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Translating electronic health record-based patient safety algorithms from research to clinical practice at multiple sites

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ABSTRACT

Introduction Researchers are increasingly developing algorithms that impact patient care, but algorithms must also be implemented in practice to improve quality and safety.

Objective We worked with clinical operations personnel at two US health systems to implement algorithms to proactively identify patients without timely follow-up of abnormal test results that warrant diagnostic evaluation for colorectal or lung cancer. We summarise the steps involved and lessons learned.

Methods Twelve sites were involved across two health systems. Implementation involved extensive software documentation, frequent communication with sites and local validation of results. Additionally, we used automated edits of existing code to adapt it to sites' local contexts.

Results All sites successfully implemented the algorithms. Automated edits saved sites significant work in direct code modification. Documentation and communication of changes further aided sites in implementation.

Conclusion Patient safety algorithms developed in research projects were implemented at multiple sites to monitor for missed diagnostic opportunities. Automated algorithm translation procedures can produce more consistent results across sites.

INTRODUCTION

Health information technology shows promise for improving patient safety. Electronic health record (EHR) data are increasingly available and can prevent or detect potential patient safety events,[1] thus providing knowledge to promote safety, learning and improvement. We previously developed electronic trigger (e-trigger) tools that query EHR databases to identify potential delays in follow-up of abnormal tests.[2] Such algorithms can identify when a laboratory or radiology report suggests the need for additional testing, but appropriate follow-up has not occurred.[3]

Patient safety algorithms developed through research must be implemented in clinical practice.[4] However, there are no well-defined methods for implementation, and most studies do not make computer code available after publication,[5 6] limiting opportunities to use algorithms clinically. Sharing code would improve replication, implementation and return on investment for research funding. A typical approach to reusing computer code in different institutions is to adapt each institution's data to a common data model (CDM).[7] Still, researchers invest much effort into algorithms that do not use CDMs. We believe that another alternative may advance the field: translate code and send it to sites with a supplemental description (figure 1).

We describe how researchers collaborated with multiple clinical sites to implement two algorithms that identify patients without timely follow-up of abnormal test results, warranting evaluation for lung or colorectal cancer. We also describe lessons learnt from the process.

METHODS

Baseline algorithms

We aimed to translate existing structured query language (SQL) code developed during Veterans Affairs (VA) research to improve healthcare delivery inside and outside VA. Our prior work developed two algorithms that identify potential delayed follow-up of tests suggesting lung or colorectal cancer.[3 8] In brief, the code contains value sets for three steps: (a) retrieve records with tests (blood, stool, imaging) concerning for cancer, (b) exclude records where follow-up is unnecessary or with known causes for abnormalities, (c) exclude records with appropriate follow-up. Extending this work, the current project demonstrates successful implementation at 11 VA sites and Geisinger, a large health system in Pennsylvania. Although VA has a national database, we sent code to VA

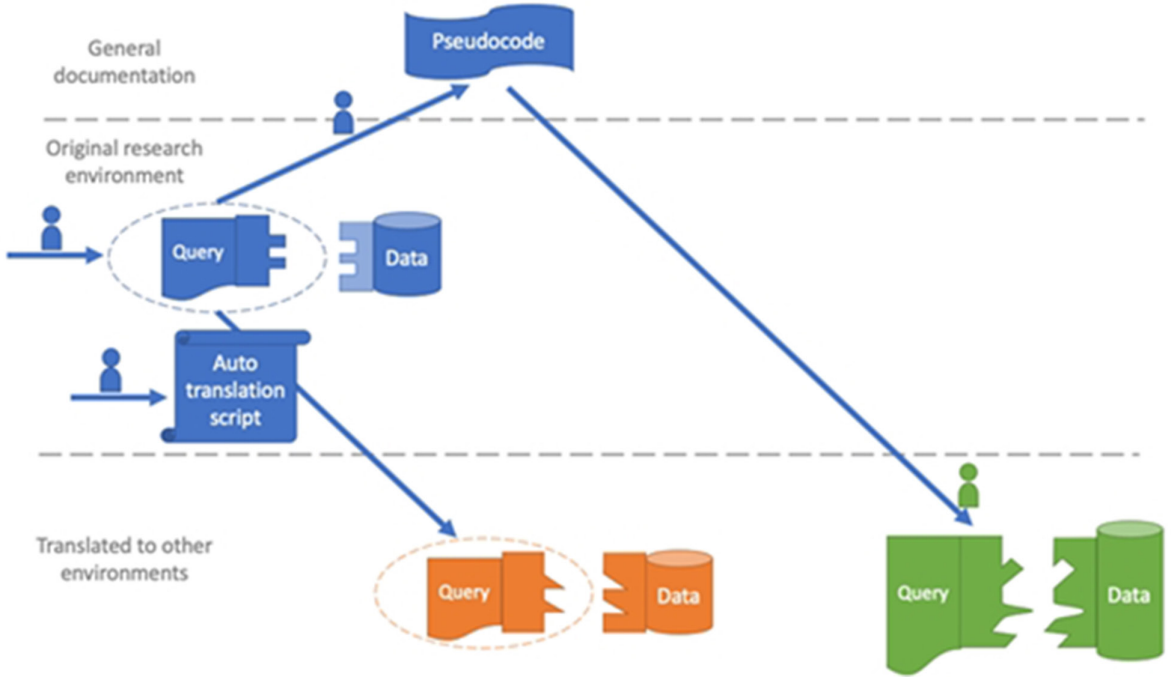

Figure 1 Workflow of code translation from the research environment to multiple operational environments. In prior work, one team member developed structured query language algorithms to retrieve potential missed cancer follow-up cases from the Veterans Affairs (VA) research data warehouse (blue). For the present study, the team developed a script to translate the algorithms automatically to the VA operational data warehouse (orange), which is structured differently. The team also created pseudocode and documentation so that the algorithms could be translated to non-VA data warehouses (green), which have very different structures from VA.

sites rather than analyse their data because each hospital knows best how to assess its safety challenges, and regulations separate research from operational data. Baylor College of Medicine and Geisinger institutional review boards approved the work (protocol H-45450).

Barriers

Translation required overcoming several barriers: (1) tables are named differently in VA operational and research databases, (2) need for ease of use for sites with varying experience, (3) VA operational database has stricter user permissions, requiring extensive changes to techniques for storing intermediate and final results and (4) need to adapt to non-VA sites.

Code translation/implementation

We wrote two Python scripts that edit SQL, automatically renaming tables using operational conventions (barriers 1 and 3). We also enhanced code usability and documentation (barriers 2 and 4). For instance, the original programmer reorganised code (eg, collecting user-defined settings together) and we drafted documentation and pseudocode (human-readable description outlining code steps to guide non-VA implementers: see online supplemental file 1). These improvements were informed by questions from sites reviewing code and documentation. Figure 1 shows a process overview. To track code and sites' requests, we stored materials on a public GitHub repository with issue tracker (https://github.com/zimolzak/instruct-project-etrigger-sql). Finally, we scheduled didactic teleconferences and hosted office hours every 1–2 weeks to answer questions.

Implementation at VA proceeded as a stepped wedge, with three cohorts, 3–4 sites per cohort, and a 3-month 'prework' phase to improve code familiarity. Geisinger implemented as a single site (e-trigger applied to all locations in the system). Site clinicians validated a sample of retrieved charts. All sites reviewed positive cases, but not all reviewed negative cases.

RESULTS

Technical

The automated script made extensive changes (30% of e-trigger code). During validation, there were 107 further code changes from 2019 to 2021. Most changes generalised to all sites (eg, expanding documentation, improving usability, improving interpretability). Site-specific changes included VA sites wishing to focus only on only one clinic among several in their city/region.

Workflow

Our centralised code adaptation saved each site from performing multiple edits (over ten large find-and-replace operations per algorithm), thus reducing work and potential errors. Estimated time saved ranges from 1 to 6 hours per site.

Outcomes

All sites successfully ran the e-triggers. Validation revealed that all cases were retrieved appropriately. False positives

fell into previously described categories,[3 8] for example, patients declining follow-up. We observed a trend towards more outside cancer care at Geisinger (eg, initial cancer diagnosis made elsewhere, before first Geisinger visit).

Support

From November 2019 to February 2022, we logged 66 e-mail conversations among all sites (average 5.5 per site), plus estimated 1 hour live discussion per site. Topics included modifying e-trigger time frames, database errors and anomalous results (eg, zero tests found). Troubleshooting occurred predominantly over e-mail, and teleconferences focused on intensive troubleshooting. We anecdotally observed that required preparation time decreased as implementation progressed through VA cohorts, although we did not measure this directly.

DISCUSSION

We successfully translated two patient safety algorithms from research to practice in multiple clinical sites, using a new approach: large-scale automated code translation rather than the typical method using a CDM.[7] Lessons learnt include:

1. Write pseudocode with a complete value set listing for organisations with different data models.
2. Use source code control such as Git. Make code open to all sites.
3. Communicate frequently with sites receiving code.
4. Clinical personnel at each site should validate results.

Our approach is valuable when a research algorithm uses a non-standard data model; others can use the algorithm after translation to a new model. We expect centralised edits to decrease risk of errors and inconsistencies. Sending code to individual sites allows healthcare operations to benefit from our algorithms for missed tests concerning for cancer, by finding individual high-risk patients, notifying providers or measuring quality in a population. Apart from business reasons, there are scientific reasons for code sharing.[9] A paper's reviewers and readers should have access to the authors' code to replicate the study, which they likely could not do from the methods section alone. Despite the push for research code sharing, a 2019 review showed 0 of 194 studies made analysis scripts available.[5] Another showed that most studies decline to submit statistical code to a journal, or they include minimal documentation.[6] Our online supplemental file 1 description is similar to the approach of Phenotype KnowledgeBase, a resource for sharing electronic phenotypes,[10] but our code translation approach is unique, and our use of pseudocode for systems with different data structures is a strength.

Our work has several limitations. The adaptations required by our sites may not be desired by others. Second, the script that edits SQL code would have to be rewritten for other codebases. Nevertheless, the methodology of a programme automatically modifying another programme would be transferable and still save time. Third, since our focus was implementation, we did not quantify the benefit of pseudocode by assessing sites' implementation before and after pseudocode, but this could be a topic for future research.

CONCLUSIONS

We describe a strategy to efficiently translate patient safety algorithms from research to practice in multiple health systems. We also provide generalisable lessons learnt. This approach impacts the care of individual patients, increases the return on investment of research funding, and potentially impacts long-term population health.

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Contributors All authors made substantial contributions to the conception or design of the work; or the acquisition, analysis or interpretation of data for the work; drafting the work or revising it critically for important intellectual content; final approval of the version to be published; agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval Baylor College of Medicine and Geisinger institutional review boards approved the work H-45450.

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Cancer Test Result e-Trigger Manual

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Overview

This manual outlines procedures for implementing e-triggers that identify missed opportunities in follow-up of 'red flag' findings suspicious for colorectal or lung cancer. In general, each SQL file proceeds by:

1. defining the red flags that warrant additional evaluation for cancer (often labs or imaging),
2. excluding other explanations for the red flags, such as already diagnosed colon cancer, or known cause of bleeding in the upper GI tract (often based on ICD/CPT codes),
3. excluding patients for whom follow-up is not deemed necessary, and
4. excluding patients for whom appropriate follow-up was already done (e.g., lung biopsy, follow-up imaging, tumor board, usually based on stop codes and procedure codes).

As an example, the e-trigger for colorectal cancer identifies patients with positive fecal blood tests or iron deficiency anemia, and then excludes patients with any of the following: advanced age, deceased status, known colon cancer, prior colectomy, terminal illnesses or hospice care, presence of a known diagnosis that would cause bleeding in the upper GI tract rather than lower GI tract, and appropriate colonoscopy or GI referral.

- Development and Validation of Trigger Algorithms to Identify Delays in Diagnostic Evaluation of Gastroenterological Cancer. *Clin Gastroenterol Hepatol.* 2018 Jan;16(1):90-98.
- Computerized Triggers of Big Data to Detect Delays in Follow-up of Chest Imaging Results. *Chest.* 2016 Sep;150(3):613-20.
- Development and Validation of Electronic Health Record-based Triggers to Detect Delays in Follow-up of Abnormal Lung Imaging Findings. *Radiology.* 2015 Oct;277(1):81-7.
- Electronic health record-based triggers to detect potential delays in cancer diagnosis. *BMJ Qual Saf.* 2014 Jan;23(1):8-16.

How are the e-triggers designed?

The lung and colorectal e-triggers are examples of one type of e-trigger, which we call a *close the loop e-trigger*. These two e-triggers answer the question, "How do you find (in the database) patients who had a test that shows a possibility of cancer, but who have **not** had timely follow-up?"

Further details about exactly what constitutes exclusion or follow-up can be found in the e-trigger manual appendices. Non-VA sites should consult these appendices, as well as SQL code in order to reimplement the e-triggers in local SQL.

How to Apply e-Trigger Process at a VA Facility

Downloading the SQL code

1. The most recent version of the code can be downloaded from github.com/zimolzak/instruct-project-etrigger-sql where you can also find additional procedures for setting dates, and guidance about which tables to export for final reporting.
2. Before downloading, jot down or copy/paste the text in the bar near the top of GitHub, especially the **seven random-looking letters and numbers** such as "LWeiBCM Update Lung.sql ... **8c2f54a** 2 days ago." This will identify the exact version of the code you downloaded, for future reference.
3. Click on the SQL file you want above (such as `Lung.sql`).
4. Click on the grey button "Raw" near the top the page that comes up.
5. Use your browser menu to save file to disk (such as "File / Save Page As... ").

Setup

This example assumes that you want to retrieve one month worth of e-trigger counts and patient information.

1. Find the first day of the current month (e.g., if today is Feb 19, you rewind to find Feb 1).
2. Subtract two more months from that (so you get Dec 1) if you are running `Lung.sql`. Subtract *three months* if you are running `Fobt.sql`.
3. Set `sp_start` equal to that (such as `set @sp_start='2019-12-01 00:00:00'`).
4. Set `sp_end` to the end of that month (such as `set @sp_end='2019-12-31 23:59:59'`).
5. You need to set your sta3n and sta6a. You can do this by commenting/uncommenting code in lines 100–124 for `Lung.sql`, or lines 118–146 for `Fobt.sql`.
6. Done! Other variables like `fu_period` can be left as-is.

Running code

1. Start your operational access to the data warehouse via your usual method (e.g., desktop or Citrix connection to SQL Server Management Studio software). Login to a SQL server (e.g. `vhacdwa01.vha.med.va.gov`) and authenticate (using either username such as `vha01\vhabhs...` plus password, or using Windows authentication).
2. *Recommended:* Run sections of the SQL file sequentially (for example, lines 1–198 of `Fobt.sql` cover the first two `INSERT INTO` operations concerning tables that were newly created), inspecting for errors.

   Alternatively: run the query all at once, inspecting for errors.

Viewing and validating data

- To view patients with positive lung e-triggers, run the following SQL, after `Lung.sql` completes: `select * from #Lung_Sta3n528_3_Ins_U_TriggerPos`
- For lung counts, `Lung_Sta3n528_4_01_Count` should display automatically.
- To view patients with positive colorectal e-triggers, run the following SQL, after `Fobt.sql` completes: `select * from #FOBT_Sta3n528_5_Ins_U_TriggerPos`

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- For colorectal counts, `FOBT_Sta3n528_5_Ins_X_count` should display automatically.

The site personnel doing **validation** should receive the "Ins_U_TriggerPos" tables (which will contain PHI, so don't send outside your station). You may review all, or randomly select a few patients with positive e-trigger, and securely transmit last name and last 4 of SSN from these patients to the reviewer, who will validate via CPRS that the sample patients have a positive red flag inside the time period of interest.

Final note: The VA Corporate Data Warehouse releases patch updates periodically, and this might require ongoing minor changes/updates to SQL code, by each site analyst. Standard codes (CPT, ICD, ICDProc, LOINC, Stop code, etc.) tend to change every year, with addition of new codes and removal of old codes. These changes require corresponding updates in the SQL code. Important note here is that you only add new codes to the SQL; do *not* remove the old ones (this is so the e-trigger continues to capture usage of both the historical and new codes).

Further reading (relevant files/attachments)

- Reducing Missed Test Results Change Package
- `Lung.sql` code file (see GitHub)
- `Fobt.sql` code file (see GitHub)

APPENDIX: Colorectal Red Flag Criteria

1. Identify all patient records with iron deficiency anemia, defined as:

(hemoglobin (Hb) less than or equal to 11 g/dL [1] *and* mean corpuscular volume (MCV) less than or equal to 81 fL [2] *and* no ferritin greater than or equal to 100 ng/mL within 12 months before or 60 days after CBC (i.e., ferritin not checked or result < 100) [3])

OR

(a positive fecal occult blood test (FOBT) or fecal immunochemical test (FIT) [4] result)

Clinical Exclusion Criteria

2. Then exclude patients < 40 years old *or* >75 years old on test result date

3. Then exclude patients listed as deceased [5] within **60 days after** test result date
4. Then exclude patients with active colon cancer diagnosis [6] within **1 year prior to** test result date
5. Then exclude patients with colectomy [7] **any time prior to and 60 days after** test result date
6. Then exclude patients enrolled in hospice or palliative care [8] within **1 year prior to and 60 days after** test result date
7. Then exclude patients with a diagnosis of pancreatic cancer [9] *or* leukemia (except acute lymphocytic) [10] *or* liver cancer [11] *or* biliary cancer [12] *or* esophageal cancer [13] *or* gastric cancer [14] *or* brain cancer [15] *or* uterine cancer [16] *or* ovarian cancer [17] *or* peritoneal, omental, or mesenteric cancer [18] *or* myeloma [19] *or* lung, bronchus, tracheal, or mesothelial cancer diagnosis [20] within **1 year prior to and 60 days after** test result date
8. Then exclude patients with diagnosis of upper GI bleeding (hematemesis) [21] *or* ulcer of esophagus, stomach or duodenum with bleeding [22] within **6 months prior to** the test result date
9. Then exclude patients with colonoscopy [23] **within 3 years prior to** test result date
10. Then for iron deficiency anemia only, exclude patients with menorrhagia [24] *or* hematuria [25] *or* epistaxis [26] *or* uterine, cervical or vaginal bleeding [27] *or* hemoptysis [28] *or* secondary hemorrhage [29] **within 6 months prior to** test result date
11. Then for iron deficiency anemia only, exclude patients with diagnosis of pregnancy [30] **within 1 year prior to or 60 days after** test result date
12. Then for iron deficiency anemia only, exclude patients with thalassemia [31] **any time prior to or within 60 days after** test result date

Expected Follow-up Criteria

13. Then exclude patients with a completed gastroenterology visit [32] **within 60 days after** test result date
14. Then exclude patients with a colonoscopy [23] performed **within 60 days after** test result date

Footnotes (colorectal)

[1] LOINC: 718-7, 30313-1, 30350-3, 30352-9

[2] LOINC: 30428-7, 787-2

[3] LOINC: 2276-4

[4] LOINC: 50196, 14563, 14564, 14565, 38527, 38526, 57803, 7905, 56490, 56491, 59841, 57804, 2335, 29771, 57804, 59841

[5] Based on status in mortality table

[6] ICD-10 colon: C18.3, C18.4, C18.6, C18.7, C18.0, C18.1, C18.2, C18.5, C18.8, C18.9, C19, C20, C21.1, C21.0, C21.8; ICD-9: 153.xx, 154.0, 154.1, 154.8 (where 'x' is any value between 0 and 9)

[7] ICD-10 colectomy: 0DTE4ZZ, 0DTE0ZZ, 0DTE7ZZ, 0DTE8ZZ; CPT: 44150, 44151, 44155, 44156, 44157, 44158, 44202, 44210, 44211, 44212; ICD-9: 45.81, 45.82, 45.83

[8] ICD-10: Z51.5, or consult code entry for completed hospice/palliative care consult, or consult with primary stop code 351 or 353. ICD-9: V66.7

[9] ICD-10 pancreas: C25.0, C25.1, C25.2, C25.3, C25.4, C25.7, C25.8, C25.9; ICD-9: 157.xx

[10] ICD-10 leukemia: C92.00, C92.4, C92.5, C92.60, C92.01, C92.41, C92.51, C92.02, C92.42, C92.52, C93.00, C93.01, C93.02, C94.00, C94.01, C94.02, C94.20, C94.21, C94.22, C95.00, C95.01, C95.02; ICD-9: 205.0, 206.0, 207.0, 207.2x, 208.0

[11] ICD-10 liver: C22.0, C22.2, C22.3, C22.4, C22.7, C22.8, C22.1, C22.9, C78.7; ICD-9: 155.0, 155.1, 155.2, 197.7

[12] ICD-10 biliary: C23, C24, C24.1, C24.8, C24.9; ICD-9: 156.xx

[13] ICD-10 esophagus: C15.3, C15.4, C15.5, C15.8, C15.9; ICD-9: 150.xx

[14] ICD-10 gastric: C16.0, C16.1, C16.2, C16.3, C16.4, C16.5, C16.6, C16.8, C16.9; ICD-9: 151.xx

[15] ICD-10 brain: C71.0, C71.1, C71.2, C71.3, C71.4, C71.5, C71.6, C71.7, C71.8, C71.9, C79.31, C79.32, C79.49; ICD-9: 191.x, 198.3, 198.4

[16] ICD-10 uterus: C55; ICD-9: 179.xx

[17] ICD-10 ovary: C56.9, C56.1, C56.2; ICD-9: 183.0

[18] ICD-10 peritoneum: C48.1, C45.1, C48.8, C48.2, C78.6; ICD-9: 158.8, 158.9, 197.6

[19] ICD-10 myeloma: C90.00, C90.01, C90.02, D47.Z9; ICD-9: 203.0x, 238.6

[20] ICD-10 lung: C34.0 to C34.3, C34.8, C34.9, C78.00, C78.01, C78.02; ICD-9: 162.0, 162.2x, 162.3x, 162.4x, 162.5x, 162.8x, 162.9x, 163.xx, 197.0, 197.2, 197.3 (where 'x' is any value)

[21] ICD-10 hematemesis: K92.0, K22.11; ICD-9: 578.0

[22] ICD-10 ulcer: K25.0, K25.1, K25.2, K25.4, K25.6, K26.0, K26.2, K26.4, K26.6, K27.0, K27.2, K27.4, K27.6, K28.0, K28.2, K28.4, K28.6, I85.01, I85.11; ICD-9: 530.21, 531.0x, 531.2x, 531.4x, 531.6x, 532.0x, 532.2x, 532.4x, 532.6x, 533.0x, 533.2x, 533.4x, 533.6x, 534.0x, 534.2x, 534.4x, 534.6x

[23] CPT scope: 44387, 44388, 44389, 44391, 44392, 44394, 45378, 45379, 45380, 45381, 45382, 45383, 45384, 45385, 45386, 45387, 45355, 45391, 45392; ICD-10: 0DJD8ZZ

[24] ICD-10 menorrhagia: N92.0, N92.1, N92.4, N95.0; ICD-9: 626.2, 626.6, 627.0, 627.1

[25] ICD-10 hematuria: R31.9, R31.0, R31.1, R31.2; ICD-9: 599.7x

[26] ICD-10 epistaxis: R04.0; ICD-9: 784.7

[27] ICD-10 uterine: N89.8, N92.5, N93.8; ICD-9: 623.8, 626.8

[28] ICD-10 hemoptysis: R04.2, R04.9, R04.89; ICD-9: 786.3x

[29] ICD-10 secondary: T79.2XXA; ICD-9: 958.2

[30] ICD-10 pregnancy: Z34.00, Z34.80, Z34.90, Z33.1, O09.00, O09.10, O09.291, O09.40, O09.211, O09.30, O09.511, O09.521, O09.611, O09.621, O09.891, O09.892, O09.893, O09.899, O09.90, O09.91, O09.92, O09.93, O00.0, O00.1, O00.2, O00.8, O00.9; ICD-9: 629.81, 631.0, 633.0, 633.01, 633.10, 633.2x, 633.8x, 633.9x, V22.0, V22.1, V22.2, V23.0, V23.1, V23.2, V23.3, V23.41, V23.49, V23.5, V23.7, V23.81, V23.82, V23.83, V23.84, V23.89, V23.9

[31] ICD-10 thalassemia: D56.9, D57.40, D57.419, D56.0, D56.1, D56.2, D56.3, D56.5, D56.8; ICD-9: 282.4x

[32] Based on VA clinic stop code 33, 307, 321, or clinical note title entry for completed GI consult

APPENDIX: Lung Red Flag Criteria

1. Identify all patient records with abnormal chest X-Ray or CT result flagged by radiologist as "suspicious for malignancy" [1]

Clinical Exclusion Criteria

2. Then exclude patients < 18 years old on imaging result date
3. Then exclude patients listed as deceased [2] within **30 days after** imaging result date
4. Then exclude patients with active lung cancer diagnosis [3] within **1 year prior to** imaging result date

5. Then exclude patients with tuberculosis diagnosis [4] within **1 year prior to** and **30 days after** imaging result date
6. Then exclude patients enrolled in hospice or palliative care [5] within **1 year prior to** and **30 days after** imaging result date
7. Then exclude patients with a diagnosis of pancreatic cancer [6] *or* leukemia (except acute lymphocytic) [7] *or* liver cancer [8] *or* biliary cancer [9] *or* esophageal cancer [10] *or* gastric cancer [11] *or* brain cancer [12] *or* uterine cancer [13] *or* ovarian cancer [14] *or* peritoneal, omental, or mesenteric cancer [15] *or* myeloma [16] *or* tracheal cancer diagnosis [17] within **1 year prior to** and **30 days after** imaging result date

Expected Follow-up Criteria

8. Then exclude patients with a repeated chest x-ray or CT [1] **within 30 days after** imaging result date
9. Then exclude patients with a completed PET scan [18] **within 30 days after** imaging result date
10. Then exclude patients with a repeated pulmonary visit [19] **within 30 days after** imaging result date
11. Then exclude patients with a completed thoracic surgery visit [20] **within 30 days after** imaging result date
12. Then exclude patients with a completed multidisciplinary tumor board conference [21] **within 30 days after** imaging result date
13. Then exclude patients with a lung biopsy [22] performed **within 30 days after** imaging result date
14. Then exclude patients with a bronchoscopy [23] performed **within 30 days after** imaging result date
15. Then exclude patients with a lung surgery [24] performed **within 30 days after** imaging result date

Footnotes (lung)

[1] CPT: X-Ray (71010, 71015, 71020, 71021, 71022, 71030, 71035, 71101, 71111); CT (71275, 71250, 71270, 71260)

[2] Based on status in mortality table

[3] ICD-10 lung: C34.00, C34.01, C34.02, C34.10, C34.11, C34.12, C34.2, C34.30, C34.31, C34.32, C34.80, C34.81, C34.82, C34.90, C34.91, C34.92, C78.00, C78.01,

C78.02, C38.4, C45.0, C78.2; ICD-9: 162.2x, 162.3x, 162.4x, 162.5x, 162.8x, 162.9x, 197.0, 163.xx, 197.2 (where 'x' is any value)

[4] ICD-10 tuberculosis: A15.0, A15.5, A15.6, A15.7; ICD-9: 010.0x, 010.1x, 010.8x, 010.9x, 011.0x, 011.1x, 011.2x, 011.3x, 011.4x, 011.5x, 011.6x, 011.7x, 011.8x, 011.9x (where 'x' is any value between 1 and 6)

[5] ICD-10: Z51.5, or consult code entry for completed hospice/palliative care consult, or consult with primary stop code 351 or 353. ICD-9: V66.7

[6] ICD-10 pancreatic: C25.0, C25.1, C25.2, C25.3, C25.4, C25.7, C25.8, C25.9; ICD-9: 157.xx

[7] ICD-10 leukemia: C92.00, C92.4, C92.5, C92.60, C92.01, C92.41, C92.51, C92.02, C92.42, C92.52, C93.00, C93.01, C93.02, C94.00, C94.01, C94.02, C94.20, C94.21, C94.22, C95.00, C95.01, C95.02; ICD-9: 205.0, 206.0, 207.0, 207.2x, or 208.0

[8] ICD-10 liver: C22.0, C22.2, C22.3, C22.4, C22.7, C22.8, C22.1, C22.9, C78.7; ICD-9: 155.0, 155.1, 155.2, or 197.7

[9] ICD-10 biliary: C23, C24, C24.1, C24.8, C24.9; ICD-9: 156.xx

[10] ICD-10 esophageal: C15.3, C15.4, C15.5, C15.8, C15.9; ICD-9: 150.xx

[11] ICD-10 gastric: C16.0, C16.1, C16.2, C16.3, C16.4, C16.5, C16.6, C16.8, C16.9; ICD-9: 151.xx

[12] ICD-10 brain: C71.0, C71.1, C71.2, C71.3, C71.4, C71.5, C71.6, C71.7, C71.8, C71.9, C79.31, C79.32, C79.49; ICD-9: 191.x, 198.3, or 198.4

[13] ICD-10 uterine: C55; ICD-9: 179.xx

[14] ICD-10 ovarian: C56.9, C56.1, C56.2; ICD-9: 183.0

[15] ICD-10 peritoneal: C48.1, C45.1, C48.8, C48.2, C78.6; ICD-9: 158.8, 158.9, or 197.6

[16] ICD-10 myeloma: C90.00, C90.01, C90.02, D47.Z9; ICD-9: 203.0x, or 238.6

[17] ICD-10 tracheal: C33, C78.39; ICD-9: 162.0, 197.3

[18] CPT: 78811, 78812, 78813, 78814, 78815, 78816, 78810, G0125, G0126, G0210, G0211, G0212, G0213;

[19] Based on VA clinic stop code 312, 104, or clinical note title entry for a completed pulmonary consult

[20] Based on VA clinic stop code 413, 64, or clinical note title entry for a completed thoracic surgery consult

[21] Based on VA clinic stop code 316, or clinical note title entry for a completed tumor board conference consult

[22] **CPT biopsy:** 3162x (where 'x' is any value between 5 and 9), 31633, 31640, 31717, 32400, 32402, 32405, 32098, 32601, 32607, 32608, 32609. **ICD-10 lung biopsy:** 0B9C3ZX, 0B9C4ZX, 0B9C7ZX, 0B9D3ZX, 0B9D4ZX, 0B9D7ZX, 0B9F3ZX, 0B9F4ZX, 0B9F7ZX, 0B9G3ZX, 0B9G4ZX, 0B9G7ZX, 0B9H3ZX, 0B9H4ZX, 0B9H7ZX, 0B9J3ZX, 0B9J4ZX, 0B9J7ZX, 0B9K3ZX, 0B9K4ZX, 0B9K7ZX, 0B9L3ZX, 0B9L4ZX, 0B9L7ZX, 0B9M3ZX, 0B9M4ZX, 0B9M7ZX, 0BBC3ZX, 0BBD3ZX, 0BBF3ZX, 0BBG3ZX, 0BBH3ZX, 0BBJ3ZX, 0BBK3ZX, 0BBL3ZX, 0BBM3ZX, 0B9K8ZX, 0B9L8ZX, 0B9M8ZX, 0BBK7ZX, 0BBK8ZX, 0BBL7ZX, 0BBL8ZX, 0BBM4ZX, 0BBM7ZX, 0BBM8ZX, 0B9K0ZX, 0B9L0ZX, 0B9M0ZX, 0BBK0ZX, 0BBL0ZX, 0BBM0ZX. **ICD-10 bronchus biopsy:** 0B933ZX, 0B934ZX, 0B937ZX, 0B938ZX, 0B943ZX, 0B944ZX, 0B947ZX, 0B948ZX, 0B953ZX, 0B954ZX, 0B957ZX, 0B958ZX, 0B963ZX, 0B964ZX, 0B967ZX, 0B968ZX, 0B973ZX, 0B974ZX, 0B977ZX, 0B978ZX, 0B983ZX, 0B984ZX, 0B987ZX, 0B988ZX, 0B993ZX, 0B994ZX, 0B997ZX, 0B998ZX, 0B9B3ZX, 0B9B4ZX, 0B9B7ZX, 0B9B8ZX, 0BB33ZX, 0BB34ZX, 0BB37ZX, 0BB38ZX, 0BB43ZX, 0BB44ZX, 0BB47ZX, 0BB48ZX, 0BB53ZX, 0BB54ZX, 0BB57ZX, 0BB58ZX, 0BB63ZX, 0BB64ZX, 0BB67ZX, 0BB68ZX, 0BB73ZX, 0BB74ZX, 0BB77ZX, 0BB78ZX, 0BB83ZX, 0BB84ZX, 0BB87ZX, 0BB88ZX, 0BB93ZX, 0BB94ZX, 0BB97ZX, 0BB98ZX, 0BBB3ZX, 0BBB4ZX, 0BBB7ZX, 0BBB8ZX, 0B930ZX, 0B940ZX, 0B950ZX, 0B960ZX, 0B970ZX, 0B980ZX, 0B990ZX, 0B9B0ZX, 0BB30ZX, 0BB40ZX, 0BB50ZX, 0BB60ZX, 0BB70ZX, 0BB80ZX, 0BB90ZX, 0BBB0ZX. **ICD-10 pleural biopsy:** 0BBC4ZX, 0BBD4ZX, 0BBF4ZX, 0BBG4ZX, 0BBH4ZX, 0BBJ4ZX, 0BBK4ZX, 0BBL4ZX, 0B9N0ZX, 0B9N3ZX, 0B9N4ZX, 0B9P0ZX, 0B9P3ZX, 0B9P4ZX, 0BBN0ZX, 0BBN3ZX, 0BBP0ZX, 0BBP3ZX, 0W990ZX, 0W993ZX, 0W994ZX, 0W9B0ZX, 0W9B3ZX, 0W9B4ZX. **ICD-10 chest biopsy:** 0W980ZX, 0W983ZX, 0W984ZX, 0WB80ZX, 0WB83ZX, 0WB84ZX, 0WB8XZX. **ICD-10 mediastinum biopsy:** 0W9C3ZX, 0W9C4ZX, 0WBC3ZX, 0WBC4ZX. **ICD-9:** 33.24, 33.25, 33.26, 33.27, 33.28 (where 'x' is any value between 4 and 8), 34.20, 34.23, 34.24, 34.25.

[23] **CPT bronchoscopy:** 3162x (where 'x' is any value between 1 and 4), 3163x (where 'x' is any value between 0 and 8), 31641, 31643, 31645, 31646, 31647, 31648, 31649, 31650, 31651, 31656, 31659, 31660, 31661, 31725, 32035. **ICD-10:** 0BBN4ZX, 0BBP4ZX, 0BJ08ZZ, 0WJQ4ZZ, 0WJC4ZZ, 0BJ08ZZ, 0BJK8ZZ, 0BJL8ZZ. **ICD-9:** 33.20, 33.21, 33.22, 33.23.

[24] **CPT surgery:** 32036, 32095, 32096, 32097, 32100, 32120, 32140, 32141, 32150, 32200, 32201, 32310, 32315, 32320, 32440, 32442, 32445, 32450, 32480, 32482, 32484, 32485, 32486, 32488, 32490, 32491, 32500, 32503, 32504, 32505, 32520, 32522, 32525, 32540, 32545, 32656, 32657, 32663, 32666, 32667, 32668, 32669, 32670, 32671, 32672, 32700, 32705. **ICD-10 ablation:** 0B5K0ZZ, 0B5L0ZZ, 0B5M0ZZ, 0B5K3ZZ, 0B5L3ZZ, 0B5M3ZZ, 0B5K4ZZ, 0B5L4ZZ, 0B5M4ZZ, 0B5K7ZZ, 0B5K8ZZ, 0B5L7ZZ, 0B5L8ZZ, 0B5M7ZZ, 0B5M8ZZ. **ICD-10 resection:** 0B5K8ZZ, 0B5L8ZZ, 0B5M8ZZ, 0BBK8ZZ, 0BBL8ZZ, 0BBM4ZZ, 0BBM8ZZ. **ICD-10 lobectomy:** 0BTC4ZZ, 0BTD4ZZ, 0BTF4ZZ, 0BTG4ZZ, 0BTJ4ZZ, 0BTC0ZZ, 0BTD0ZZ, 0BTF0ZZ, 0BTG0ZZ, 0BTJ0ZZ.

ICD-10 thoracotomy: 02JA0ZZ, 0WJC0ZZ. **ICD-10 thoracoscopy:** 0BJ04ZZ, 0WJQ4ZZ. **ICD-10 excision:** 0BBK4ZZ, 0BBL4ZZ, 0B5K0ZZ, 0B5K3ZZ, 0B5K7ZZ, 0B5L0ZZ, 0B5L3ZZ, 0B5L7ZZ, 0B5M0ZZ, 0B5M3ZZ, 0B5M7ZZ, 0BBK0ZZ, 0BBK3ZZ, 0BBK7ZZ, 0BBL0ZZ, 0BBL3ZZ, 0BBL7ZZ, 0BBM0ZZ, 0BBM3ZZ, 0BBM7ZZ, 0BBC4ZZ, 0BBD4ZZ, 0BBF4ZZ, 0BBG4ZZ, 0BBH4ZZ, 0BBJ4ZZ, 0BBK4ZZ, 0BBL4ZZ, 0BTH4ZZ, 0BBK0ZZ, 0BBK3ZZ, 0BBK7ZZ, 0BBL0ZZ, 0BBL3ZZ, 0BBL7ZZ. **ICD-10 pneumonectomy:** 0BTK4ZZ, 0BTL4ZZ, 0BTM4ZZ. 0BTK0ZZ, 0BTL0ZZ, 0BTM0ZZ. **ICD-10 bronchus excision:** 0B534ZZ, 0B538ZZ, 0B544ZZ, 0B548ZZ, 0B554ZZ, 0B558ZZ, 0B564ZZ, 0B568ZZ, 0B574ZZ, 0B578ZZ, 0B584ZZ, 0B588ZZ, 0B594ZZ, 0B598ZZ, 0B5B4ZZ, 0B5B8ZZ, 0BB34ZZ, 0BB38ZZ, 0BB44ZZ, 0BB48ZZ, 0BB54ZZ, 0BB58ZZ, 0BB64ZZ, 0BB68ZZ, 0BB74ZZ, 0BB78ZZ, 0BB84ZZ, 0BB88ZZ, 0BB94ZZ, 0BB98ZZ, 0BBB4ZZ, 0BBB8ZZ, 0B530ZZ, 0B533ZZ, 0B537ZZ, 0B540ZZ, 0B543ZZ, 0B547ZZ, 0B550ZZ, 0B553ZZ, 0B557ZZ, 0B560ZZ, 0B563ZZ, 0B567ZZ, 0B570ZZ, 0B573ZZ, 0B577ZZ, 0B580ZZ, 0B583ZZ, 0B587ZZ, 0B590ZZ, 0B593ZZ, 0B597ZZ, 0B5B0ZZ, 0B5B3ZZ, 0B5B7ZZ, 0BB30ZZ, 0BB33ZZ, 0BB37ZZ, 0BB40ZZ, 0BB43ZZ, 0BB47ZZ, 0BB50ZZ, 0BB53ZZ, 0BB57ZZ, 0BB60ZZ, 0BB63ZZ, 0BB67ZZ, 0BB70ZZ, 0BB73ZZ, 0BB77ZZ, 0BB80ZZ, 0BB83ZZ, 0BB87ZZ, 0BB90ZZ, 0BB93ZZ, 0BB97ZZ, 0BBB0ZZ, 0BBB3ZZ, 0BBB7ZZ, 0BT30ZZ, 0BT34ZZ, 0BT40ZZ, 0BT44ZZ, 0BT50ZZ, 0BT54ZZ, 0BT60ZZ, 0BT64ZZ, 0BT70ZZ, 0BT74ZZ, 0BT80ZZ, 0BT84ZZ, 0BT90ZZ, 0BT94ZZ, 0BTB0ZZ. **ICD-9:** 32.0, 32.01, 32.09, 32.1, 32.20, 32.23, 32.34, 32.25, 32.26, 32.28, 32.29, 32.3, 32.39, 32.4, 32.41, 32.49, 34.02, 34.21, 32.5, 32.59.