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On Capturing Radiological Diagnoses of Brain Tumors to Provide Complete Population Data in Cancer Registries in Canada

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Abstract: Nonmalignant brain tumors are underreported by an estimated 60% in Canadian cancer registries. One explanation is that radiology facilities or their databases may not be adequately included in the cancer reporting infrastructure. A multidisciplinary stakeholder team met for 1 day, followed by teleconferences, to discuss the evidence for the importance of incorporating radiology diagnoses in brain tumor reports. A role for the neuroradiologist was delineated in brain tumor diagnosis and in ensuring that radiology report information is available to support cancer case ascertainment in the cancer surveillance system. It was noted that brain tumors identified through imaging are clinically managed depending on the diagnosis and the prognosis of the disease, and that patient radiology reports become a part of a larger administrative information system. The proportion of patients with nonmalignant brain tumors diagnosed (49.3%) than in Canada (99%), suggesting that a higher proportion of cases with nonhistologic (likely radiology) diagnoses are captured by the US system (eg, tumors of the sellar region, cranial and spinal tumors, and tumors of the meninges). Finding a way to use existing electronic radiology reports to identify nonmalignant brain tumors needs to be prioritized. This will require access to electronic radiology reports, as manual reporting is impractical. Once access is achieved, an electronic flag to identify new cases through a natural language processing algorithm could be pursued. As radiologists and cancer registrars become more familiar with each other’s mandates and workflow demands, innovative and collaborative solutions to improve case ascertainment for brain and other cancers are likely to emerge.

Keywords: algorithm solution, electronic access, natural language processing, radiology reports, tumors

Introduction

Brain and other central nervous system (CNS) tumors account for only approximately 2% of primary cancer diagnoses among Canadians annually. However, these tumors cause a strain on the health care system that is disproportionate to their incidence. 2 Due to the anatomical location of these tumors, the associated clinical and public health burden is substantial and classified as critical. Recognizing this, including diagnoses of nonmalignant brain and other CNS tumors in comprehensive surveillance efforts for brain tumors has been mandated. For example, the Canadian House of Commons passed legislation (MB-235) in 2007 for the “creation of uniform national standards for all malignant and benign brain tumors.” 3

Provincial cancer registries are mandated to collect population-based data on cancer incidence, and aim to maintain high-quality databases so that patterns of disease generated from these data reflect all reportable cases within a jurisdiction. However, accuracy and completeness of cancer registry data is assessed using criteria developed by the North American Association of Central Cancer Registries (NAACCR), which only takes into account certain tumor sites and behaviors when calculating completeness, omitting nonmalignant tumors. 4 Therefore, provincial registries are able to meet the criteria for NAACCR certification while missing a large proportion of reportable brain tumor cases. These data may cause an underestimation of the extent to which nonmalignant brain tumors are missing from cancer registry data in Canada. Further, barriers to efficient capture of nonmalignant tumors in provincial registries designed to collect data on malignancies have not been clearly outlined or addressed.

A report by the Public Health Agency of Canada (PHAC) highlighted a potential barrier to nonmalignant CNS tumor registration related to the method of diagnosis for these tumors, which is predominantly through radiology. 5 In this report, PHAC suggested that radiology facilities may not have been sufficiently integrated into the reporting infrastructure. 5 A subsequent report compared the brain tumor cases captured in the Canadian Cancer Registry (CCR) database from 2006 to 2010 to the number of expected cases based on incident rates from the Central Brain Tumor Registry of the United States (CBTRUS). 6 At that time, it found that Canada registered only 33% of expected nonmalignant brain tumors. The Ontario Cancer Registry was the least complete in capturing nonmalignant brain tumors, while the Manitoba Cancer Registry was the most complete, capturing 73% of expected cases. Efforts are being made in Canada to fill these gaps. For example, in some provinces, hospital discharge records are now being used to supplement casefnding, which has significantly improved completeness of nonmalignant brain tumors. 7

The Brain Tumor Foundation of Canada (BTFC) has made the establishment of a Canadian brain tumor registry a priority, with support from both Brain Canada and the BTFC. During an inaugural team meeting of affiliates of the registry in June 2017, the missing of radiologically diagnosed brain and other CNS tumors in Canadian cancer registries was determined to be a priority. The team decided to identify potential solutions by inviting experts to a workshop aimed at gaining insight into the pathways to brain tumor diagnosis and registration, with a focus on the role of radiology.

Methods

Meeting Organization and Agenda

To review the current status of under-registration of nonmalignant brain tumors and radiological diagnosis in the role of radiology in current cancer reporting infrastructure, we organized a meeting titled, “Capturing Radiology Diagnoses of Primary Brain Tumors” on April 24, 2018 in Edmonton, Alberta. Participants examined a series of presentations, including a surveillance data review, a review of neuroradiology diagnosis of brain tumor and its data flow in Alberta, the neuropathology diagnosis of brain tumor and its synergy with neuroradiology, and an example of available software that captures brain tumors by processing pathology and radiology reports. Group discussions followed, focusing on the current use of radiology data across provinces and challenges associated with incorporating brain tumor diagnoses from radiology reports.

Data Analysis

Surveillance data on the diagnostic methods associated with brain tumor diagnosis were compared for Canada (CCR data release 2015, version 1) and the United States (Table 6 of the 2016 CBTRUS statistical report) to better understand the contribution of radiology in brain tumor registration. 8 Canadian data were limited to malignant tumors.

Discussion Synthesis and Proposed Solutions

All presentations and discussions were recorded, and detailed notes were taken throughout the meeting and used to develop a draft of the discussion synthesis, which was then circulated for review by the attending cancer registrars, physicians, and epidemiologists. Meeting participants provided feedback during the meeting. The proposed solutions were developed into a set of recommendations during follow-up discussions among the coauthors.

Results

Participants brought their expertise and experience to this discussion as the following 6 questions were explored.

What is the Current Status of Brain Tumor Diagnosis by Radiology in Canada?

Neuroradiology has a critical role in the diagnosis and management of brain tumors. Imaging procedures such as computed tomography (CT) and magnetic resonance imaging (MRI) are the most commonly used interventions for the initial evaluation and characterization of suspected brain tumors. 9 The field of neuroradiography is rapidly expanding beyond traditional anatomical examinations to also assess functional and cellular-level abnormalities. In the future, multimodality imaging techniques such as magnetic resonance/position emission tomography (PET) may enable radiologists to make fairly accurate diagnoses of histological tumor types, grade brain tumors, and identify structural and physiological changes to brain parenchyma. 10 In light of recent changes to the classification of gliomas by the World Health Organization, 11 which now incorporates both histology and molecular parameters, there has been an increased interest around the role of biology-driven MRI techniques for noninvasive identification of the association between neuroimaging findings and molecular level tissue alterations. 12

Patient-related demographic and clinical factors— including age, sex, clinical history, anatomical location, tumor spread, calcifications, and contrast enhancement—guide the radiological diagnosis of brain tumors. For example, glioblastoma, a highly aggressive brain tumor, is diagnosed with contrast enhancement of the tumor and ring enhancement. Imaging findings supplemented by relevant clinical history help the radiologist reach the most probable diagnosis from a list of differentials. Neuroimaging findings are then correlated with other diagnostic information and genetic mutations. For example, MRI findings of high contrast enhancing/necrotic volume and increased perfusion are being associated with epidural growth factor receptor amplifications, which is characteristic of glioblastoma tumors. 13

Neuroradiology also plays a key role in clinical care, treatment protocol decisions, and evaluation of tumor progression. For example, the radiological diagnostic work up of grade III astrocytoma is supplemented by histological and molecular marker assessments to determine tissue diagnosis and help direct help treatment planning. Neuroimaging findings are a key driver in identification of candidates who typically followed-up for years on neuroimaging without undergoing biopsy and active treatment. These "wait and watch" tumor diagnoses are more likely to be missed by the cancer case roles, leading to delayed reporting or under-reporting of these tumors.

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How Does Radiology Reporting Affect Brain Tumor Surveillance Information?

In the United States, approximately a third of all registered brain tumors were malignant and two-thirds were nonmalignant during 2009–2013. The proportion of malignant tumors identified through histology was similar in Canada during 2004–2015 to that of the United States (Table 1) and this proportion was also similar across Canadian provinces (Table 2). This suggests that the impact of a radiology diagnosis on case ascertainment may be mild, although the proportions of radiological confirmation of malignant brain tumors varied from 4.4% in Ontario to 20.5% in Manitoba (Table 2), raising concern about the comparability of data on malignant tumors across provinces. It should also be noted that radiology diagnosis still plays a significant part in the diagnosis of certain subtypes of malignant brain tumors both in the United States and Canada: the CCR data showed that 16.7% of unclassified and 47.0% of glioma (not otherwise specified) malignant tumors were diagnosed radiologically during 2004–2015.

With respect to nonmalignant tumors, the proportion of tumors diagnosed by histology and radiology were similar (49.3% and 47.8%, respectively) in US data (Table 1). The proportion diagnosed by radiology varied by tumor type. For example, 96.3% of tumors of the sellar region were confirmed using a nonhistological diagnosis. Other subtypes of brain tumors likely to be diagnosed without histology due to tumors of cranial and spinal nerves (85.9%) and tumors of meninges (66.4%). Further, the proportion of nonmalignant brain tumors diagnosed using histology is lower in the United States (49.3%) compared to Canada (59%) (Table 1).

Assuming confirmation methods for nonmalignant brain tumors in the United States are similar to those used in Canada, this comparison suggests that Canada is missing nonmalignant cases, especially those diagnosed by radiology. In the United States, electronic capture of radiology reports for casefinding has been shown to improve case entertainment for CNS neoplasms compared to traditional methods (pathology reports and hospital discharge lists).

How Do Radiology Report Results Move from Clinical to Administrative Databases?

Multiple information systems are involved in the creation, transmission, storage, and distribution of neuro-radiology reports. Using Alberta as an example, the process is initiated when a neuroradiology referral containing patient information and brief clinical indication enters the Radiology Information System (RIS) database, which houses imaging requests and the final text reports. When a patient undergoes the requested radiological procedure, the resulting image is transmitted to the picture archiving and communication system and is then analyzed by a radiologist, who has available patient clinical information and previous imaging results in the system for review. The radiologist dictates an unstructured medical record that relays key imaging findings with an initial diagnosis. The dictated text report is then sent to the RIS database for storage and further distributed to several electronic health record systems, including a provincial test result repository and physician electronic medical records database. However, currently there is no natural language processing solution available in Alberta to interpret the unstructured text data. It is unclear whether this is standard procedure across provinces or regions. These variations need to be better understood at the local level.

Where is the Gap between the Clinical Practice and Cancer Registration?

For a patient and a clinician, the pathway to clinical care is most important, but for surveillance researchers and stakeholders, the completeness and accuracy of cancer registration is also important. Patients cared for by oncologists are routinely being registered, since oncologists are part of the cancer care system (Table 3). The question arises as to what happens when a radiologically diagnosed patient is not immediately seen by a surgeon or an oncologist. If new patients do not require this attention, confidence in surveillance data decreases. If repeated MRI studies establish a diagnosis and a patient requires surgical or oncological care at a later date, the cancer registry information will be delayed and the level of accuracy is uncertain. If repeated MRIs indicate neither surgical intervention nor oncological care, the potential for that case to be missed in the surveillance system increases. This may help explain why information on malignant brain tumors appears to be complete and the information on nonmalignant tumors is incomplete. As discussed above, underreporting varies by province and tumor subtype. Therefore, policymakers and researchers using these data need to be cautious with data interpretation.

How May Software Applications Be Used to Process Radiology Reports?

Natural language processing is increasingly being used to read pathology reports for case identification. Different solutions are being explored in different registries. For example, Manitoba and Newfoundland and Labrador use Artificial Intelligence in Medicine Inc (AIM) and some institutions in Quebec use the System of ARrèves des Données en Oncologie (SARDO) to process pathology reports. Both of these software packages are used to identify cancer cases for cancer surveillance purposes. Recently, AIM developed an imaging interpreter software that uses natural language processing and artificial intelligence to detect reportable lesions in the central nervous system. This image of interpreter software processes the unstructured narrative radiological reports of MRI and PET scans of the brain and CT scans of the head, selects relevant reports to be forwarded to the cancer registry or other authorized department, and provides coding assistance for registrars. The AIM software processes the unstructured reports in several stages. The first stage uses text analysis and context determination to identify concepts such as cancer terms based on terminology and specific terms from the International Classification of Diseases for Oncology, third edition (ICD-O-3), such as metastatic or mention of history. It assigns every report a yes/no value for each of the 4 categories: primary tumor, previously known, metastatic, and past history of cancer. In the second stage, a logic module is applied to all reports using these category values previously assigned to determine 1 of 5 classes: negative, negative but has

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**Table 1. Summary of Diagnostic Confirmation Methods of All Primary Brain Tumors**

<table>
<thead>
<tr>
<th>Diagnostic Confirmation</th>
<th>Malignant Tumors</th>
<th>Nonmalignant Tumors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Histology (%)</td>
<td>83.5</td>
<td>83.0*</td>
</tr>
<tr>
<td>Radiology (%)</td>
<td>9.6</td>
<td>7.3</td>
</tr>
<tr>
<td>All other (%)</td>
<td>5.1</td>
<td>9.8</td>
</tr>
</tbody>
</table>

*Defined as histology and cytology.

**Table 2. Method of Diagnosis of Malignant Brain Tumors in 4 Canadian Provinces (2004–2015)**

<table>
<thead>
<tr>
<th>Province</th>
<th>Microscopic Confirmation (%)</th>
<th>Radiological Confirmation (%)</th>
<th>Other* (%)</th>
<th>Unknown (%)</th>
<th>Total of</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alberta</td>
<td>2,600 (83.9)</td>
<td>475 (15.3)</td>
<td>25 (0.8)</td>
<td>0 (0.0)</td>
<td>3,100</td>
</tr>
<tr>
<td>British Columbia</td>
<td>3,650 (84.4)</td>
<td>305 (7.1)</td>
<td>370 (8.6)</td>
<td>0 (0.0)</td>
<td>4,325</td>
</tr>
<tr>
<td>Manitoba</td>
<td>885 (79.0)</td>
<td>230 (20.5)</td>
<td>5 (0.5)</td>
<td>0 (0.0)</td>
<td>1,120</td>
</tr>
<tr>
<td>Ontario</td>
<td>11,265 (84.0)</td>
<td>590 (4.4)</td>
<td>215 (1.6)</td>
<td>1,340 (10.0)</td>
<td>13,410</td>
</tr>
<tr>
<td>Total</td>
<td>18,400 (83.8)</td>
<td>1,600 (7.3)</td>
<td>615 (2.8)</td>
<td>1,340 (6.1)</td>
<td>21,955</td>
</tr>
</tbody>
</table>

Note: Quebec data is only available up to 2010 and thus is not included in the table. Numbers are randomly rounded in accordance with Statistics Canada requirements.

*Other category includes death certificate, clinically confirmed, surgically confirmed, autopsy, and positive lab markers.
Given the advances in radiology diagnosis (particularly for brain tumors), it is important to recognize that provincial legislation may allow for re-evaluation of cases for case reporting as relevant to today’s clinical practice.

Artificial intelligence solutions for analyzing radiology reports need to be considered in the context of busy, high-volume hospital environments, where rare brain tumor diagnosis is a needle in a haystack. Any manual approach would put a significant burden on individual radiologists/clinics and cancer registry systems. These solutions may also assist in making imaging diagnosis (if performed) may be inconclusive, making data extraction more complex. As general systems for electronic reporting systems exist, building new information solutions (electronic or manual) to address the case ascertainment process may have collaboration with the cancer registry community and the radiology community. An electronic approach could be developed within provincial health information/surveillance systems. While unstructured radiology reports make information extraction difficult, natural language processing solutions are beginning to emerge.

In the long term, it might be helpful to explore adopting a form of synoptic reporting for radiology reports, which has been shown to help the flow of clinical information and increase the overall completeness for case capturing in pathology reporting. However, the advantages would need to clearly outweigh the burden of doing so in such a high-volume environment, and the structure of the synoptic report should not require radiologists to oversimplify descriptions of complex cases to the point they become less informative.

With the passing of MB-235, provincial cancer registries are undertaking the added responsibility for the collection of all primary brain tumors in the cancer registry system without additional resources. Radiologists, by extension, have a role in reporting nonmalignant (as well as malignant) brain tumors and cancer registries have the freedom to consider cooperative arrangements for these tumors. Doing this effectively will dramatically improve the surveillance information on nonmalignant brain tumors, but it could also improve the completeness of care registration for patients from nonradiologists. Solving these issues for better using radiologists and radiology reports at the provincial level were discussed:

**British Columbia:** Engage all clinical staff at hospitals, diagnostically to laboratory departments, and other diagnostic facilities, to update, educate, and advise compliance with registry guidelines regarding reportable cases (as per CCIR). Update coding and abstracting guidelines and associated reference material to match national and international standards; work with tumor registrars to understand of undue adherence to the updated guidelines. Create and improve algorithms to capture cases from other sources, particularly those based on brain terminology, while collaborating with information management and information technology departments to flag appropriate radiology reports for the registry.

**Alberta:** Explore the opportunity to search radiology reports to find a solution for notifying the registry of new cases of imaging.

**Manitoba:** Engage the radiation community; discuss their understanding of the provincial legislation and work to find a solution notifying the cancer registry of new cases of nonmalignant brain tumors found on imaging.

**Quebec:** Varied. Each hospital registry will try a strategy and compare the effectiveness of different approaches, in addition to ongoing efforts to develop SARDO so it can process imaging reports and report cancer cases to the registers.

**Conclusion and Recommendations**

Radiologically diagnosed nonmalignant brain tumors are disproportionally underreported in Canada. Registries need to adopt new casefinding strategies to capture clinically diverse cases from a variety of data sources, including radiology information. This review highlights that cancer registries are free to modify case reporting strategies within the context of their provincial law in order to ensure high-quality capture of nonmalignant cases. It also becomes clear that an electronic solution is likely, given that manual review of radiology reports is impractical.

Finding a way to use existing electronic reporting tools to identify nonmalignant brain tumors should be prioritized in the near future, as using some form of electronic text search or natural language processing approach seems readily doable. Specific solutions will vary by province, but must involve cancer registry access to radiology reports and ways to use the information in electronic radiology reports. Another question to explore for the longer term would be to find out whether synaptic reporting in radiology is being used as a pathologic reporting, would have any advantage with respect to improved data quality and data completeness for cancer registration and other purposes.

As radiologists and cancer registrars become more familiar with each other’s mandates and workflow demands, innovative and collaborative solutions to improve case ascertainment for brain and other cancers are likely to emerge.

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