Who You Gonna Call? Automatically Connecting Radiologists to the Right Clinician

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Abstract Contacting clinicians to convey critical results is a critical part of radiology workflow, but many obstacles prevent easy and timely communication. Integration of radiology applications and workflow with an EHR-based patient coverage database demonstrated subjective and objective improvement in radiologist workflow and satisfaction.

Keywords Clinical result reporting · PACS integration · Radiology workflow · Communication · Efficiency · Imaging informatics · Productivity

Introduction/Background

Barriers to radiologist-clinician communication have been identified particularly since the introduction of Picture Archiving and Communication Systems (PACS) [1]. Contacting clinicians to convey critical results in a timely manner is considered best practices at many institutions and indeed by the American College of Radiology [2–6]. However, it is sometimes very difficult to find the appropriate referring clinician in order to convey critical results [7]. At our institution, it has historically been difficult to find the appropriate covering clinician for many reasons: changes in patient location, transfer of service coverage, shift changes,

undocumented contact information, missing patient information, and discrepancies between ordering and covering clinicians.

An example of a representative order from our institution will likely look familiar to many radiologists (Fig. 1). The requesting physician field is blank; the only physician listed is a high-level department chair who is almost certainly not the appropriate clinician to contact with a critical finding. The phone number and pager number for the requesting physician as well as the critical result contact number fields are all blank. There is no information regarding patient location or unit phone number. Historically, if we had a critical result for such an exam, it would be a difficult exercise to find the right clinician to receive that information.

Materials and Methods/Methods

This study was exempted from full review by our institutional review board (IRB).

In July of 2014, our institution installed a new system to track inpatient-team-provider relationships in real time (“CORES Smart Handoffs”; TransformativeMed Inc.; Seattle WA). This application was embedded into our electronic health record (EHR), and clinicians used it to track which hospitalized inpatients they were responsible for as well as notes, checklists, and other clinical tools (Fig. 2).

Radiologists have access to our EHR including the CORES application and information, but the barrier of leaving the radiology environment and workflow in addition to other documented usability barriers with EHRs [8] proved to be far too high and radiologists rarely accessed this information. We then developed a plugin for our

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Fig. 1 Representative radiology order from our institution demonstrating many missing details

DATE REQUESTED: 06/20/2016 10:31
DATE ORDERED: 06/20/2016 10:31
LAST EXAM: 06/17/2016 22:35
ALLERGIES: NKA
CRITICAL RESULT CONTACT NO.:

REQUESTER: _____
ATTENDING DOCTOR: _____
ISOLATION INDICATOR: _____
ISOLATION FLAG: _____
DIAGNOSIS: S/P PANCREATICOUDENECTOMY
REASON FOR EXAM: CT ABDOMEN PELVIS W CONTRAST - Known Cancer (Specify Site)
COMMENTS: Duodenal adenocarcinoma s/p Whipple Please also add PO contrast
INVISION BILLING NO.: _____
PROCEDURE ACCESSION NUMBER: _____
9907 - CT ABDOMEN PELVIS W CONTRAST
May Modify per Radiology Protocol: YES

FOR CLINICAL INFORMATION REFER TO:
Exam: _____ **Date:** _____

Handwritten notes:
 CT abdomen & pelvis w IV + PO
 [Signature]

CORES Handoff

My Team: GUH Internal Medicine Float None Selected View Patient List + More

Facility: GUH **Unit:** All Units **Service:** All Services **Filter by Last Name (letter):** A B C D E F G H I J K L M N O P Q R S T U V

Filter by Age (years): _____ Search by Age

Patient Name	MRN	Age	ADT Se...	ADT At...	Unit	Room	CORE...	CORE...	CORES Pri...	CORES Te...	CORES Su...	CORES Se...	CORES Nu...	CORES Ph...
15 Y... Pediat...					GU...	5313	Pedi...	Blue			Not Appli...	Not Appli...	Not Appli...	Not Appli...
56 Y... Psychi...					GU...	5106								
87 Y... Medicine					GU...	4115	Inter...	C41			Not Appli...	Not Appli...	Not Appli...	Not Appli...
54 Y... Surgery					GU...	7026	Gene...	Coffe...			Not Appli...	Not Appli...	Not Appli...	Not Appli...
69 Y... Neuro...					GU...	6206	Neur...	Neur...			Not Appli...	Not Appli...	Not Appli...	Not Appli...
59 Y... Medicine					GU...	4023	Inter...	Bles 4			Not Appli...	Not Appli...	Not Appli...	Not Appli...
50 Y... Medicine					GU...	4306	Inter...	M43			Not Appli...	Not Appli...	Not Appli...	Not Appli...
52 Y... Medicine					GU...	4205	Inter...	ICU			Not Appli...	Not Appli...	Not Appli...	Not Appli...
81 Y... Medicine					GU...	2219	Inter...	Nort...			Not Appli...	Not Appli...	Not Appli...	Not Appli...
3 Ye... Pediat...					GU...	5104	Pedi...	Gold			Not Appli...	Not Appli...	Not Appli...	Not Appli...

Provider Contact:
Care Provider: _____
Page Recipient: _____ MD
Pager Number: 202 _____
RE: _____ (GUH B7) - **Send**
Private Message: ☒ (your page will not be displayed publicly)
Callback Number: _____ ☐ No callback required

Fig. 2 CORES Smart Handoffs application embedded in our EHR

Patient Summary

DR ABDOMEN	DR ANKLE	DR CHEST	US RENAL BILATERAL	US LOWER EXTREM...	DR CHEST	DR CHEST	DR CHEST	DR CHEST
6/20/2016	6/15/2016	6/15/2016	10/7/2010	10/7/2010	10/5/2010	10/3/2010	10/2/2010	10/1/2010
P	F	F	F	F	F	F	F	F

☐ Relevant ☐ Hide

Documents **Observations** **Clinical Information** **CORES** **Retrieve Studies**

Fig. 3 Button in our enterprise PACS to open the CORES plugin

Primary Team: Bles 2 (Internal Medicine)

Primary Contact: _____, MD: 202-_____

Team Attending: _____, MD: No pager info

Secondary Team: Consult (Infectious Diseases)

Primary Contact: ID Pager: 202-_____

Primary Contact: _____, DO: 202-_____

Fig. 4 Coverage information from CORES displayed within our radiology environment

PACS to integrate the patient coverage information from this tool directly into our radiologist workflow. With a single click (Fig. 3), context-specific coverage information is displayed in a small Web page within PACS (Fig. 4). Because of the patient and radiologist context awareness of our plugin, the user can then page one of the covering clinicians by a single click with a prepopulated message that includes patient and exam information as well as the phone number nearest the radiologist (Fig. 5).

In an attempt to objectively measure the impact of this tracking system and PACS plugin on radiologist workflow, we developed a randomized trial design. Radiologist users were randomized to either use their old methods of clinician contact or the CORES plugin when they clicked the CORES button in PACS. Our system logged information related to each radiologist and exam. Once a combination of radiologist and exam accession number had been randomized, the randomization would be “sticky” so a user could not game the system by repeatedly requesting CORES information in an attempt to get re-randomized. We used a critical result turnaround time metric to determine whether there was improvement between old methods and the new CORES plugin. This metric is defined as the time between recognition and communication of a critical result; our hypothesis was that it would decrease using the CORES plugin. Because our department mandates the use of a standard template for documentation of critical result communication (Fig. 6), we can

Primary Team: Bles 2 (Internal Medicine)

Primary Contact: _____, MD: 202-_____

Please call Radiology re: _____ (MRN: _____) at 4-_____. Thanks!

Send Page to _____ MD

Team Attending: _____, MD: No pager info

Fig. 5 PACS integration and shared context allow pre-population of a standard page to the clinician

Critical findings, first recognized at 9:20 PM on June 17, 2016 were communicated to Dr. _____ of the neurosurgery service by phone by Dr. _____ at 9:40 PM on June 17, 2016.

Fig. 6 Standard departmental critical result communication template

automatically parse this data from incoming Health Level 7 result messages for radiology reports and store it in a database for further analysis. A survey was also distributed within our department to evaluate for more subjective assessment of change in workflow and satisfaction.

Results

Prior to implementation of our system, there were 211 exams where critical results were communicated during a 3-month baseline period (June 1, 2014 to September 1, 2014). The average critical result turnaround time during this period before any awareness of our new system was 11.2 min.

Our randomization period from September 5, 2014 to October 3, 2014 was ended after only 4 weeks because of extremely high radiologist satisfaction such that we chose to end our trial early because of what was perceived as obvious benefit. During that period, we completed 13,781 total exams of which 3550 were inpatient exams where radiologists would expect CORES coverage information to be available. Thirty-six users participated during the trial period involving 338 exams which was 9.5% of inpatient exams. One hundred sixty of these exams were randomized to use the new CORES system, and 178 were randomized to use their old methods. A total of 555 requests were made to the CORES system and 96 pages were sent using the automated pre-populated paging tool (Fig. 7).

Of the 160 exams that were randomized to use the CORES system, 12 had critical results with an average critical result turnaround time of 6.9 min. Of the 178 exams that were randomized to use old methods, 16 had critical results with an average critical result turnaround time of 11 min which was very similar to the pre-implementation critical result turnaround time of 11.2 min. Critical result communications using

Dates	9/5/2014 – 10/3/2014		
	Number	Low	High
Users	36		
Exams	338	1	85
Requests	555	1	138
Pages	96	1	23

Fig. 7 CORES plugin usage during the trial period

BEFORE the CORES plugin, how did you locate inpatient referring clinician information?

How reliable is/are these method(s) in finding the right referring clinician for inpatients?

Fig. 8 Survey results regarding communication prior to the CORES plugin

the CORES plugin had a shorter mean turnaround time, but the results were not quite significant (p value 0.068; unequal variances t test). This may have been due to inadequate power as we stopped our randomization period early due to overwhelming subjective support, but also could be related to a number of potential weaknesses in measuring critical result turnaround time that are discussed below.

Thirty-seven radiologists responded to our survey of which 21 were attendings, 15 residents, and 1 fellow. Thirty-five (94.6%) had used the CORES plugin. Prior to development of this plugin, the respondents used a wide variety of methods to find covering clinicians ranging from calling the operator, calling a floor, paging someone, or asking a resident to do it for them. On a scale

Please rate the CORES plugin ease of use

How reliable is the CORES plugin in finding the right referring clinician for inpatients?

Fig. 9 Survey results regarding usability of the CORES plugin

How easy was it to page someone through the CORES plugin?

Difficult and confusing: 1	0	0%
2	0	0%
3	0	0%
4	4	12.5%
Easy and intuitive: 5	28	87.5%

How often was the prepopulated page text correct?

Never: 1	0	0%
2	0	0%
3	1	3.1%
4	15	46.9%
Always: 5	16	50%

Did the page go through successfully?

Never: 1	0	0%
2	0	0%
3	0	0%
4	13	40.6%
Always: 5	19	59.4%

Fig. 10 Survey results regarding communication and paging using the CORES plugin

of 1–5, most respondents (88.6%) rated these methods as a 2 or 3 and estimated it that took an average of 12 min to find the correct covering clinician (Fig. 8).

On a scale of 1–5, 29 (82.9%) rated the plugin as a 5 for ease-of-use and 35 (100%) rated the plugin as a 4 or 5 in terms of reliability (Fig. 9). Respondents estimated it that took an

average of 4 min to find the correct covering clinician when using the plugin. Twenty-eight (87.5%) rated the paging interface as a 5 on a scale of 1–5, and the vast majority gave a rating of 4 or 5 in terms of accuracy of the prepopulated page (96.9%) and success of the page getting to the correct person (100%) (Fig. 10). Overall, 28 respondents (80%) gave an

Please give an overall rating of how useful the CORES plugin is to you.

Terrible - please get rid of it: 1	0	0%
2	0	0%
3	0	0%
4	7	20%
Amazing - I can't live without it: 5	28	80%

Fig. 11 Survey results regarding overall rating of the CORES plugin

Dates	9/5/2014 – Present		
	Number	Low	High
Users	145		
Exams	20,921	1	1332
Requests	21,200	1	1398
Pages	10,362	1	799

Fig. 12 CORES plugin usage since inception

overall rating of the plugin of 5 with the remaining 20% rating it a 4 (Fig. 11).

Sample free-text comments included the following:

Nothing short of a miracle - from conception to execution. Truly.

Revolutionized workflow during call. Thanks!

It is immensely helpful. LOVE it!

Accurate, high yield and incredibly user-friendly w [sic] a simple click of a button.

Cores plugin is amazing. Thank you!

Its [sic] been a game changer in terms of increasing resident efficiency on call.

This satisfaction has been borne out in usage statistics. Since the plugin was instituted, 145 distinct radiologists have used the system involving 20,921 exams. A total of 21,200 requests for coverage information have been made through the CORES plugin and 10,362 pages have been sent. One resident

who took the bulk of their call during the past 2 years sent 799 pages themselves through the plugin (Fig. 12). The system is in continual use today, and while usage fluctuates, there has been persistent usage as of most recent data from June 2016 (Fig. 13).

Discussion

Once an institution uses a patient coverage tracking system such as CORES, it is technically feasible to integrate this highly relevant coverage information directly into radiologist workflow. This integration streamlines the process of contacting referring clinicians and results in highly improved workflow and radiologist satisfaction. Objective metrics demonstrate improvement that may have become statistically significant given enough time and power. Survey results and usage statistics confirm that radiologists overwhelmingly believe that this integration dramatically improves workflow and user experience.

One of the main limitations of this model is the accuracy of the coverage database. The clinicians in our institution reliably use the CORES system because it integrates directly into our EHR and because clinical services use it to transfer notes and document to-do lists, thus providing incentives to use the system beyond just coverage information. Without associated incentives that provide direct benefit to clinicians, as in our case, we believe that it would be difficult to get clinicians to reliably and accurately participate just for the sake of

Fig. 13 CORES plugin requests over time since inception including moving average

radiologist or other consulting physician convenience. We have been fortunate that it works as well as it does at our institution, but this may not always be achievable and likely depends on institutional policy and workflow. In fact, we attempted to institute this plugin at a sister hospital within our healthcare system, and it did not work well at all because of poor usage and inaccuracies in their CORES database. Finally, the coverage database is only used at our institution for inpatients, but other patient classes are generally much easier to communicate critical results; our emergency department is available through a single phone number and outpatient orders have more reliable contact information. In fact, we have used outpatient order information to populate the paging component of our plugin where CORES data is not available and this works quite well.

There are some technical challenges in integrating with PACS, sharing relevant context information, creating a lookup table of computer names and phone numbers, and integrating with the paging system, but these can generally be overcome with the right resources.

Related specifically to our project, there are some weaknesses that likely confounded our results. The best objective metric we could come up with relied on critical result communication templates as described above. These data are fairly easily mined, but can be subject to both human transcription and computer parsing error. Additionally, we rely on radiologists to use recall to determine when these timestamps occurred which means we often see turnaround times of 5, 10, and 15 min because it is a round number approximation of communication time good enough for underlying documentation and compliance purposes. These timestamps are also frequently entered at the time of report finalization; so, if one sees a finding, then communicates it to a clinician, and then finishes editing a report before signing, one likely uses somewhat imprecise memory recall to enter the template timestamps. Nevertheless, we believe that this provided interesting objective insight into the quality of our implementation.

Conclusions

Building a plugin to integrate clinician coverage information into radiologist workflow is technically feasible, fairly straightforward, and results in dramatic improvement in radiologist satisfaction and subjective assessment of workflow.

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