Can Text-Search Methods of Pathology Reports Accurately Identify Patients with Rectal Cancer in Large Administrative Databases?

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Abstract

Background: The aim of this study is to derive and to validate a cohort of rectal cancer surgical patients within administrative datasets using text-search analysis of pathology reports. Materials and Methods: A text-search algorithm was developed and validated on pathology reports from 694 known rectal cancers, 1000 known colon cancers, and 1000 noncolorectal specimens. The algorithm was applied to all pathology reports available within the Ottawa Hospital Data Warehouse from 1996 to 2010. Identified pathology reports were validated as rectal cancer specimens through manual chart review. Sensitivity, specificity, and positive predictive value (PPV) of the text-search methodology were calculated. Results: In the derivation cohort of pathology reports (n = 2694), the text-search algorithm had a sensitivity and specificity of 100% and 98.6%, respectively. When this algorithm was applied to all pathology reports from 1996 to 2010 (n = 284,032), 5588 pathology reports were identified as consistent with rectal cancer. Medical record review determined that 4550 patients did not have rectal cancer, leaving a final cohort of 1038 rectal cancer patients. Sensitivity and specificity of the text-search algorithm were 100% and 98.4%, respectively. PPV of the algorithm was 18.6%. Conclusions: Text-search methodology is a feasible way to identify all rectal cancer surgery patients through administrative datasets with high sensitivity and specificity. However, in the presence of a low pretest probability, text-search methods must be combined with a validation method, such as manual chart review, to be a viable approach.

Keywords: Administrative databases, pathology reports, rectal cancer, text search

Introduction

With progressive digitization of healthcare and enhanced computing power, administrative data have become an increasingly available resource for clinical researchers. The use of administrative databases for healthcare-related research publications has risen steadily over the past two decades, with results that often lead to important conclusions. In administrative data, disease cohorts are primarily identified using diagnostic or procedural codes. Several problems exist regarding the use of healthcare-related codes to identify patient cohorts within administrative datasets. A wide range of the accuracy of administrative data codes has been reported. There frequently appears to be no accepted standard collection of codes to identify particular diseases, for example, Hohl et al. (2014) demonstrated extensive variability between studies in the numbers and types of codes used to identify the same population. In addition, very few studies actually validate the codes they use to create datasets for analysis. This indicates that the accuracy of the surrogate (the code) for the entity it is supposed to represent is unknown. As such, the generalization of results using the code to those involving the entity that is trying to be studied is unreliable. The use of administrative database diagnostic and procedural codes for cohort identification can be particularly problematic.
when studying patients with rectal cancer. Despite clear differences in both outcomes and treatment protocols, differentiating rectal from colon cancer patients using administrative codes can be extremely difficult. One reason for this is the varying definitions that can be used for rectal cancer including tumors that are within 15 cm of the anal verge, lie below the peritoneal reflection of the abdominal cavity (i.e., the division between the abdominal cavity and the pelvis), are amenable to radiation therapy, or are described as “rectal cancers” by the clinician. The range of potential rectal cancer definitions can make it difficult to create a homogeneous population of patients, especially in retrospective studies where the inclusion criteria cannot be made a priori. The patient misclassification resulting from these varying clinical definitions would be amplified in studies using health administrative data in which cases are identified using diagnostic codes. In this situation, error associated with the clinical classification of rectal cancer is amplified by error associated with inaccurate diagnostic codes that are assigned based on medical record review by a health records analyst.

Because of these issues, novel ways to create reliable patient cohorts are necessary to study rectal cancer using health administrative data. Text-analytical methods using radiology and pathology reports have been successfully utilized in the study of cardiac and breast cancer patients. To date, no published data on the use of text-search methods to identify rectal cancer surgery cohorts are available. The purpose of the present study was to derive and to validate a cohort of rectal cancer surgery patients using a text-search algorithm of pathology reports from 1996 to 2010 at a single, tertiary-care institution.

**Materials and Methods**

**Definition of rectal cancer**

This study defined rectal cancer as “an adenocarcinoma of the rectum for which the distal margin of the tumor was within 15 cm of the anal verge.” This definition is consistent with that used in major clinical trials for the disease. Distance measurements based on rigid sigmoidoscopy were preferentially used. If such measurements were unavailable from medical records, measurements from the anal verge were based on the following sources (in order of preference): Flexible endoscopy; magnetic resonance imaging; and digital rectal examination. If no distance measurement could be found from any of these sources, rectal cancer status was determined using best clinical judgment from information available in the medical record.

**Datasets**

The Ottawa Hospital Data Warehouse (OHDW) is a relational database containing data from all operational information systems at The Ottawa Hospital (TOH), a tertiary care institution. Operational information systems include clinical data such as laboratory results, clinical notes, pathology reports, hospitalization discharge abstract records, and demographic data. This study also used the TOH-Colon and Rectal Cancer (CRC) registry. This database included all patients who were coded with Canadian Classification of Health Intervention procedure codes indicating colorectal surgery between 2002 and 2010 at TOH. The accuracy and completeness of this registry is unknown.

**Development of text-search algorithm**

With permission from our research ethics board, we extracted from the TOH-CRC all patients and surgery dates of rectal cancer resections [Figure 1-A]. The medical records for each of these encounters were reviewed by RM. Patients meeting inclusion criteria listed in Table 1 were classified with rectal cancer and were included in the study. The dataset of rectal cancer patients was uploaded to the OHDW, wherein the health record number was encrypted to permit anonymous linkage with patient-specific records within the OHDW [Figure 1-B].

**Figure 1**: Flow diagram depicting methodology used to identify all rectal cancers at our institution. Letters A-G represent specific steps used to create the cohort and are referenced in the study’s text. Letters H-K represent steps taken to validate the text-search algorithm of pathology reports through manual chart review. TOH-CRC: The Ottawa Hospital-Colorectal Cancer, OHDW: Ottawa Hospital Data Warehouse.
We applied the text-search algorithm to the validation cohort of pathology reports containing diagnoses of rectal cancer, colon cancer, and noncolorectal cancer specimens. The algorithm was then further modified to maximize sensitivity and specificity until a final rectal cancer pathology text-search algorithm was identified [Figure 1-G].

**Text-search of all pathology reports**

The final rectal cancer pathology text-search algorithm was then applied to all pathology reports stored in the OHDW [Figure 1-H]. All pathology reports identified by the rectal cancer pathology text-search algorithm were then manually reviewed with their associated operative notes, clinic notes, radiology reports and hospitalization discharge summaries to determine if they met inclusion criteria for rectal cancer listed in Table 1 and Figure 1-I. Those not meeting inclusion criteria outlined in Table 1 were considered to be false positive rectal cancer pathology text-search algorithm results and were excluded from the rectal cancer cohort. Finally, we linked this cohort of rectal cancer patients to the original TOH-CRC registry to determine if any rectal cancer cases were missed [Figure 1-J]. This yielded the final cohort of patients who underwent a surgical resection for rectal cancer at TOH between 1996 and 2010 [Figure 1-K]. Sensitivity, specificity, and positive predictive value (PPV) for the text-search algorithm were calculated.

**RESULTS**

Seven hundred and twenty patients with a surgical resection for rectal cancer were identified in the TOH-CRC registry [Figure 1-A]. After manual review of patient records, 694 met study inclusion criteria [Figure 1-C]. These pathology reports were reviewed to identify keywords and phrases potentially indicating rectal cancer. Multiple iterations of the text-search algorithm were then attempted to maximize the identification of known rectal cancer cases. A total of 7 iterations of the text-search algorithm were applied to the pathology reports of the 694 known rectal cancer cases. Each text-search iteration utilized different keywords and phrases, with the best sensitivity score being 100%.

This preliminary algorithm was applied to a validation cohort of pathology reports that contained the 694 known rectal cancers, 1000 known colon cancer resections, and 1000 randomly selected noncolon, nonrectal cancer patients. A total of five iterations of the text-search algorithm modifications were created [Table 2]. Different iterations were tested to find the combination of words and phrases that maintained 100% sensitivity while maximizing specificity, producing the final rectal cancer pathology text-search algorithm. This final

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**Table 1: Inclusion and exclusion criteria for surgically treated rectal cancer patients**

| Inclusion criteria | Exclusion criteria |
|--------------------|-------------------|
| Diagnosis of rectal cancer (adenocarcinoma with distal tumor margin ≤15 cm of anal verge) | Cancer of the colon (based on pathology reports and clinical notes) |
| Age ≥18 years | Rectal cancer with palliative resection |
| Resection of rectal cancer with nonpalliative surgery between 1996 and 2010 | Pathology reports, hospitalization records, and outpatient clinic notes available |

To modify the preliminary algorithm, we identified a large sample of pathology reports for patients without rectal cancer [Figure 1-F]. First, 1000 random pathology reports were extracted from the OHDW. These included surgical specimens and biopsy results from a variety of procedures. These reports were reviewed to ensure no colon or rectal pathology was included. Then, 1000 colon cancer reports were identified using the TOH-CRC and added to this population. Finally, we added the pathology reports from the 694 rectal cancer patients identified in Figure 1-E. This resulted in a total of 2694 pathology reports on which we tested our text-search algorithm. This population of pathology reports was termed the “validation cohort.”

We linked the colorectal cancer patient database to the repository of pathology reports using patient unique identifiers and date of surgery to retrieve pathology reports for all rectal cancer cases in TOH-CRC [Figure 1-C]. These pathology reports were manually reviewed by RM to identify potential clauses and phrases that were repeated frequently that might be used in a text-search algorithm to identify pathology reports of rectal cancers [Figure 1-D]. Once identified, different iterations of these words, clauses, and phrases within the text-search macro were tested for their ability to accurately identify rectal cancer resections.

We applied these phrases to a SAS macro (SAS Institute, Cary, NC, USA) that analyzes text for clauses of interest with or without preceding or following specified qualifiers [Figure 1-E]. This SAS macro facilitates computerized text analysis of clinical reports to identify different disease processes or diagnoses within large data warehouses and has been previously described and validated for this use.[21] Search terms identified in step 1D were then applied in several iterations (i.e., using slightly different versions of the words or terms and in different order each time) to the dataset from Figure 1-C to create a text-search algorithm using terms as specific as possible while maintaining a sensitivity of at least 99% to ensure we identified essentially all surgically treated rectal cancer patients at our institution. This was termed the preliminary rectal cancer pathology text-search algorithm.

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Table 2: Second round results of text-search algorithm* development

| Iteration number | Keyphrases leading to study inclusion** | Keyphrases leading to study exclusion¹ | Sensitivity (%) | Specificity (%) |
|------------------|----------------------------------------|----------------------------------------|----------------|----------------|
| 1                | (“Rectum” or “Rectal”) AND (“Cancer” or “Malignancy”) within 20 spaces of (“Diagnosis” or “Diagnoses”) | None | 100 | 74.2 |
| 2                | (“Rectum” or “Rectal”) AND (“Cancer” or “Malignancy”) within 20 spaces of (“Diagnosis” or “Diagnoses”) | (“Colo” or “Colon”) | 62.2 | 99.6 |
| 3¹               | (“Rectum” or “Rectal”) AND (“Cancer” or “Malignancy”) within 20 spaces of (“Diagnosis” or “Diagnoses”) | (“Colo” or “Colon”) NOT within 20 spaces of (“Rectum” or “Rectal”) | 98.6 | 95.0 |
| 4                | (“Rectum” or “Rectal”) AND (“Cancer” or “Malignancy”) within 20 spaces of (“Diagnosis” or “Diagnoses”) | [“(Colo” or “Colon”) NOT within 20 spaces of (“Rectum” or “Rectal”) AND within 20 spaces of (“Diagnosis”) | 100 | 91.2 |
| 5¹               | (“Rectum” or “Rectal”) AND (“Cancer” or “Malignancy”) within 20 spaces of (“Diagnosis” or “Diagnoses”) | [“(Colo” or “Colon”) NOT within 20 spaces of (“Rectum” or “Rectal”) AND within 20 spaces of (“Specimen” or “Diagnosis”) | 100 | 98.6 |

*Algorithm development is based on a modified version of a previously described software code template called a “macro” using SAS statistical software, version 9.2 (NC, USA). **These represent key words and phrases included in the algorithm that, when identified within the pathology report, would lead to a screen-positive, and therefore, inclusion of that pathology report into the study, provided no exclusion phrases are found. ¹These represent key words and phrases that, if identified within the pathology report, lead to automatic exclusion from the study, regardless of whether or not key inclusion words/phrases are identified. Combination of key words/phrases used for the final text-search algorithm. Each iteration was performed on pathology reports from a population of 694 known rectal cancer resections performed at The Ottawa Hospital, along with 1000 known colon cancer resections, and 1000 random, noncolorectal cancer cases. Sensitivity: Calculated by dividing the number of true positives captured in the test by the total number of true positives (n=694), Specificity: Calculated by dividing the number of true negatives captured in the test by the total number of true negatives (n=2000).

Algorithm produced a screening test that was 100% sensitive and 98.6% specific [Table 2].

All pathology reports available at TOH between January 1, 1996 and December 31, 2010 were extracted from the OHDW (n = 284,032) [Figure 2-A]. The final rectal cancer pathology text-search algorithm was applied and a total of 5588 pathology reports were identified by final text-search algorithm [Figure 2-B]. The medical records associated with these pathology reports were reviewed to determine those meeting final criteria for rectal cancer [Table 1]. Of the 5588 screen-positive reports between January 1, 1996 and December 31, 2010, 4106 were excluded on the first-pass reading of the pathology reports themselves [Figure 2-C]. This left 1482 for manual chart review of medical records, which included operative reports, clinic notes, and radiology reports. This process excluded another 444 patients, leaving a total of 1038 patients who met inclusion criteria of the present study [Figure 2-D]. All 694 cases initially identified from the TOH-CRC registry were included in this final cohort of 1038 rectal cancers.

Assuming a sensitivity of 100%, the specificity of the text-search algorithm alone (i.e., not in combination with manual review of patient records) was calculated [Table 3]. This was done by labeling all reports that were excluded through manual chart review as false positive reports (i.e., reports that were positively identified by the text-search algorithm but ended up not being associated with a rectal cancer resection). A total of 5588 reports were successfully identified through text-search from 284,032 total reports. 4550 false-positive reports were excluded through manual chart review, resulting in a specificity of 98.4%. This is essentially identical to the specificity of 98.6% calculated during the testing phase of the text-search algorithm [Table 2], and resulted in a PPV of 18.6% and a negative predictive value of 100%.

**Discussion**

In the present study, we created a cohort of patients who had a surgical resection for rectal cancer through a novel text-search approach of pathology reports. When measured against a cohort of 694 known rectal cancer resections with 2000 nonrectal cancer patients, this algorithm produced a sensitivity of 100% and specificity of 98.6%. When applied to all pathology reports
Several limitations exist for our study. First and foremost is the low pretest probability for rectal cancer in our study population. Only 1038 of 284,032 total pathology reports were for rectal cancer, yielding a pretest probability of just 0.36%. This very low disease prevalence explains the low PPV of only 18.6% for a text-search algorithm with a very high sensitivity and specificity (100% and 98.4%, respectively). Therefore, this method is not a viable option for cohort identification unless it is combined with manual chart review to validate the cohort. This may limit its usefulness when applied to larger, population-based databases for which access to individual patient records is not possible or feasible. One alternative would be to adjust the algorithm so that specificity is increased at the expense of sensitivity, but this would result in a greater number of missed patients. These results are consistent with the notion that text-search methods usually increase sensitivity but lower specificity when compared to other methods of dataset creation using administrative data.[23]

A second limitation is the fact that our search was limited to pathology reports at a single institution, which may limit the generalizability of the results. For example, TOH introduced syndromic pathological reporting of rectal cancer since 2002. Syndromic reporting, with predetermined subject headings and repeating terminology, may lend itself to text-search methods with improved success. Similar methods applied to text documents that do not contain syndromic reporting may not fare as well. Similarly, the OHDW contains actual text reports for both pathology and radiology that are continually uploaded into the datawarehouse. Without this, text-search methods would be impossible. Larger, population-based databases may or may not contain the actual text necessary to carry out this method of cohort creation, thereby limiting the generalizability of the method.

Related to this limitation is the lack of external validation of our text-search algorithm. Because the text-search terms utilized in the overall algorithm were only applied to pathology reports of a single institution, they were likely over-fitted to the data at this institution. To make this algorithm generalizable to research within other institutions and datasets, it should be tested on pathology reports generated outside TOH.

Finally, as previously mentioned, the definition of rectal cancer can vary, making differentiating it from sigmoid colon cancer sometimes difficult. For the purposes of this study, we used the widely accepted definition for rectal cancer of cancer that lies within 15 cm of the anal verge.[13] However, pathology reports may or may not use this definition, focusing their diagnosis on cancer of the colon instead. Such a subtle distinction may not be relevant for other diagnoses such cancer of the breast or pancreas, making text-search methods more relevant for these other diagnoses. Therefore, the text-search method can be limited depending on the type of patient one is trying to identify administratively.

### Conclusions

The present study created and validated a cohort of all rectal cancer resections performed at TOH over a 15-year period using a novel text-search method of pathology reports combined with manual chart review. The text-search algorithm developed yielded a very high sensitivity and specificity of 100% and 98.4%, respectively. This suggests text-search of pathology reports is a viable way to identify rectal cancer patients within limited datasets such as cancer registries. However, in our study, where the denominator was greater than 600,000 hospital admissions (of varied diagnoses) we could only produce a PPV of 18.6% despite a very high specificity. This means each report positively identified by the algorithm had an 18.6% probability of having a diagnosis of rectal cancer. Therefore, in the presence of a low pretest probability for rectal cancer, text-search methods may not be relevant for other diagnoses such cancer of the breast or pancreas.

Several other studies have found that the use of text-search methods to identify surgical complications and patients with ischemic heart disease have similar or better sensitivity and specificity when compared to methods that rely on diagnostic or procedural codes.[14,22] Despite its relative success, evidence suggests that text-search methods for cohort identification and dataset creation are underutilized.[23]
probability, as is the case in large, population-based databases, text-search methods of pathology reports yield too many false positives despite a very high specificity. In these circumstances, text-search should be combined with a validation method, such as manual chart review, to be a viable approach. Alternatively, more complex text-search techniques such as natural language processing have shown potential for improved discrimination within clinical reports, which may become more relevant with the widespread adoption of electronic medical records.\[34\]

Regardless, future research should look at the possibility of utilizing text-search as a tool for cohort identification in larger, population-based administrative datasets. Validation of such methods would improve the validity of administrative data research by ensuring accurate cohort identification.

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**Conflicts of interest**
There are no conflicts of interest.

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