incidence for men was 8.02 per 100,000 population (2255 cases) in 2005, whereas that year for women 7.4 per 100,000 (1801 cases). In over time, ASR of CRC incidence for men reached 12.7 per 100,000 population (3527 cases) in 2008 and for women to 11.12 per 100,000 (2658 cases) in the same year. The trend of CRC from 2005 to 2008 for both sexes is shown in Fig 1.

Among the 30 provinces, 18 provinces in which the number of cancer cases varied from their expected number were selected based on the percentage of expected cancer coverage, to correct the misclassification error in the registered data of neighboring provinces.

For example, the reported percentage of CRC expected coverage for Fars province as a province with suitable medical facilities and services was 120.8% in 2008. it means that Fars

![Fig 1. Age standardized rate of colorectal cancer incidence and its trend for male and female in Iran (2005–2008).](https://doi.org/10.1371/journal.pone.0199273.g001)
province have covered 20.8% of the new cases more than expected, while Hormozgan, which is adjacent to Fars, has a 19% expected coverage of cancer incidence, indicating clear misclassification in registering cancer cases. The expected coverage for all provinces in Iran between 2005 and 2008 is reported in Table 1. Also the estimated misclassification rate for all provinces in 2005–2008 is reported in Table 2.

For example by using the Bayesian method, misclassification rate was estimated 58% between Fars and Hormozgan in 2008. So, after Bayesian correction, ASR and number of cancer incidence decrease for Fars province and increase for Hormozgan province. ASR and number of cancer incidence, before and after Bayesian correction from 2005 to 2008 are reported in Tables 3 and 4.

Table 1. Expected coverage of cancer cases in provinces of Iran (2005–2008).

| Province             | 2005    | 2006    | 2007    | 2008    |
|----------------------|---------|---------|---------|---------|
| East Azarbayjan      | 108.2   | 110.9   | 138.5   | 123.6   |
| Isfahan              | 113.9   | 116.2   | 119.6   | 107.5   |
| Razavi Khorasan      | 114.1   | 109.11  | 120.9   | 155.5   |
| Tehran               | 157.11  | 162.25  | 145.7   | 155.6   |
| Fars                 | 84.2    | 119.4   | 143.3   | 120.8   |
| Mazandaran           | 77      | 78      | 76.1    | 102.1   |
| West Azarbayjan      | 81.9    | 75.3    | 82.5    | 69      |
| Hormozgan            | 25.4    | 25.11   | 25.3    | 19      |
| Chaharmahal          | 40.7    | 34.3    | 40.7    | 38      |
| Lorestan             | 40.2    | 41.5    | 47.1    | 76      |
| North Khorasan       | 30.8    | 40.4    | 44.8    | 34.8    |
| South Khorasan       | 30.3    | 45.1    | 41.02   | 41.4    |
| Sistan               | 27.2    | 19.1    | 18.85   | 19.5    |
| Golestan             | 50.7    | 58.6    | 58.2    | 50.8    |
| Qazvin               | 65.1    | 71.4    | 72.8    | 66.3    |
| Markazi              | 43.3    | 53.06   | 57.4    | 69.6    |
| Qom                  | 38.6    | 62.7    | 60.9    | 53.9    |
| zanjan               | 52.9    | 48.5    | 54.3    | 46.4    |

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Table 2. Bayesian estimated from misclassification rate between provinces (2005–2008).

| Estimated misclassification rate |
|----------------------------------|
| 2005    | 2006    | 2007    | 2008    |
| East Azarbayjan       | West Azarbayjan | 0.19   | 0.19   | 0.3    | 0.43   |
| Fars            | Hormozgan    | 0.45   | 0.61   | 0.58   | 0.58   |
| Isfahan          | Chaharmahal  | 0.44   | 0.43   | 0.38   | 0.47   |
| Isfahan          | Lorestan     | 0.52   | 0.51   | 0.51   | 0.32   |
| Razavi Khorasan   | North Khorasan| 0.57   | 0.66   | 0.53   | 0.55   |
| Razavi Khorasan   | South Khorasan| 0.6    | 0.3    | 0.56   | 0.55   |
| Razavi Khorasan   | Sistan       | 0.73   | 0.74   | 0.74   | 0.76   |
| Mazandaran        | Golestan     | 0.44   | 0.53   | 0.34   | 0.43   |
| Tehran           | Qazvin       | 0.33   | 0.36   | 0.36   | 0.43   |
| Tehran           | Markazi      | 0.49   | 0.44   | 0.41   | 0.45   |
| Tehran           | Qom          | 0.48   | 0.41   | 0.33   | 0.45   |
| Tehran           | zanjan       | 0.45   | 0.48   | 0.35   | 0.58   |

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Discussion

It is obvious that the neighboring provinces due to the same eating habits, lifestyle and climate, have the same health outcomes [13]. But sometimes when analyzing registered data, it is observed that the neighboring provinces not only have different outcomes but are also inconsistent. This situation implies that there is misclassification in registered data. This problem is a

Table 3. Age standardized rate of colorectal cancer incidence before and after Bayesian correction in Iranian provinces 2005–2008.

| Province                  | 2005   | 2006   | 2007   | 2008   | 2005   | 2006   | 2007   | 2008   |
|---------------------------|--------|--------|--------|--------|--------|--------|--------|--------|
| East Azarbayegan          | 3.52   | 3.26   | 10.68  | 14.15  | 2.51   | 1.95   | 8.60   | 11.15  |
| Isfahan                   | 8.19   | 9.26   | 9.05   | 9.54   | 4.74   | 5.00   | 5.78   | 4.14   |
| Razavi Khorasan           | 6.10   | 9.44   | 11.04  | 12.96  | 3.53   | 5.32   | 7.04   | 9.65   |
| Tehran                    | 9.26   | 10.78  | 7.56   | 11.60  | 7.30   | 9.21   | 3.55   | 6.64   |
| Fars                      | 5.10   | 6.65   | 9.96   | 18.71  | 3.30   | 5.28   | 8.39   | 16.59  |
| Mazandaran                | 9.03   | 10.08  | 10.36  | 12.76  | 6.30   | 6.20   | 13.32  | 9.21   |
| West Azarbayegan          | 5.31   | 6.46   | 7.59   | 6.30   | 6.54   | 8.09   | 10.35  | 10.23  |
| Hormozgan                 | 3.46   | 3.00   | 4.19   | 4.99   | 9.59   | 10.29  | 13.80  | 20.23  |
| Chaharmahal               | 6.00   | 7.83   | 10.15  | 7.55   | 12.49  | 17.65  | 19.63  | 16.88  |
| Lorestan                  | 3.96   | 4.52   | 5.45   | 9.52   | 9.08   | 10.07  | 11.35  | 13.53  |
| North Khorasan            | 3.00   | 1.70   | 3.20   | 5.02   | 8.55   | 4.48   | 6.99   | 12.94  |
| South Khorasan            | 2.48   | 2.89   | 2.88   | 4.40   | 7.39   | 4.81   | 6.81   | 10.24  |
| Sistan                    | 1.79   | 2.10   | 1.75   | 1.86   | 6.20   | 10.13  | 8.62   | 9.09   |
| Golestan                  | 5.44   | 7.69   | 9.12   | 7.73   | 10.16  | 14.65  | 14.45  | 14.27  |
| Qazvin                    | 7.92   | 6.66   | 5.80   | 9.23   | 11.93  | 10.02  | 8.67   | 15.22  |
| Markazi                   | 4.88   | 6.19   | 6.16   | 7.58   | 10.40  | 11.32  | 10.56  | 12.48  |
| Qom                       | 5.66   | 6.06   | 9.06   | 9.49   | 12.70  | 10.02  | 13.97  | 17.42  |
| zanjan                    | 5.43   | 5.38   | 9.21   | 5.23   | 10.05  | 10.70  | 15.15  | 11.77  |

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Table 4. Number of colorectal cancer incidence and the percent of change before and after Bayesian correction in Iranian provinces 2005–2008.

| Province                  | before Bayesian correction | after Bayesian correction |
|---------------------------|---------------------------|---------------------------|
| East Azarbayegan          | 95                        | 85                        |
| Isfahan                   | 268                       | 312                       |
| Razavi Khorasan           | 307                       | 396                       |
| Tehran                    | 819                       | 1034                      |
| Fars                      | 166                       | 212                       |
| Mazandaran                | 192                       | 214                       |
| West Azarbayegan          | 118                       | 135                       |
| Hormozgan                 | 33                        | 33                        |
| Chaharmahal               | 41                        | 46                        |
| Lorestan                  | 53                        | 70                        |
| North Khorasan            | 19                        | 10                        |
| South Khorasan            | 9                         | 11                        |
| Sistan                    | 31                        | 39                        |
| Golestan                  | 67                        | 91                        |
| Qazvin                    | 59                        | 57                        |
| Markazi                   | 49                        | 65                        |
| Qom                       | 44                        | 47                        |
| zanjan                    | 39                        | 38                        |

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notable matter in medicine which may result in deflecting of health programing and health resources allocation [28]. Such deflection could make irrecoverable damage on national scale. The aim of the present study was to help reducing misclassification error in registered colorectal cancer data in Iran. Firstly, the means in accessing health resources in welfare provinces and secondly the lack of health facilities in their neighboring provinces are elements in creating misclassification error. Fortunately, some studies have been conducted in Iran in order to eliminate the misclassification errors for mortality and morbidity registered cancer data in the case of Liver [29], Gastric [22], and colorectal cancers [23]. Applying the results of the studies above may be more reliable, since they had re-estimated and produced valid data. According to the result of our research, there was a non-ignorable estimated misclassification rate among adjacent provinces. The highest estimated misclassification parameter, belongs to North Khorasan, Hormozgan, and Sistan which are in the east and south of Iran. So the real rates of CRC in those provinces are higher than the rates that are reported by cancer registry system.

On the contrary, in studies that use cancer registry data and ignore the existence of misclassification error, it is reported that the highest incidence rates of CRC in Iran were found in the central, northern, and western provinces; and the southwest provinces of Iran had the lowest incidence rates of CRC in the country [2]. Therefore, ignoring the misclassification error in registered data, leads to a wrong image of distribution of CRC incidence across the country. Expected cancer coverage revealed that from 30 provinces, 18 provinces need misclassification correction. These provinces are those which are different in economic situation and there are some points in them which are welfare and probably patients for better health care, refers to those welfare places, so they have more referring people than their capacity. On the other hand, some provinces due to their fewer facilities, have fewer referring patients. Table 2 is indicating how the data of some provinces are registered in their adjacent locations. For example, some neighboring Tehrani patients like Qom’s patients, were referred to Tehran.

Identifying the exact distribution of a disease in different areas is a suitable way for finding the geographic pattern of the disease and causations, assessing the influential factors on disease incidence [30,31], and quantifying the potentials for disease control and prevention [32,33]. However, spatial analysis is usually deployed for this purpose which is based on registered data while existence of misclassification is often ignored. In spatial analysis, the morbidity or mortality rates for each province are combined with local information for the same province and the result may lead to an integrated geographical map. This type of maps is helpful for comparing among different provinces in aspect of disease incidence rate or probable risk factors [34]. In order to achieve this goal, we have prepared geographical map to evaluate incidence distribution of colorectal cancer registered data for before and after misclassification correction in Fig 2. Fig 2 showed that after correction the southern provinces have high incidence rate, while in the previous studies that ignored misclassification, southern provinces had low incidence rate [35].

The maps of present study also revealed that considerable changes happened in some provinces respect to before correction status. Thus, there are major differences in the incidence of CRC, while it is expected that the incidence of cancer to be the same in adjacent provinces. This can be justified by existence of misclassification error in registering permanent address of patients who are diagnosed in neighboring facilitate provinces. It leads to overestimation of CRC rate in some provinces and underestimation of its rate in some neighboring provinces.

For future researches, to recognize high risk spatial clusters, using our colorectal cancer valid data, is suggested. Also we could comparison and validate the information from this study in misclassification, with random sample of provinces in the future studies.

In conclusion, proper planning for cancer control and prevention, and allocating healthcare facilities to different areas, requires an increase in the quality and accuracy of registering system in different provinces and the correction of the existing deficiencies especially misclassification
error in registering patient’s permanent residence. The hardware and software resources need to be enhanced, more educated staff need to be trained in different sectors of cancer registry program, and the opinions of expert researchers in medicine, biostatistics and epidemiology need to be implemented [36]. In the absence of valid data, Bayesian method can be adopted as a fast and cost effective method to correct the regional misclassification error.

Supporting information

S1 File. The original data of colorectal cancer incidence for both sexes, and age group, and calculated ASR, for all Iranian provinces which included in this study, 2005–2008. (RAR)

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Author Contributions

Data curation: Nastaran Hajizadeh, Hadis Najafimehr, Maryam Nasserinejad, Sara Ashtari.

Formal analysis: Sajad Shojaee, Ahmad Reza Baghestani.

Investigation: Nastaran Hajizadeh, Hadis Najafimehr.

Methodology: Nastaran Hajizadeh, Luca Busani, Mohamad Amin Pourhoseingholi, Ahmad Reza Baghestani.

Project administration: Mohamad Amin Pourhoseingholi.

Software: Hadis Najafimehr, Ahmad Reza Baghestani.

Supervision: Mohamad Amin Pourhoseingholi, Mohammad Reza Zali.

Writing – original draft: Sajad Shojaee, Nastaran Hajizadeh, Hadis Najafimehr, Maryam Nasserinejad, Sara Ashtari.

Writing – review & editing: Luca Busani, Mohamad Amin Pourhoseingholi, Ahmad Reza Baghestani, Mohammad Reza Zali.

References

1. Ferlay J, Soerjomataram I, Ervik M, Dikshit R, Eser S, Mathers C, et al. Cancer incidence and mortality worldwide: sources, methods and major patterns in GLOBOCAN 2012. Int J Cancer. 2015; 136(5): E359–86. https://doi.org/10.1002/ijc.29210. PMID: 25220842

2. Khosravi Shadmani F, Ayubi E, Khazaei S, Sani M, Mansourni Hanis S, Khazaei S, et al. Geographic distribution of the incidence of colorectal cancer in Iran: a population-based study. Epidemiology and health. 2017; 39. http://doi.org/10.4178/epih.e2017020. PMID: 28774167

3. Mohagheghi MA, Mosavi-Jarrah A, Malekzadeh R, Parkin M. Cancer incidence in Tehran metropolis: the first report from the Tehran Population-based Cancer Registry, 1998–2001. Arch Iran Med. 2009; 12(1):15–23. PMID: 19111024

4. Johnson CM, Wei C, Ensor JE, Smolenski DJ, Amos CI, Levin B, et al. Meta-analyses of colorectal cancer risk factors. Cancer Causes Control. 2013; 24(6):1207–22. http://doi.org/10.1007/s10552-013-0201-5. PMID: 23563998

5. Larsson SC, Orsini N, Wolk A. Diabetes mellitus and risk of colorectal cancer: a meta-analysis. J Natl Cancer Inst. 2005; 97(22):1679–87. http://doi.org/10.1093/jnci/dji375. PMID: 16288121

6. Arnold M, Karim-Kos HE, Coebergh JW, Byrnes G, Antilla A, Ferlay J, et al. Recent trends in incidence of five common cancers in 26 European countries since 1988: Analysis of the European Cancer Observatory. Eur J Cancer. 2015; 51(8):1164–87. http://doi.org/10.1016/j.ejca.2013.09.002. PMID: 24120180

7. Mathers C, Fat DM, Boerma JT. The global burden of disease: 2004 update. World Health Organization;2008.

8. Parkin DM. The evolution of the population-based cancer registry. Nat Rev Cancer. 2006; 6(8):603–12. http://doi.org/10.1038/nrc1948. PMID: 16862191

9. Das A. Cancer registry databases: an overview of techniques of statistical analysis and impact on cancer epidemiology. Methods Mol Biol. 2009; 471:31–49. http://doi.org/10.1007/878-1-59745-416-2_2. PMID: 19109773

10. Pourhoseingholi MA, Vahedi M, Moghimi-Dehkordi B, Pourhoseingholi A, Ghafarmajed F, Maserat E, et al. Burden of hospitalization for gastrointestinal tract cancer patients-Results from a cross-sectional study in Tehran. Asian Pac J Cancer Prev. 2009; 10(1):107–10. PMID: 19469935

11. Yavari P, Sadrolhefazi B, Mohagheghi MA, Madani H, Mosavizadeh A, Nahvijou A, Mehrabi Y, Pourhoseingholi M. An epidemiological analysis of cancer data in an Iranian hospital during the last three decades. Asian Pac J Cancer Prev. 2008; 9(1):145–50. PMID: 18439094

12. Mohagheghi MA, Mosavi-Jarrah A. Review of cancer registration and cancer data in Iran, a historical prospect. Asian Pac J Cancer Prev. 2010; 11(4):1155–7. PMID: 21133641

13. Islamic Republic of Iran. Ministry of Health and Medical Education. Center for Disease Control & Prevention. Noncommunicable Deputy. Cancer Office. Iranian Annual of National Cancer Registration Report;2009.
14. Lyles RH. A note on estimating crude odds ratios in case–control studies with differentially misclassified exposure. Biometrics. 2002; 58(4):1034–36. PMID: 12495160

15. Corbin M. Bayesian methods to address multiple comparisons and misclassification bias in studies of occupational and environmental risks of cancer: a thesis by publications presented in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Public Health. Massey University, Wellington, New Zealand; 2013.

16. Whittemore AS, Gong G. Poisson regression with misclassified counts: application to cervical cancer mortality rates. J R Stat Soc Ser C Appl Stat. 1991; 40(1):81–93. PMID: 12157994

17. Spostò R, Preston DL, Shimizu Y, Mabuchi K. The effect of diagnostic misclassification on non-cancer and cancer mortality dose response in A-bomb survivors. Biometrics. 1992; 48(2):605–17. PMID: 1637983

18. McInturff P, Johnson WO, Cowling D, Gardner IA. Modelling risk when binary outcomes are subject to error. Stat Med. 2004; 23(7):1095–109. http://doi.org/10.1002/sim.1656. PMID: 15057880

19. Available at: https://www.iarc.fr/en/media-centre/pr/2018/pdf/pr258_E.pdf

20. Stamey JD, Young DM, Seaman JW. A Bayesian approach to adjust for diagnostic misclassification between two mortality causes in Poisson regression. Stat Med. 2008; 27(13):2440–52. http://doi.org/10.1002/sim.3134. PMID: 17979218

21. Ahmad OB, Boschetti-Pinto C, Lopez AD, Murray CJ, Lozano R, Inoue M. Age standardization of rates: a new WHO standard. Global Programme on Evidence for Health Policy Discussion Paper Series: no. 31. World Health Organization; 2001.

22. Hajizadeh N, Pourhoseingholi MA, Baghestani AR, Abadi A, Zali MR. Bayesian adjustment for over-estimation and under-estimation of gastric cancer incidence across Iranian provinces. World J Gastro-intest Oncol. 2017; 9(2):87–93. http://doi.org/10.4251/wjgo.v9.i2.87. PMID: 28255430

23. Pourhoseingholi MA, Faghihzadeh S, Hajizadeh E, Abadi A, Zali MR. Bayesian estimation of colorectal cancer mortality in the presence of misclassification in Iran. Asian Pac J Cancer Prev. 2009; 10(4):691–4. PMID: 19827896

24. Hajizadeh N, Baghestani AR, Pourhoseingholi MA, Ashtari S, Fazeli Z, Vahedi M, Zali MR. Trend of hepatocellular carcinoma incidence after Bayesian correction for misclassified data in Iranian provinces. World J Hepatol. 2017; 9(15):704–10. http://doi.org/10.4254/wjh.v9.i15.704. PMID: 28596818

25. Paulino CD, Soares P, Neuhaus J. Binomial regression with misclassification. Biometrics. 2003; 59(3):670–5. PMID: 14601768

26. Paulino CD, Silva G, Achcar JA. Bayesian analysis of correlated misclassified binary data. Computational statistics & data analysis. 2005; 49(4):1120–31. https://doi.org/10.1016/j.csda.2004.07.004.

27. Liu Y, Johnson WO, Gold EB, Lasley BL. Bayesian analysis of risk factors for anovulation. Stat Med. 2004; 23(12):1901–19. http://doi.org/10.1002/sim.1773. PMID: 15195323

28. Pourhoseingholi MA. Bayesian adjustment for misclassification in cancer registry data. Translational Gastrointestinal Cancer. 2014; 3(4):144–8. http://doi.org/10.3978/j.issn.2224-4778.2014.08.08.

29. Hajizadeh N, Baghestani AR, Pourhoseingholi MA, Najafimehr H, Fazeli Z, Bosani L. Bayesian correction model for over-estimation and under-estimation of liver cancer incidence in Iranian neighboring provinces. Gastroenterol Hepatol Bed Bench. 2017; 10(Suppl1):S54–S61. PMID: 29511473

30. Mehrabani D, Tabei SZ, Heydari ST, Shamsina SJ, Shokrpour N, Amini M, et al. Cancer occurrence in Fars Province, Southern Iran. Iran Red Crescent Medical Journal. 2008; 10(4):314–22.

31. Kamangar F, Dores GM, Anderson WF. Patterns of cancer incidence, mortality, and prevalence across five continents: defining priorities to reduce cancer disparities in different geographic regions of the world. J Clin Oncol. 2006; 24(14):2137–50. http://doi.org/10.1200/JCO.2005.05.2308. PMID: 16682732

32. Pandey S, Mishra M, Chandrawati C. Human papillomavirus screening in north Indian women. Asian Pac J Cancer Prev. 2012; 13(6):2643–6. PMID: 22938435

33. Zou L, Bao YP, Li N, Dai M, Ma CP, Zhang YZ, et al. Life-style and genital human papillomavirus in a cross-sectional survey in Shanxi Province, China. Asian Pac J Cancer Prev. 2011; 12(3):781–6. PMID: 21627383

34. Zayeri F, Kavousi A, Najafimehr H. Spatial analysis of Relative Risks for skin cancer morbidity and mortality in Iran, 2008–2010. Asian Pac J Cancer Prev. 2015; 16(13):5225–31. PMID: 26225657

35. Mahaki B, Mehrabi Y, Kavousi A, Akbari ME, Waldhoer T, Schmid VJ, et al. Multivariate Disease Mapping of Seven Prevalent Cancers in Iran using a Shared Component Model. Asian Pacific J Cancer Prev. 2011; 12(9):2353–8. PMID: 22296383

36. Teppo L, Pukkala E, Lehtonen M. Data quality and quality control of a population-based cancer registry. Experience in Finland. Acta Oncol. 1994; 33(4):365–9. PMID: 8018367