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Single-Center Experience Implementing the LOINC-RSNA Radiology Playbook for Adult Abdomen/Pelvis CT and MR Procedures Using a Semi-Automated Method

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Abstract The LOINC-RSNA Radiology Playbook represents the future direction of standardization for radiology procedure names. We developed a software solution ("RadMatch") utilizing Python 2.7 and FuzzyWuzzy, an open-source fuzzy string matching algorithm created by SeatGeek, to implement the LOINC-RSNA Radiology Playbook for adult abdomen and pelvis CT and MR procedures performed at our institution. Execution of this semi-automated method resulted in the assignment of appropriate LOINC numbers to 86% of local CT procedures. For local MR procedures, appropriate LOINC numbers were assigned to 75% of these procedures whereas 12.5% of local MR procedures could only be partially mapped. For the standardized local procedures, only 63% of CT and 71% of MR procedures had corresponding RadLex Playbook identifier (RPID) codes in the LOINC-RSNA Radiology Playbook, which limited the utility of RPID codes. RadMatch is a semi-automated open-source software tool that can assist radiology departments seeking to standardize their radiology procedures via implementation of the LOINC-RSNA Radiology Playbook.

Keywords RSNA · Playbook · LOINC · Python

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Background

The RadLex Playbook represents the effort of the Radiological Society of North America (RSNA) to formally standardize the terminology used for radiology procedures, which can improve workflow within healthcare organizations. Through this effort, the RSNA created unique numerical identifiers for each procedure known as RadLex Playbook Identifiers (RPIDs). These codes may contain information concerning modality, body region, contrast use, anatomic focus, laterality, reason for exam, technique, and view. Each procedure name has short and long forms as well as corresponding RPID number and letter codes. For example, RPID2 is linked to letter code CTABCA, which corresponds to short name "CT Abd Angio w/wo" and long name "CT Abdomen Angio w and wo IV Contrast" [1]. The RadLex Playbook is available in two versions: Core Playbook and Complete Playbook. Core Playbook contains over 1000 codes pertaining to a single large academic center. Complete Playbook contains over 4000 codes and represents a superset of the Core Playbook, though some of these codes are deprecated or discouraged. Subsequent updates to the RadLex Playbook have preferentially focused on Core Playbook with the RSNA recommending its use over Complete Playbook for new site implementations [1]. A similar but broader effort within healthcare has been carried out by the Regenstrief Institute, which developed Logical Observations, Identifiers, and Numerical Codes (LOINC). This standardized lexicon of tests in medicine contains a radiology section. To this end, the RSNA began a collaboration with Regenstrief Institute to integrate their separate efforts and create the definitive source for standardized radiology procedure names. This collaboration has culminated in the release of the LOINC-RSNA Radiology Playbook. While previous publications have analyzed RadLex and LOINC as distinct entities, the LOINC-RSNA Radiology Playbook has not yet been studied as a single source for

radiology procedure names [2, 3]. The LOINC-RSNA Radiology Playbook csv file contains the standardized radiology procedure LOINC names with unique LOINC numbers as well as corresponding Core Playbook RPID codes, if available. Associated attributes that are specified for each procedure include modality, anatomic location, view, timing, maneuver, pharmaceutical, reason for exam, guide and subject [4]. Manually implementing this tool requires matching procedure names between large csv files with thousands of entries, which can be both time and labor intensive. LOINC has previously published RELMA, a software solution to assist in LOINC code mapping. However, RELMA does not adequately incorporate the LOINC-RSNA Playbook (e.g., RPID codes are not available in RELMA) [5]. Therefore, we aimed to create a custom software solution that would streamline implementation of the LOINC-RSNA Radiology Playbook.

Methods

This study was performed at an academic radiology department at a large tertiary care center in New York, NY. All currently performed diagnostic radiology procedures pertaining to adult abdomen and/or pelvis CT and MRI were selected for LOINC-RSNA Radiology Playbook implementation.

Using Python 2.7, a custom script utilizing FuzzyWuzzy was created to facilitate radiology procedure name matching. FuzzyWuzzy is an open-source fuzzy string matching algorithm created by SeatGeek, which uses the Levenshtein distance (also known as edit distance) to compare two strings. The edit distance is determined by the number of edits necessary to transform one string into the other string. The FuzzyWuzzy algorithm quantifies this difference by outputting a ratio between 0 and 1, with 1 indicating a perfect match. Additionally, a token sort function can be executed before calculating the edit distance, which achieves comparison of strings irrespective of word order. This is accomplished by breaking up strings into tokens that are then sorted in alphabetical order and rejoined before edit disease calculation [6, 7]. For our Python script, the LOINC-RSNA Radiology Playbook csv file version 2.56 as well as a csv file containing the local procedure names served as inputs (Fig. 1). The output was a new csv file detailing the fuzzy matching score (token sort ratio), LOINC name, LOINC number, and associated RPID code (if available) for each local procedure (Fig. 2). The script reads through the local exam name input csv file and catalogs these names in a list. When the user executes the script, it prompts the user to select the applicable modalities and body regions of interest from the standardized options in the LOINC-RSNA Radiology Playbook (Figs. 3 and 4) since this information improves the performance of RadMatch. The

script then uses these selections to search through the input LOINC-RSNA Radiology Playbook to identify entries pertaining to these selections and saves them to a dictionary. Next, a for loop goes through each local exam name in the list and formats common synonyms by replacing them with the LOINC preferred terms using regular expressions (re module). Extraneous terms are also removed at this step (ex. "PROTOCOL"). Next, a for loop cycles through the dictionary containing LOINC-RSNA Radiology Playbook entries pertaining to the user's selection of modality and body region of interest. At this point, the entire local exam list is run against each individual LOINC-RSNA Radiology Playbook procedure of interest using the FuzzyWuzzy string matching algorithm. Each fuzzy matching attempt is appended to a list along with the token sort ratio. For each local exam name, the list of possible matches is reverse sorted by token sort ratio. Then, the local exam name followed by the top five results (containing the token sort ratio, LOINC name, LOINC number, and RPID code) are appended to the output csv file. Each output csv file containing the match results was reviewed independently by two radiologists. For each local procedure, a match was assigned by each radiologist with a score (0 = no match, 0.5 = partial match, 1 = complete match with highest token sort ratio, 2 = complete match with second highest token sort ratio, 3 = complete match with third highest token sort ratio, 4 = complete match with fourth highest token sort ratio, 5 = complete match with fifth highest token sort ratio). For each procedure name, manual matching was constrained to the five choices generated by RadMatch. Procedures were matched with respect to exam type and contrast use. If a direct match was not available, then the procedure was matched to an appropriate parent procedure (such as those not specifying contrast use). Procedures were not matched to parent procedures that did not address differences in technique if these differences were explicitly stated in their names, with particular attention paid to post-contrast phases. Procedures with explicitly stated differences in the phases acquired were considered separate procedures requiring unique identifiers. If there was more than one appropriate match, the average of the scores was reported and used for statistical analysis. The matches were then compared. Statistical analysis was performed with Microsoft Excel version 15.11.2.

RadMatch Python 2.7 script:

Results

29 CT and 24 MR local procedures pertaining to examination of the adult abdomen and/or pelvis were selected for LOINC-RSNA Radiology Playbook implementation (Tables 1 and 2). 4/29 (14%) CT and 3/24 (12.5%) MR local procedures yielded no match (score 0) in the LOINC-RSNA Radiology Playbook

```
# Import fuzzywuzzy
from fuzzywuzzy import fuzz
from fuzzywuzzy import process

# Import csv module
import csv

# Import regular expressions module
import re

# Import easygui
import easygui

# Input csv files should be placed in the same folder as this python file
# Get local procedure input csv file name from user using easygui
local_procedure_msg = "Enter title of csv file containing procedure names to be matched in LOINC-RSNA PLAYBOOK (ex. procedures.csv)"
local_procedure_title = "LOCAL PROCEDURES CSV FILE NAME"
filename_local_procedure = easygui.enterbox(local_procedure_msg, local_procedure_title)

# Default name of the LOINC-Playbook csv file, user must modify this if the default name is changed!
filename_loinc = "LoincRsnaRadiologyPlaybook.csv"

# Have user select output csv file name using easygui
output_msg = "Enter desired title for output csv file containing match results (ex. results.csv)"
output_title = "OUTPUT CSV FILE NAME"
writefile = easygui.enterbox(output_msg, output_title)

# Create list to store local procedure names
local_procedure_list = []

# Create dictionary to store LOINC-Playbook procedures
loinc_dict = {}

# User selects modality from LOINC options
modality_msg = "Please select 1 modality in LOINC-RSNA PLAYBOOK for matching."
modality_title = "SELECT MODALITY"
modality_choices = ["CT", "MR", "US", "NM", "PT", "XR", "MG", "DXA", "RF", "RP"]
modality = easygui.choicebox(modality_msg, modality_title, modality_choices)

# User selects body region from LOINC options
body_region_msg = "Please select 1 body region in LOINC-RSNA PLAYBOOK for matching. \n(Otherwise you may decrease the accuracy of the match results)"
body_region_title = "SELECT BODY REGION"
body_region_choices = ["Head", "Neck", "Chest", "Breast", "Abdomen", "Pelvis", "Extremity", "Upper extremity", "Lower extremity", "Whole body", "Unspecified"]
body_region = easygui.multchoicebox(body_region_msg, body_region_title, body_region_choices)

# Open and read through local procedure csv file
with open(filename_local_procedure) as f_obj_local_procedure_list:
            reader_local_procedure_list = csv.reader(f_obj_local_procedure_list)

        for row_local_procedure_list in reader_local_procedure_list:

                # Store local procedure names in list
                local_procedure_list.append(row_local_procedure_list[0])

# Open and read through LOINC-RSNA Playbook csv file
with open(filename_loinc) as f_obj_loinc_dict:
            reader_loinc_dict = csv.reader(f_obj_loinc_dict)

        for row_loinc_dict in reader_loinc_dict:

                # Only include procedures in body region of interest specified by column 5 PartName in LOINC-RSNA Playbook
                for body_region_selection in body_region:
                    if row_loinc_dict[4] == body_region_selection:

                        # key is LOINC name, values are LOINC number and RPID
                        loinc_dict[row_loinc_dict[1]] = [row_loinc_dict[0], row_loinc_dict[8]]
```

```
# Create list to store fuzzy matches
fuzz_list = []

# Loop through each local procedure name
for local_procedure in local_procedure_list:

        # Capitalize all letters in all local procedure names to facilitate comparision
        local_procedure = local_procedure.upper()

        # Partial string replacement to standardize contrast terms with respect to LOINC to improve fuzzy matching
        local_procedure = local_procedure.replace("+", "AND")
        local_procedure = local_procedure.replace("WITHOUT", "WO")
        local_procedure = local_procedure.replace("WITH", "W")
        local_procedure = re.sub(r"\bCON\b", "CONTRAST", local_procedure)

        # Account for preferred synonyms in LOINC
        local_procedure = local_procedure.replace("CTA", "CT ANGIOGRAM")
        local_procedure = local_procedure.replace("MRA", "MR ANGIOGRAM")
        local_procedure = local_procedure.replace("RENAL", "KIDNEY")
        local_procedure = local_procedure.replace("ENTEROGRAPHY", "SMALL BOWEL")
        local_procedure = local_procedure.replace("UROGRAM", "KIDNEY AND URETER AND URINARY BLADDER")
        local_procedure = local_procedure.replace("MRCP", "ABDOMEN MRCP")
        local_procedure = re.sub(r"\bANGIOGRA\w..", "VESSELS ANGIOGRAM", local_procedure)
        local_procedure = re.sub(r"\bVENOGRA\w..", "VEINS ANGIOGRAM", local_procedure)

        # Remove extraneous terms to improve fuzzy matching
        local_procedure = local_procedure.replace("PROTOCOL", " ")

        # Loop through each LOINC-RSNA Playbook procedure
        for loinc_name, idnum in loinc_dict.items():

                # Capitalize all letters in all LOINC-RSNA Playbook procedure names to faciltate comparision
                loinc_name = loinc_name.upper()

                # Account for lack of modality specification in name for SPECT procedures in LOINC-RSNA Playbook prior to modality selection

                loinc_name = loinc_name.replace("SPECT", "SPECT NM")

                # Select modality via LOINC-RSNA Playbook procedure name using regular expressions
                modality_regex = r"\b" + re.escape(modality) + r"."
                if re.search(modality_regex, loinc_name):

                        # Utilize fuzzywuzzy for fuzzy matching. Generate token sort ratio and store this value in variable wuzzy
                        wuzzy = fuzz.token_sort_ratio(local_procedure, loinc_name)

                        # Add token sort ratio, LOINC-RSNA Playbook procedure name, LOINC number, RPID to fuzz_list
                        holder = (wuzzy, loinc_name, idnum[0], idnum[1])
                        fuzz_list.append(holder)

        # Sort fuzz list to identify token sort ratios in descending order
        fuzz_list.sort(reverse=True)

        # Store local procedure names as list to write to csv
        local_procedure_list = [local_procedure]

        # Open and append output csv file
        with open(writefile, "a") as f:
                        writer = csv.writer(f)
                        writer.writerow(local_procedure_list)

                        # List top 5 fuzzy matches for each local procedure
                        writer.writerow(fuzz_list[0])
                        writer.writerow(fuzz_list[1])
                        writer.writerow(fuzz_list[2])
                        writer.writerow(fuzz_list[3])
                        writer.writerow(fuzz_list[4])

        # Clear list for next local procedure
        del fuzz_list[:]
```
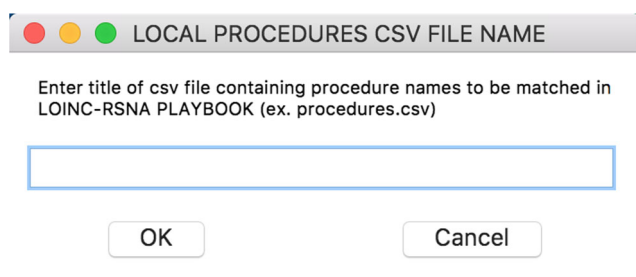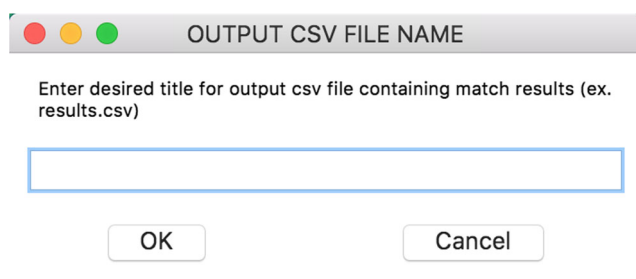
Fig. 1 First prompt for user input after executing the Python script

Fig. 2 Second prompt for user input

(Figs. 5 and 6). 0/29 (0%) CT and 3/24 (12.5%) MR local procedures had only a partial match (score 0.5). 25/29 (86%) CT and 18/24 (75%) MR local procedures had a complete match (scores 1–5). There was 100% agreement between the two radiologists.

Discussion

RadMatch successfully assisted radiologists in implementing the LOINC-RSNA Radiology Playbook for local CT and MR procedures pertaining to the abdomen and/or pelvis in adult patients. For CT procedures, a complete match was identified

in 25/29 (86%) of cases. For MR procedures, a complete match was identified in 18/24 cases (75%) of cases. For those cases in which a complete match was not found, multiple causes were identified.

Deficiencies were present within the LOINC-RSNA Radiology Playbook, which hindered matching in some cases. For example, "CT angiography abdomen and pelvis with and without IV contrast" did not have a corresponding procedure name in LOINC-RSNA RSNA Radiology Playbook ("Abdominal and Pelvic vessels CT angiogram W and WO contrast IV" was not present). Further, there was no corresponding procedure in the LOINC-RSNA Radiology Playbook for "MR abdomen or pelvis venography without IV contrast." Inconsistencies were also present within the LOINC-RSNA Radiology Playbook. For example, "Abdomen MRCP with and without contrast IV" breaks with the format of all other standardized names and should be listed as "Abdomen MRCP W AND WO CONTRAST IV."

In some cases, the local procedure name was more specific than the corresponding procedure name in the LOINC-RSNA Radiology Playbook. For example, "CT chest and abdomen w and wo IV contrast—ao dissection" matched with "chest and abdomen CT wo and w contrast IV" since the LOINC-RSNA Radiology Playbook did not specify the indication of aortic dissection. In another example, "CT liver advanced and volume w and wo IV contrast" matched with "liver CT wo and w contrast IV" since there was no corresponding liver volume code in the LOINC-RSNA Radiology Playbook. Likewise, "MR abdomen without IV contrast—research" matched with "abdomen MR wo contrast" since LOINC-RSNA Radiology Playbook does not contain an applicable research code. In an extreme example, "MR abdomen with + without IV contrast + 3D liver recon + cut planes + seg volume" was too specific and RadMatch was unable to suggest an appropriate match secondary to inundation with extraneous terms. This limitation is one of many inherent to the

Fig. 3 Third prompt for user input
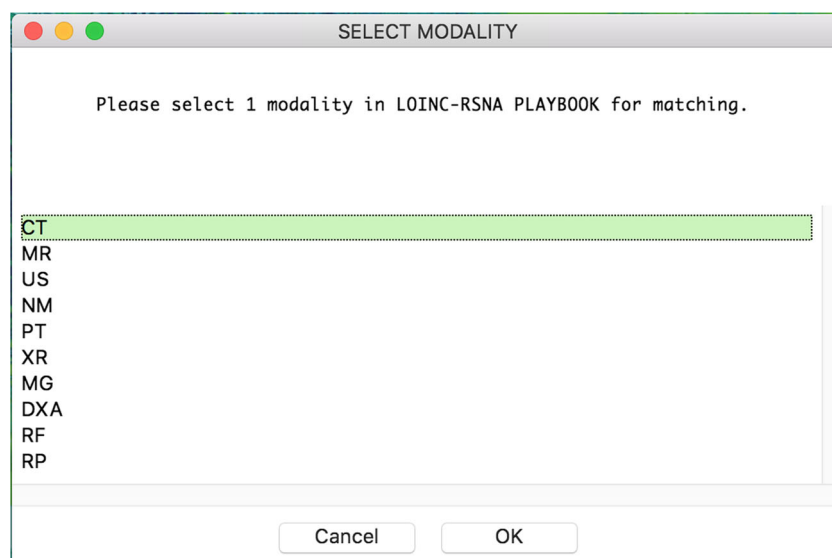
Fig. 4 Fourth and final prompt
for user input, after which the
script generates the output CSV
file containing the match results

Table 1 Select CT abdomen/pelvis local procedures with RadMatch results and radiologist match selection

Modified local procedure name	Token sort ratios	LOINC-RSNA Radiology Playbook procedure names	LOINC no.	RPID no.	Score
3D reconstruction on separate workstation CT					0
	53	Pelvis CT by reconstruction WO contrast	79,076–6	RPID161	
	49	Pelvis CT by reconstruction W contrast IV	79,075–8	RPID156	
	47	Colon and rectum CT for screening	79,101–2	RPID86	
	43	Colon and rectum CT for screening WO contrast	79,069–1	RPID148	
	38	Pelvis CT 3D post processing WO post processing	79,099–8	RPID1278	
CT abdomen and pelvis W contrast					2
	98	Abdomen and pelvis CT WO contrast	36,952–0	RPID144	
	96	**Abdomen and pelvis CT W contrast IV**	**36,813–4**	**RPID145**	
	86	Abdomen CT WO and W contrast IV	36,267–3	RPID4	
	86	Abdomen and pelvis CT WO and W contrast IV	42,274–1	RPID198	
	85	Chest and abdomen and pelvis CT WO contrast	72,253–8		
CT abdomen and pelvis W and WO IV contrast					1
	100	**Abdomen and pelvis CT WO and W contrast IV**	**42,274–1**	**RPID198**	
	91	Abdomen and pelvis CT W contrast IV	36,813–4	RPID145	
	90	Chest and abdomen and pelvis CT W Contrast IV	72,254–6		
	89	Chest and abdomen and pelvis CT WO and W contrast IV	72,252–0		
	88	Abdomen and pelvis CT WO contrast	36,952–0	RPID144	
CT abdomen and pelvis WO IV contrast					2
	99	Abdomen and pelvis CT W contrast IV	36,813–4	RPID145	
	96	**Abdomen and pelvis CT WO contrast**	**36,952–0**	**RPID144**	
	92	Abdomen and pelvis CT WO and W contrast IV	42,274–1	RPID198	
	90	Abdomen CT WO and W contrast IV	36,267–3	RPID4	
	86	Chest and abdomen and pelvis CT W contrast IV	72,254–6		

Please see supplementary material for the complete tables

Table 2   Select MR abdomen/pelvis local procedures with RadMatch results and radiologist match selection

| Modified local procedure name	Token sort ratios	LOINC-RSNA Radiology Playbook Procedure Names	LOINC no.	RPID no.	Score
3D reconstruction on separate workstation MR					0
	39	Prostate MR WO contrast	36,519–7	RPID4832	
	37	Prostate MR WO and W contrast IV	36,389–5		
	35	Prostate MR contrast IV	36,244–2	RPID5959	
	34	Uterus MR WO contrast	36,542–9		
	34	Pancreas MR WO AND W contrast IV	36,585–3		
Abdomen MRCP and MR abdomen W and WO IV contrast					3
	79	Chest and abdomen MR WO and W contrast IV	36,284–8		
	78	**Abdomen MR WO and W contrast IV**	**24,557–1**	**RPID474**	
	76	Abdominal aorta MR WO and W contrast IV	36,273–1		
	74	**Abdomen MRCP with and without contrast IV**	**72,248–8**		
	74	Abdomen and pelvis MR W contrast PO and WO and W contrast IV	72,246–2		
Abdomen MRCP and MR abdomen WO IV contrast					0.5
	82	Abdomen MR WO AND W contrast IV	24,557–1	RPID474	
	75	Abdomen MRCP with and without contrast IV	72,248–8		
	74	Chest and abdomen MR W contrast IV	36,942–1		
	74	Abdominal aorta MR WO and W contrast IV	36,273–1		
	73	**Abdomen MRCP WO contrast**	**58,740–2**		
Abdomen MRCP WO IV contrast					1
	94	**Abdomen MRCP WO contrast**	**58,740–2**		
	94	Abdomen MR W contrast IV	36,134–5	RPID475	
	90	Abdomen MR WO contrast	30,668–8	RPID473	
	86	Abdomen MR WO and W contrast IV	24,557–1	RPID474	
	79	Chest and abdomen MR W contrast IV	36,942–1		

Please see supplementary material for the complete tables

use of a fuzzy string matching algorithm. These limitations include stringent requirements for explicit rules, difficulty handling unanticipated scenarios and issues with scalability. Applying RadChanges to other modalities or types of procedures (e.g., interventional) would require supplemental modifications to the script that account for preferred synonyms in the LOINC-RSNA Radiology Playbook. Furthermore, as more users adopt and contribute to this open-source software tool, these limitations could also be overcome in future versions by the inclusion of additional removal criteria in the script for anticipated extraneous terms that are not present in the LOINC-RSNA Radiology Playbook.

On the other hand, situations arose where the local procedure name was less specific than the corresponding standardized procedure name. These situations were evaluated on a case by case basis to determine if the appropriate match could be achieved by combining codes in the LOINC-RSNA Radiology Playbook. Along these lines, bundled local procedures required matching

% Matching Local CT & MR Procedures

No Match, 13%
Partial Match, 6%
Complete Match, 81%
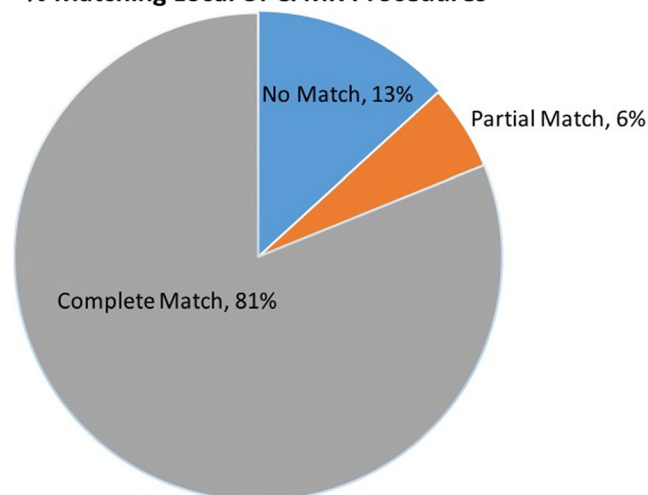
Fig. 5 Total percentage of matching local procedures for both CT and MRI

% Matching Local CT & MR Procedures
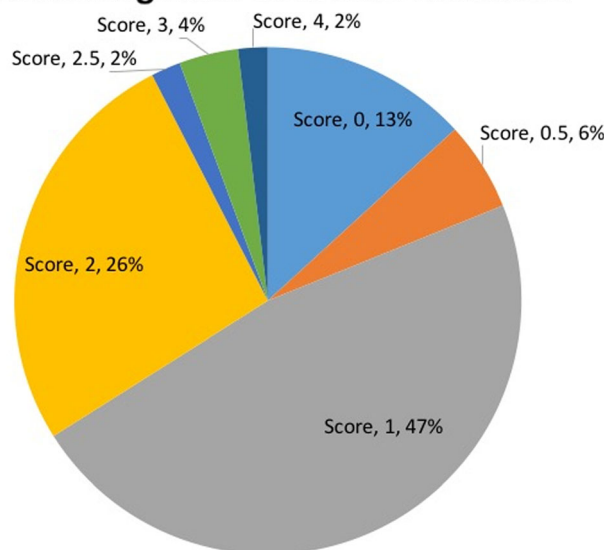
Fig. 6 Score and associated percentage of matching local procedures for both CT and MRI (0 = no match, 0.5 = partial match, 1–5 = complete match with rank). No local procedure had a score of 5

to multiple entries in the LOINC-RSNA Radiology Playbook. For example, local procedures pertaining to MRCP were bundled with MR abdomen procedures. Therefore, "MRCP + MR abdomen with + without IV contrast" matched with both "abdomen MR wo and w contrast IV" and "abdomen MRCP with and without contrast IV." In the case of "MRCP and MR abdomen without IV contrast," this bundling led to only a partial match with "abdomen MRCP wo contrast" based on the available choices generated by RadMatch. The same result also occurred with "MR angiography liver adv + vol with + without IV contrast," which only partially matched with "abdominal vessels MR angiogram wo and w contrast IV." RadMatch already demonstrated that it can identify appropriate complete matches for these local procedures when they are not bundled. Therefore, we recommend separating any combined local procedure names prior to utilizing RadMatch to improve the matching process.

Issues arose when the local procedure names were too generic compared with the LOINC-RSNA Radiology Playbook entries. RadMatch could not identify matching entries for local procedures pertaining to "CT or MR 3D post processing on a separate workstation" since the associated Playbook entries specify a body region of interest. Furthermore, local procedures without a specified body region (e.g., "CT body screening complete," "CT limited" or "localized follow up—body") did not yield an appropriate match and would require segregation and subsequent script execution using the "whole body" or "unspecified" body region options.

After implementing the LOINC-RSNA Radiology Playbook using RadMatch, it became apparent that performing standardization with LOINC numbers is preferred over RPID codes. All local procedures with complete matches

had corresponding LOINC numbers that could be assigned to those local procedures. However, many procedures within the LOINC-RSNA Radiology Playbook do not have applicable RPID codes available for use. In our case, only 17 RPID codes were available for the 27 LOINC numbers corresponding to local CT procedures, indicating that 37% of these standardized procedures had no applicable RPID codes. Similarly, only 15 RPID codes were available for the 21 LOINC numbers corresponding to local MR procedures, indicating that 29% of these standardized procedures had no applicable RPID codes. These observations are not unexpected given the inclusion of Core Playbook (rather than Complete Playbook) in the LOINC-RSNA Radiology Playbook [2]. Given these findings, we recommend the use of LOINC numbers for implementation of LOINC-RSNA Radiology Playbook. Nonetheless, RadMatch provides users with both LOINC and RPID numerical codes. Future work should focus on implementing the LOINC-RSNA Radiology Playbook in other areas of radiology as well as interventional radiology. For example, ultrasound exams pertaining to the abdomen/pelvis or the subspecialty of chest imaging are prime considerations for future work. Our ultimate goal is to expand the scope of RadMatch to facilitate implementation of the entire LOINC-RSNA Radiology Playbook.

This initiative is a work in progress and has been made available as an open-source solution on GitHub [8]. The authors invite anyone with an interest to try the software and modify/update the source code as needed to improve the product.

Conclusion

RadMatch is a semi-automated open-source software tool that has successfully demonstrated its utility in assisting our radiology department with the implementation of the LOINC-RSNA Radiology Playbook.

Compliance with ethical standards   This article does not contain any studies with human participants or animals performed by any of the authors.

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