Evaluation of data quality at the National Cancer Registry of Ukraine

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\textbf{A R T I C L E   I N F O}

\textbf{Keywords:} Cancer registry, Data quality, Comparability, Completeness, Validity, Timeliness, Ukraine

\textbf{A B S T R A C T}

\textbf{Background:} Cancer notification has been mandatory in Ukraine since 1953, with the National Cancer Registry of Ukraine (NCRU) established in 1996. The aim of this study was to provide a comprehensive evaluation of the data quality at the NCRU.

\textbf{Methods:} Qualitative and semi-quantitative methods were used to assess the comparability, completeness, validity and timeliness of cancer incidence data from the NCRU for the period 2002–2012.

\textbf{Results:} Cancer registration procedures at the NCRU are in accordance with international standards and recommendations. Semi-quantitative methods suggested the NCRU's data was reasonably complete, although decreases in age-specific incidence and mortality rates in the elderly indicated some missing cases at older ages. The proportion of microscopically-verified cases increased from 73.6\% in 2002 to 82.3\% in 2012, with death-certificate-only (DCO) proportions stable at around 0.1\% and unknown stage recorded in 9.6\% of male and 7.5\% of female solid tumours. Timeliness was considered acceptable, with reporting > 99\% complete within a turnaround time of 15 months.

\textbf{Conclusion:} While timely reporting of national data reflects the advantages of a mandatory data collection system, a low DCO\% and observed age-specific declines suggest possible underreporting of incidence and mortality data, particularly at older ages. Overall, the evaluation indicates that the data are reasonably comparable and thus may be used to describe the magnitude of the cancer burden in Ukraine. Given its central role in monitoring and evaluation of cancer control activities, ensuring the sustainability of NCRU operations throughout the process of healthcare system reform is of utmost importance.

\section{1. Introduction}

Ukraine is an Eastern European country with a population of 45.5 million that has formed a part of the former Soviet Union (FSU) until its dissolution in 1991. Similarly to other FSU countries, cancer notification has been mandatory since 1953 \cite{1,2}, with every medical institution or laboratory required by the state cancer registration system to send standard paper notification forms to the regional population-based cancer registries (PBCR) for each new cancer case, as well as for prevalent cases receiving treatment. As of 2012, there were 27 PBCR in Ukraine, each operating as a division of the regional oncological center (ROC).

By Order of the Ministry of Health, every ROC is designated to provide comprehensive oncological care to the population of the respective region according to administrative division of Ukraine. ROCs are also responsible for cancer control planning within the region, including assessment of cancer burden, activities on cancer prevention and early detection. Official notification and report forms have been developed and implemented in the everyday practices of oncologists, epidemiologists, public health specialist at local and national levels. These practices were of great importance for starting the computerization of regional PBCRs in 1989. The National Cancer Registry of Ukraine (NCRU) was established by the Order of the Ministry of Health in 1996 and currently is part of the Ukrainian National Cancer Institute in the capital Kyiv. The NCRU and regional PBCRs use the same in-house developed software for data collection, internal consistency and statistical analysis. Since 2000, the NCRU publishes the annual report "Cancer in Ukraine" that compiles incidence, mortality and prevalence, with an English translation available online \cite{3}; this information is used for research and evaluation of health care system and quality of care.

This study provides the first systematic and comprehensive overview of the NCRU's data in terms of comparability, completeness,
validity and timeliness, as documented in international cancer registration guidelines [4–7]; the paper also provides a commentary on the specifics of cancer registration techniques in the former Soviet countries.

2. Material and methods

The main data sources at the NCRU are paper notification forms completed for each newly diagnosed case and excerpts from the medical records completed for all cancer patients upon discharge from a hospital, both mandatory by law, as collected passively by regional PBCRs. The death certificate data and follow-up information is collected actively via district oncologists at the primary health care level and via registrars at regional vital statistics offices. However, in some regions access to cause of death information is limited. At the beginning of each calendar year all regional PBCRs submit their data to NCRU to create a national database that contains a dataset of more than 100 variables, including patients’ demographic data and information on diagnosis and treatment from both clinical and laboratory departments.

A dataset comprising 1,601,624 new cancer cases of all sites excluding non-melanoma of skin (ICD-10 codes C00-96 excl. C44) diagnosed in Ukraine 2002–2012 (799,967 in males, 810,657 in females) was extracted from the database of the NCRU on 1 March 2014. Deaths by year of death, cancer site and sex were extracted for Ukraine from the WHO mortality database [8]. The population at risk stratified by year, age and sex was derived from the database of the State Statistics Service of Ukraine [9].

The technical aspects of evaluating data quality at a cancer registry were examined in a two-part review [4,5], and subsequently there have been papers from several registries that have reviewed their incidence data [10–14] using this template. The review covers four key areas of data quality at the NCRU: i) comparability – consideration of the registry’s procedures, including the standards and definitions used in registration; ii) completeness – the extent to which all of the incident cancers occurring in the population are included in the registry database; iii) validity (or accuracy) – the proportion of cases in a dataset recorded as having a given characteristic (e.g. cancer site, sex or age) that truly have that attribute; iv) timeliness – the rapidity at which a registry can collect, process and report sufficiently reliable and complete cancer data [4,5].

For the Ukrainian evaluation the completeness of the data was assessed using semi-quantitative approaches. Historic data methods [4] included an assessment of the stability of incidence rates over time, a comparison of the rates in other countries from the region, the shape of age-specific curves and childhood cancers incidence rates. Mortality to incidence (M:I) ratios for the period 2007–2011 were compared to one minus the five-year relative survival estimates (based on diagnoses 2002–2006) using the Ederer II method [15] for all major sites. Regression lines where fitted through the observed relative survival rates and the calculated ratios for selected sites. Deviations from the line \( Y = X \) were evaluated and commented upon.

Validity [4] was examined using the percentage of microscopically verified cases (MV%), of death certificate only cases (DCO%), and of cases with stage unknown (SU%) for the period 2002–2012 by site and sex. For the international comparison we extracted data from CI5 Volume XI database [16] for the period 2008–2012 for Ukraine and selected a number of Central and East European Countries (CEE) with national coverage of cancer registration and considered of sufficiently high quality to serve as gold standards: Belarus, Bulgaria, Croatia, the Czech Republic, Estonia, Latvia, Lithuania, Slovakia and Slovenia. Statistical tests for international comparison of ASRs, MV% and M:I ratios described in [17] were applied. Timeliness was evaluated in terms of the time from diagnosis to registration, and the time from registration to the reporting of incidence in the annual report.

3. Results

3.1. Comparability

The NCRU collects information on all malignant and in situ neoplasms according to the International Classification of Diseases, 10th revision, codes C00-96 and D00-09 respectively, while only new cases of invasive cancers (C00-96) are reported in the “Cancer in Ukraine” annual report. Topography and morphology are coded using an in-house system, whereby cancer registrars select a pre-defined text of topography and morphology diagnoses which is converted automatically to ICD-10 and ICD-O-3 codes by the cancer registry software [18].

The registration of the date of incidence follows ENCR recommendations [19], but only month and year of diagnosis are collected. The patient’s age at diagnosis is calculated as number of complete years of life on the 15th day of the month of the diagnosis.

There is an in-house system of coding basis of diagnosis, inherited from the Soviet cancer registration system. Two data items are collected, namely “method of verification of diagnosis” (histological, cytological, clinical, x-ray, ultrasound, unknown etc.) and “circumstances of finding the case” (in person, occupational screening, discovered posthumously after autopsy, discovered posthumously without autopsy etc.). Neither DCI (death-certificate initiated), DCN (death certificate notified), nor DCO status are stored in the database. Therefore, we define a DCO case as a case found posthumously, without autopsy or with autopsy with “unknown” method of verification of diagnosis. The recording and reporting of multiple primary tumours follow the IARC/IACR rules [20].

During the period 2002–2011, stage of disease at diagnosis was coded according to the UICC’s TNM coding system guidelines, 4th edition [21], where applicable. Implementation of the 6th edition of the TNM started during 2012 in 21 of the 27 regional PBCRs. Clinical and pathological TNM stage is entered in the registry software which contains the algorithms for conversion to TNM Stage Groups.

3.2. Completeness

The numbers of cases in major diagnostic groups in 2002–2012 are shown in Fig. 1 and Supplementary Table 1, while the age-standardized incidence rates (ASR), using the World Standard [22] are shown by sex in Fig. 2 and Supplementary Table 2. Overall cancer incidence rates increased over time from an ASR of 233.7 (per 100,000) to 241.7 in men and from 163.6 to 184.2 in women. The ASRs of major diagnostic groups were mostly stable over time, apart from a decrease observed for cancers of respiratory organs in males. The ASR for all cancers excl. non-melanoma of skin for both males and females were significantly lower (p-value < 0.01 for both males and females) than in the countries from the region (Table 1). The age-specific curves corresponded to the expected curves based on the biological characteristics of the respective diagnoses, other than the drop in incidence and mortality rates observed in older age groups for all sites and in both sexes. This suggests a degree of missing cases and deaths by the health care system, possibly due to less diagnostic accuracy in the elderly patients (Fig. 3).

The age-specific incidence rates for childhood cancers for two periods 2003–2007 and 2008–2012 are within expected limits for each age group for boys and girls (Table 2), calculated as the lower and upper deciles of the childhood incidence rates published in Volume X [23] and Volume XI [16] of the CI5.

The comparison of the M:I ratios and 1 minus 5-year relative survival for selected sites is presented in Fig. 4. M:I ratios are generally lower than 1 minus 5-year survival, in particular in females, but no systematic deviation from the line \( Y = X \) for both males and females were found. The estimated adjusted \( r^2 \) values were the same for males (92.65%) and females (92.70%) indicating limited inherently random variations most according to case fatality. The absolute difference
between the M:I ratios and the survival measure in males did not exceed 0.1, the limit indicating reasonable completeness proposed in [24], while for females the ratio was lower than survival for oesophageal cancer (by 0.13) and from multiple myeloma (by 0.14). For liver cancer M:I ratios for males was 1.02 and for females 0.96. M:I ratios for all cancers combined observed in Ukraine were somewhat higher in men and similar in women to those in other selected CEE countries (Table 1). The observed differences were not statistically significant (p-values 0.067 for men and 0.218 for women). Site-specific comparisons of the M:I ratios observed in Ukraine in 2008–2012 with the regional standard for Eastern Europe were performed as part of the evaluation process of CI5 vol. XI; no significant differences were observed, other than for “Brain, CNS” (ICD10 C70-72, both sexes), where observed M:I ratios were significantly lower than expected.

3.3. Validity

The values of indices of data accuracy are presented by sex and selected sites in Table 3. The proportion of microscopically verified cases increased from 73.6% in 2002 to 82.3% in 2012 (Fig. 5). During the study period, the MV% was 73.9% for males and 83.2% for females (Table 3).

The proportion of cases with unspecified morphology codes (ICD-O-3 morphology codes 8000 to 8005) compared to the overall number of microscopically verified cases ranged from 0.2% (haematological malignancies) to 8.3% (breast cancer in females). The proportion of unspecified cases with cytological confirmation in the NCRU’s database varied from 15.3% (cancers grouped as “eye, brain, CNS”, ICD-10 C69-72) to 71.5% (mouth and pharynx, C00-14) during the study period (data not shown).
3.4. Timeliness

The overall percentage of DCO cases in Ukraine was very low, 0.1% for both sexes, with the highest values seen for cancers of the liver (0.5% in males, 0.4% in females), brain (0.4% in both sexes) and pancreas (0.3% in males, 0.2% in females). The overall percentage of cases with unknown basis of diagnosis during the study period was also low (0.1%). During 2002–2012 the proportion of cases with stage unknown for solid tumours (ICD-10 codes C00-80 excl. C44) decreased from 11.9% to 9.5% in males, and from 9.2% to 6.8% in females. The highest proportions were observed for cancers of the brain (72.0% during the period 2002–2012) followed by bones (44.6%), liver (29.3%) and pancreas (22.4%) in males, with a similar pattern observed in females. We observed increases in the proportions of SU cases in 2012 compared to 2011 in the subgroups “Melanoma of skin”, from 8.6% to 23.0% (both sexes combined), and “Male genitals”, from 4.1% to 14.7%; and a decrease in the subgroup “Bone” (both sexes combined), from 42.0% to 36.4%, following the introduction of TNM 6th Edition. The proportion of cases with ill-defined site (ICD-10 codes C76-C80) in the period 2002-1012 in males was 3.5%, and in females 2.6%. A comparison of data quality indicators between Ukraine and Central and East European countries for 2008–2012 (Table 1) indicates that the DCO proportion in Ukraine was the lowest in the region in both sexes. No significant difference in the MV% were observed in males (p-value = 0.186) or females (p-value = 0.674) between Ukraine and the other countries from the region.

3.4. Timeliness

In developing official statistics on cancer incidence in Ukraine, a specific form has to be submitted by the regional PBCRs no later than 5 February following the year of diagnosis. It includes cases diagnosed and registered within the calendar year, stratified by site, sex and 5-year age groups. By 1 March, the final aggregated report has to be submitted to the Ministry of Health. At the same time, the NCRU starts producing its annual bulletin, “Cancer in Ukraine”. Along with the official cancer statistics for the recent year (3 months delay) the bulletin presents up-to-date number of cancer cases and deaths that occurred in the year before (15 months delay).

Table 4 presents number of cancer cases diagnosed in the year 2011 and published in two consecutive reports in 2012 (corresponding to state official statistics) and 2013 (to ensure greater completeness), as well as their proportions in the final dataset, as of March 2014. The proportion of underreported cases in official statistics varies – from 4.7% for cancers of oesophagus to 10.2% for thyroid cancers, with all cancers excl. non-melanoma of skin in between (6.6%). After a year had passed, the difference ranged from 0.4% (oesophagus) to 2.6% (leukaemia). The overall level of underreporting 15 months after the year of the diagnosis was 0.7%. Differences greater than 1% were seen for bone, prostate and brain cancers, as well as multiple myeloma and leukaemia.

In the NCRU database, both the date of diagnosis and the date of registration are stored, so it is possible to analyze the percentage of cases diagnosed and registered within the same and subsequent years. In the whole dataset the average time difference between the date of incidence and date of registration was 1.5 months. The percentage of cases diagnosed and registered by the end of the year of diagnosis varied in the study period from 92.3% to 94.1%, with 4.1% to 6.5% cases registered during the subsequent calendar year (Supplementary Fig. 1).

4. Discussion

In this study we have presented for the first time an overview of registration practices and a systematic evaluation of the comparability, completeness, validity and timeliness of data at the National Cancer Registry of Ukraine, the largest national PBCR in Europe. Supported by international organizations and societies (IARC, IAGR, European Network of Cancer Registries (ENCR), Danish Cancer Society, Estonian Cancer Registry etc.), the NCRU has since its beginnings followed international rules and guidelines where feasible, and when not – developed and implemented its own in-house coding systems, while maintaining as much comparability to international classifications as possible. This was recognized by inclusion of the NCRU’s incidence data into Volume X (2003-7) and Volume XI (2008-12) of the Cancer in Five Continents series [16,28]. NCRU data have also been included in several articles by South Eastern Europe Cancer Registry Group [25–28].

The long history of cancer registration during Soviet times, with obligatory reporting of all patients diagnosed or treated from cancer and the official notification and registration forms preserved after gaining independence in 1991, facilitated the introduction of the computerized database of the NCRU. The sustainability of the data collection system and operation procedures despite the continuing presence of a lack of human and technical resources was achieved via the implementation of a network of regional PBCRs.

According to a survey of European cancer registries performed in 2010, only 39% collected full TNM stage for a limited number of cancer sites [29]. The comparative advantage of the historical reporting system in Ukraine is that the TNM stage is a mandatory data item for health statistics with consequently high completeness of TNM stage information for most cancer sites. Site-specific comparisons for selected sites (breast, colon, rectum, lung, stomach, melanoma of skin and thyroid) reported from the EUROCare-5 project [30] have shown that the proportions of SU cases in the NCRU’s database were generally lower than in other European countries.

On the other hand, as reporting cancer morphology is not mandatory for health statistics purposes, the NCRU, as well as other cancer registries from FSU countries, have a relatively high proportion of cases with unspecified morphology [16]. This may be partly attributed to poor completeness of the pathology, and in particular cytology reports, but also to imprecise recording of the available morphology data in cancer notifications [31]. The cytologically-confirmed cases are not followed up further for histological confirmation.

Furthermore, the DCO cases are rarely traced back, resulting in the unavailability of DCI and DCN status, with only the most valid source of information regarding the cancer case recorded. It was therefore not

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**Table 1**

Data quality indicators – comparison with selected Central and East European cancer registries and NCRU for cases diagnosed in 2008–2012, all cancer sites excl. non-melanoma of skin, by sex, C15-X1 [16].

<table>
<thead>
<tr>
<th>Population</th>
<th>ASR</th>
<th>MV%</th>
<th>MVV%</th>
<th>DCO%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ukraine</td>
<td>238.6</td>
<td>67.9</td>
<td>77.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Belarus</td>
<td>301.9</td>
<td>58.0</td>
<td>95.7</td>
<td></td>
</tr>
<tr>
<td>Bulgaria</td>
<td>254.0</td>
<td>61.6</td>
<td>82.1</td>
<td>7.4</td>
</tr>
<tr>
<td>Croatia</td>
<td>322.5</td>
<td>65.3</td>
<td>73.6</td>
<td>6.5</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>346.2</td>
<td>50.8</td>
<td>82.5</td>
<td>0.4</td>
</tr>
<tr>
<td>Estonia</td>
<td>359.8</td>
<td>53.8</td>
<td>87.8</td>
<td>2.0</td>
</tr>
<tr>
<td>Latvia</td>
<td>323.5</td>
<td>63.9</td>
<td>73.0</td>
<td>7.7</td>
</tr>
<tr>
<td>Lithuania</td>
<td>391.2</td>
<td>51.3</td>
<td>81.7</td>
<td>8.5</td>
</tr>
<tr>
<td>Slovakia</td>
<td>358.2</td>
<td>53.6</td>
<td>90.6</td>
<td>3.0</td>
</tr>
<tr>
<td>Slovenia</td>
<td>347.4</td>
<td>52.9</td>
<td>93.4</td>
<td>0.3</td>
</tr>
</tbody>
</table>

| Females    |     |     |      |      |
| Ukraine    | 179.2 | 52.3 | 85.1 | 0.1  |
| Belarus    | 199.8 | 42.9 | 97.1 |      |
| Bulgaria   | 201.7 | 49.0 | 87.5 | 5.8  |
| Croatia    | 231.3 | 55.4 | 75.7 | 6.6  |
| Czech Republic | 250.2 | 47.3 | 84.2 | 0.5  |
| Estonia    | 218.4 | 51.6 | 88.0 | 2.0  |
| Latvia     | 223.7 | 53.9 | 78.5 | 6.1  |
| Lithuania  | 232.8 | 48.3 | 83.1 | 8.2  |
| Slovakia   | 250.3 | 43.4 | 90.9 | 2.6  |
| Slovenia   | 238.6 | 53.0 | 92.2 | 0.5  |

Abbreviations: ASR, age standardized rate per 100,000; MV, mortality to incidence ratio; MVV, microscopically verified; DCO, death certificate only.
Fig. 3. Age-specific rates of (a) incidence and (b) mortality for the major diagnosis groups per 100,000, 2002–2012, Ukraine. Abbreviations: M, males; F, females.
*Mortality data available only for the period 2005–2012.
possible to apply quantitative methods of estimating completeness: methods that require DCI cases to be registered and M:I ratios that estimate the proportion of initially unregistered cancer cases that do not die [6,32]. The semi-quantitative methods applied here indicated a reasonably high degree of completeness at the NCRU, however. The incidence rates for childhood cancers were between referenced values,
and the age-specific rates adhered to standard reference curves for specific cancers, although they tended to decline at older ages, suggesting some underreporting among older patients, both in terms of incidence and mortality. The high M:I ratios compared to survival measures observed for liver cancer in both sexes, might indicate incompleteness in incidence, but also misclassification of cause of death in death certificates, as liver is a frequent site for metastases. In general, M:I ratios for all sites observed in Ukraine were within expected limits compared to standard values in the region. Lower ASR relative to other CEE countries might suggest a certain degree of under-registration, but could also reflect different socio-economic patterns and risk factor profiles, which should be further explored on a site-specific basis.

The low DCO proportions typical of FSU cancer registries could have resulted from an underreporting of deaths among elderly patients, as well as a high proportion of autopsy in general and in this age group. Furthermore, some DCO cases could have been missed due to limited access to the cause of death in some regional PBCRs, as well as the practice of registering deaths by place of death and not by place of residence, which hinders the prospects of linking regional data [33]. In general, civil registration and vital statistics system in Ukraine is considered to be of medium quality [34]. An advantage of the mandatory reporting system in Ukraine is timeliness; at the NCRU the acceptable level of completion was obtained after 15 months, as compared to the median of 18 months reported by a survey report of European cancer registries [35].

To summarize, the NCRU operational procedures are similar to other registries from the former Soviet Union. This implies an exhaustive passive data collection system and the recording of all new, as well as prevalent cancer cases, with timely reporting. TNM stage is reported for all solid tumours, as it is one of the mandatory health statistics indicators. The limitations of the system are the lack of readily available information on DCO status and on different data sources (only the information on the most reliable source is stored) and the low specificity of morphological diagnoses. The use of ICD-10 is suboptimal for cancer registration; ICD-O-3 is not in use, and data are rarely presented or analyzed by morphology either in Ukraine or other FSU countries. Moreover, cancer registries in FSU and other post-communist countries are often poorly visible and recognized by the clinical community, resulting in a lack of feedback and use of data for purposes other than routine reporting, which would contribute to further improvement of data quality [36]. A series of activities to improve the quality and coverage of cancer registration in the FSU have been undertaken within IARC’s Global Initiative for Cancer Registry Development (GICR, http://gicr.iarc.fr/) programme, including the translation of IARC’s Technical Report No 43 “Planning and developing population-based cancer registration in low- and middle income settings” published in the Russian language [7,37,38].

Despite the limitations mentioned above, the present study shows that the NCRU provides internationally comparable data with reasonable levels of completeness, validity and timeliness. The NCRU’s data may be used to describe the magnitude and dynamics of the cancer burden in Ukraine, which is of great importance in informing national cancer control activities, as well developing international research collaborations. The challenge is however to preserve the functional data

<table>
<thead>
<tr>
<th>Age group</th>
<th>Boys 2003–2007 Ref.\textsuperscript{a}</th>
<th>2008–2012 Ref.\textsuperscript{b}</th>
<th>Girls 2003–2007 Ref.\textsuperscript{a}</th>
<th>2008–2012 Ref.\textsuperscript{b}</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–4</td>
<td>21.21 &lt; 13.7; &gt; 25.6</td>
<td>20.89 &lt; 12.6; &gt; 26.4</td>
<td>17.29 &lt; 11.3; &gt; 23.2</td>
<td>17.04 &lt; 12.1; &gt; 23.7</td>
</tr>
<tr>
<td>5–9</td>
<td>12.62 &lt; 8.9; &gt; 16.5</td>
<td>12.10 &lt; 8.9; &gt; 17.9</td>
<td>9.62 &lt; 7.0; &gt; 12.7</td>
<td>9.85 &lt; 7.0; &gt; 13.0</td>
</tr>
<tr>
<td>10–14</td>
<td>10.83 &lt; 9.2; &gt; 16.3</td>
<td>10.76 &lt; 9.6; &gt; 17.2</td>
<td>9.94 &lt; 7.9; &gt; 14.9</td>
<td>11.01 &lt; 8.2; &gt; 16.0</td>
</tr>
</tbody>
</table>

Reference: The lowest and highest deciles for childhood cancer incidence rates published in volume X\textsuperscript{a} [23] and volume XI\textsuperscript{b} [16] of CI5.

![Fig. 4. Mortality to incidence ratios (2007–2011) versus 1 minus five-year relative survival (based on diagnoses in 2002–2006), by sex, Ukraine. Abbreviations: M:I ratio, mortality to incidence ratio; 1-Survival, 1 minus five-year relative survival](image_url)
collection system and the continuum of cancer registry operations throughout the ongoing reform from the centralized state health-care system (based on the Semashko model of medical care from the FSU [31]), towards insurance-based healthcare. The latter might result in the abolishing of the posts of district oncologists in favour of general practitioners, as well as the reorganization, merging or closure of ROCs, putting the operations of the National Cancer Registry of Ukraine in jeopardy.

Authorship contribution

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The authors listed above have made substantial contributions to the intellectual content of the paper in the various sections described below.

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- analysis and interpretation of data: A Ryzhov, F Bray, J Ferlay, Z Fedorenko, A Znaor
- drafting of the manuscript: A Ryzhov, A Znaor, F Bray, J Ferlay, Z Fedorenko, L Goulak, Y Gorokh, O Soumkina
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- statistical analysis: A Ryzhov, J Ferlay

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Conflict of interest

None declared.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.canep.2018.02.002.

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