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Exploring the persistence of paper with the electronic health record

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ABSTRACT

Objective: Healthcare organizations are increasingly implementing electronic health records (EHRs) and other related health information technology (IT). Even in institutions which have long adopted these computerized systems, employees continue to rely on paper to complete their work. The objective of this study was to explore and understand human-technology integration factors that may be causing employees to rely on paper alternatives to the EHR.
Methods: We conducted semi-structured interviews with 20 key-informants in a large Veterans Affairs Medical Center (VAMC), with a fully implemented EHR, to understand the use of paper-based alternatives. Participants included clinicians, administrators, and IT specialists across several service areas in the medical center.
Results: We found 11 distinct categories of paper-based workarounds to the use of the EHR. Paper use related to the following: (1) efficiency; (2) knowledge/skill/ease of use; (3) memory; (4) sensorimotor preferences; (5) awareness; (6) task specificity; (7) task complexity; (8) data organization; (9) longitudinal data processes; (10) trust; and (11) security. We define each of these and provide examples that demonstrate how these categories promoted paper use in spite of a fully implemented EHR.
Conclusions: In several cases, paper served as an important tool and assisted healthcare employees in their work. In other cases, paper use circumvented the intended EHR design, introduced potential gaps in documentation, and generated possible paths to medical error. We discuss implications of these findings for EHR design and implementation.
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1. Introduction

When optimally implemented, electronic health records (EHRs) hold tremendous potential benefit for healthcare systems and can enhance how patient data are documented and organized. EHRs provide improved legibility of patient data; simultaneous, remote access; and integration with other information sources [1]. While some of the potential benefits of EHRs are well-known, they do not produce completely "paperless" processes. Previous research described the phenomenon of "paper-persistence" for medical ordering processes in healthcare organizations where computerized provider order entry (CPOE) was implemented [2–4]. CPOE is only one potential component of many integrated clinical applications in EHRs, and so while implementation of CPOE does not eliminate all paper, even if the paper is related specifically to ordering, the intent is to *reduce* the dependency on paper-based ordering processes and improve patient care [3]. However, even if a completely paperless CPOE system or broader EHR system were feasible, current limitations of these clinical applications would make a completely paperless system problematic.

Indeed, the limitations and shortcomings of electronic records were outlined in a recent New England Journal of Medicine commentary [5]. These included copied, repetitive notes that desensitized clinicians to new, important data and more attention directed to the computer, which may result in less attention directed to the patient during patient encounters. These types of scenarios may lead to paper-based workarounds. For example, Hartzband and Groopman presented an anecdote of a colleague who, to manage copied, repetitive electronic notes, used index cards to handwrite new developments so that he could refer to them at the bedside [5]. The underlying issue contributing to the use of paper index cards as a workaround in this example may also be related to the way documentation is performed in the EHR, such as excessive copying from previous notes, rather than simply the apparent convenience of the paper cards themselves.

We investigated use of paper-based workarounds, and the underlying factors that contributed to their existence, at a Veterans Affairs Medical Center (VAMC). This particular VAMC was an ideal site to assess the use of paper with the EHR, as it was undergoing an initiative to eliminate as much paper generation as possible to free space for new interventional radiology equipment in a location currently occupied by a paper file room. Although this VAMC used a widely integrated, nationally used EHR, known as the Computerized Patient Record System (CPRS), a substantial amount of administrative and medical paperwork was processed and stored by the facility. At the time this study began (August 1, 2007), paper accumulated in a designated file room at a rate of approximately eight feet of stacked paper per week. In fact, this was more paper volume than the year prior to the implementation of CPRS at this facility in 1998, where about six feet of stacked paper was received by the file room per week. Larger patient volume and additional paperwork requirements contributed to the larger paper volume today despite the use of an EHR. For example, the U.S. Department of Veterans Affairs (VA) mandates that certain forms be printed and filed, especially if they contain original signatures. System workflow and EHR usability issues also contributed to paper generation. There are also many cases of "temporary" paper (i.e., paper that does not become part of the permanent record); this paper is eventually disposed of in the various sections of the hospital and not sent to the file room for storage.

Previous research has identified several paper-based strategies used by clinicians to circumvent parts of the VA's computerized clinical reminder system [6], suggesting that parts of the CPRS may be inadequately designed to support some clinical workflow and tasks. Recent studies have identified integration of health information technology (IT) into clinical workflow as major challenge for current IT efforts [6–11]. Further, the way EHRs visually organize patient data may be incompatible with clinical care delivery activities [12]. These situations may cause clinicians to generate paper-based workarounds while using an EHR. Based on this literature, as well as administrative knowledge at our VAMC regarding policy-driven paper processes and systems-level design factors, we developed the framework in Fig. 1 to guide our study.

The framework in Fig. 1 classifies sources of paper generation into three major areas: (1) policy, (2) system design, and (3) EHR design. Predicted sources of paper generation are further depicted at the systems/process level and EHR level. The first category, policy mandate, is a substantial source of paper generation but not related to the scope of the study objective and, thus, was not expanded further. We expanded subcategories for second category, suboptimal systems design, since they are potentially related to EHR-level factors and informative. The study objective was to explore and understand human-technology integration factors (e.g., computer usability and human–computer interaction issues) at the EHR level that may be causing employees to rely on paper alternatives. Thus, while it was important to understand all sources of paper generation, this study focused on the third category, EHR user interface flaws, and its sub-categories related to human-technology integration factors (d–f). By understanding the motivation behind the use of paper-based alternatives, we expected to find corresponding opportunities to improve EHR design to better support the needs of the clinicians and staff who strive to deliver effective patient care.

2. Methods

Three of the authors (JS, AR, and CJ) conducted 20 semi-structured, key informant interviews from October 2007 to March 2008 in order to document and understand paper use and paper-based workarounds associated with CPRS and related clinical software. CPRS, as opposed to many EHRs which are more physician-centric, was designed to be used by a broad range of VHA healthcare workers. Thus, we interviewed a convenience sample of employees at the VAMC, including three physicians, two pharmacists, two nurse practitioners (NPs), four registered nurses (RNs), two health technicians, one dietician, three administrators, and three IT specialists (Table 1). The IT specialists develop and maintain clinical software applications at the hospital. Hereafter, we use the general term "clinician" to describe the participants involved in the treatment or observation of patients:

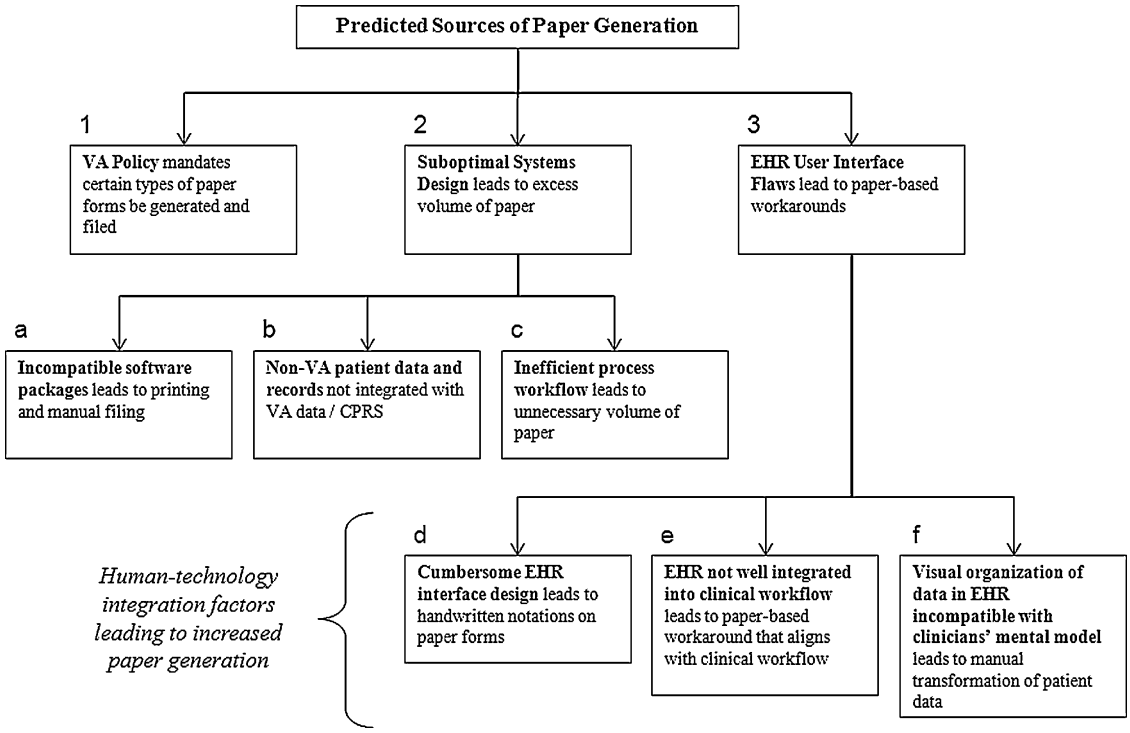

Fig. 1 – Guiding framework for predicted sources of paper generation. Sources of paper use include policy-level (1), systems/process-level (2), and EHR-level factors (3). The study objective explores human-technology integration factors (d–f). "Suboptimal" in box 2 refers to systems level and process factors which are not ideally aligned in the overall system.

physicians, pharmacists, NPs, RNs, and health technicians. Participant experience in the VA system was quite variable, ranging from 1 to 31 years, with an average of 12 years. Note that CPRS was implemented at this facility in 1998, about 10 years before the completion of this study. Participants spanned a broad range of responsibilities and service areas in the medical center: primary care, dialysis service, specialty clinics, inpatient wards, surgery, medical and surgical intensive care units, nutrition, psychology, medical records/file room, and the office of information and technology. The diversity of workflow processes represented by this sample was quite large. For example, the workflow of a physician and a nurse in primary care, and their use of CPRS, is substantially different. The workflow and CPRS interaction of administrators and IT specialists was even more diverse. We attempted to represent as much of this diversity as possible, since CPRS was designed to used by this broad sample of healthcare workers. At the time of this study, there were approximately 250 physicians, 20 pharmacists, 500 nurses, 80 health technicians, and 30 IT specialists working at the VAMC.

The IRB-approved interview script included questions that prompted participants to describe how paper is used in conjunction with or instead of CPRS. Questions included, for example:

- Do you ever print information from CPRS? If so, what do you print and why?
- What paper-sources do you use in your clinical work?
- Have you ever experienced frustration in viewing or combining information from CPRS (e.g., patient data) during your clinical work? If so, please give example(s).

Table 1 – Interviewee characteristics. CPRS was implemented 10 years prior to this study and thus 10 years represents the maximum level of experience.

Role (*n*)	Gender (F/M)	VA experience (years)	Experience with CPRS (years)
Physicians (3)	1/2	6, 4, 8	6, 4, 8
Pharmacists (2)	1/1	2.5, 30	2.5, 10
Nurse practitioners (2)	2/0	1, 10	1, 10
Registered nurses (4)	4/0	18, 19, 15, 16	10, 10, 10, 10
Health technicians (2)	2/0	1, 18	1, 10
Dietician (1)	1/0	31	10
Administrators (3)	2/1	19, 10, 18	10, 10, 10
IT specialists (3)	1/2	8, 3, 4	8, 3, 4

CPRS: Computerized Patient Record System. F/M: number of female participants/number of male participants.

Table 2 – Paper-based workarounds by category. Order of categories corresponds to the occurrence frequency across interview transcripts, beginning with the most frequent. Categories with the same frequency are not listed in a particular order.

Category	Freq.	Description	Example(s)
Efficiency	20	Using a workflow process that improves actual or perceived efficiency.	"The emergency room uses pre-printed [paper] forms for orders…this paper "workaround" is more efficient/expedient."
Knowledge/skill/ease of use	20	Training/support/experience/ease of finding needed information.	"Now we're trying to get doctors to view them [test results] in CPRS [instead of printed results]. But sometimes physicians will get frustrated and say - where is it?"
Memory	17	Reminder about "old" or existing information.	"Without a sheet of paper, I sometimes forget about a [walk-in] patient."
Sensorimotor preferences	15	Preferred sensory input for task: "hear", "tangible", easily modified (i.e. hand notes); mobility, something to "deliver".	"I like to have something to walk into the patient's room with"; "I hand write the labs down on paper… I can't write on the screen."
Awareness	12	Recognize new/important information: notify, alert, trigger; adjusting "signal to noise" ratio.	"The patient brings…a sheet of paper – colored pink for high BP… There is a [computerized] clinical reminder for high BP, but I guess this is a way to make sure we see that the patient has high BP in case we don't see it in the computer."
Task specificity	12	Need specificity or ability to customize to patient, provider, department, etc.; some signal/noise issues.	"We have a print out of that day's patient schedule for myself… No way to see that [personal] list in the computer."
Task complexity	9	Complexity of task dictates workflow issues or functionality issues.	"Oncology does their orders on paper…each patient's orders are very complex. CPRS is not designed to support this complexity…"
Data organization	9	Data layout issues; need to view existing data differently.	"In CPRS you can't view it like that. You can't put it [data for a given patient] all on one sheet."
Longitudinal data processes	9	Task requires processing multiple data points across time.	"Need to chart vitals every 15 minutes - so it's done on paper."
Trust	1	Greater trust in paper over electronic version.	"Some doctors say it's easier to do on paper because 'I have proof'."
Security	1	Security associated with the EHR encourages paper use as an alternative.	"I can't send information securely [to university account] so I print it off."

Freq.: frequency of occurrence; CPRS: Computerized Patient Record System; BP: blood pressure.

- Have you ever manually transformed patient data from CPRS onto paper to better organize information during your clinical work? If so, please give example(s).
- Have you or others in your clinic developed "workarounds" to circumvent "poor" CPRS design? If so, please explain.
- What is your ideal workflow during your clinical work and how does it relate to CPRS?
- How can CPRS be better designed to meet your needs?

Administrators and IT specialists who do not directly care for patients were asked variations of the same questions and questions more related to CPRS design than patient care. These additional questions included, for example:

- Are there CPRS improvements that you envision that could eliminate or reduce production and storage of some paper forms? Please explain.
- Are you aware of any "incompatible" software packages as part of CPRS or separate from CPRS that may cause paper generation as a result (e.g., printing from one package and scanning into the other)?

These types of questions helped guide the semi-structured interviews. This approach provided flexibility and gave interviewees an opportunity to identify and explain important examples that may not have surfaced otherwise. However, the interviews were also repeatable since the same core questions were asked of each interviewee. Interviews were audio recorded, as permitted by the participants, and used as back up to handwritten notes. Interviews were scheduled for 30 min; average interview length was 27.5 min.

Two of the authors (JS and AR) independently coded the typed transcripts into distinct cases of paper use associated with the EHR. We integrated findings across the interviews into meaningful patterns and abstracted the data into emerging themes [13–16] for recurrent paper-based workaround strategies. Fig. 2 illustrates the data analysis and abstraction process used to derive themes from the interview data. Data anal-

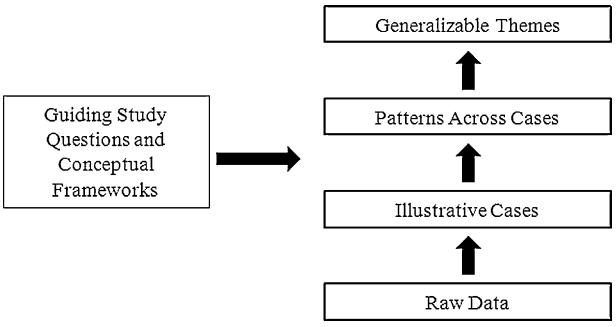

Fig. 2 – Data analysis and abstraction process [13–16], where higher levels in the hierarchy represent a greater level of abstraction, ending in generalizable themes.

ysis began at the bottom of the abstraction hierarchy with the raw interview data. The interview transcripts were then reviewed by independent coders for cases of paper use with the EHR (the guiding question), guided by 'human-technology integration factors' from the framework in Fig. 1. This corpus of illustrative cases represented the next level of the data analysis abstraction hierarchy. Then patterns (i.e., recurrent paper-based workaround strategies) were documented across the illustrative cases and interview transcripts by using similar codes to group them into a common theme. Finally, a generalizable label was give to each theme (by "generalizable", we mean a descriptive word that represented a pattern across the interview transcripts). These generalizable themes, or "categories", are the 11 categories that appear in Table 2.

All differences in the independently coded transcripts for paper-based workaround strategies were resolved to consensus by the two researchers through a series of six meetings, each lasting 1–1.5 h. In the first two consensus meetings, the coding scheme was refined and finalized from the independently generated codes by JS and AR. Each researcher then independently re-coded the data based on the finalized coding scheme. After recoding the transcripts, the final four consensus meetings were used to resolve differences in workaround classification. Every difference in coding was discussed by JS and AR until consensus was reached.

3. Results

From 125 instances of paper use where codes were assigned, we identified 11 categories that represent distinct reasons for paper-based workarounds associated with CPRS. Each category is described in this section and summarized in Table 2; the order of categories corresponds to the occurrence frequency across interview transcripts, beginning with the most frequently identified workaround type. Categories with the same frequency are not listed in a particular order. In several cases, a participant described two or more separate examples of workarounds that fell under the same category type. In other cases, a particular workaround clearly related to two or more categories; therefore, we assigned more than one code to these workarounds. For each category, we provide at least one example that illustrates the reason for a specific paper-based workaround.

3.1. *Efficiency*

There were 20 cases where individuals used paper forms instead of computerized processes because paper use enhanced actual or perceived efficiency. A majority of these cases related to placing orders (e.g., medication orders and consultation requests) instead of using the order entry system in the CPRS. These examples ranged from use of formal paper forms to handwritten notes on a patient's printed medication list. They also ranged from placing simple orders on paper, which can be readily entered through the order entry function of CPRS, to complex orders, which are more readily specified on paper and more challenging to request through CPRS. In the ambulatory clinic setting, some physicians prefer to write orders on paper and give them to the nurse to enter into CPRS. For the orders to be processed, the physicians must electronically sign the nurse-entered orders. In the emergency department (ED), all orders are done on paper because ED personnel generally believe that ordering via paper is more efficient and better integrated into the ED workflow.

3.2. *Knowledge/skill/ease of use*

Interviews also revealed 20 cases of paper workarounds related to three scenarios: clinicians' knowledge of CPRS or related health IT systems; individual skill level with computerized tools; and/or the ease of use of health IT tools. A relevant quote from a RN was: "The [X software] package is horrible. I don't use it. I use [paper] notes instead; I hand notes to the secretary personally. It's too easy to mess up in [X]. I use paper because I'm not comfortable with [X]."

Several cases related to clinicians who were unaware that a task could be performed in CPRS instead of with paper or, alternatively, were aware of the CPRS capability but did not have sufficient training to perform the task in CPRS themselves. Two examples included entering a complex medication order and viewing magnetic resonance imaging (MRI) results. A relevant quote from an administrator was: "As we learn more about what CPRS can do, we're slowly getting away from paper things. We're used to doing things on paper."

3.3. *Memory*

We found 17 examples where clinicians and staff use paper as a reminder tool involving previously existing information. Cases where the information was new and caused the creation of a paper-based "alert" were categorized under "awareness" as described later in the text. The memory examples related to the use of paper as a cognitive memory aid. In one example, a RN described how she prints the coversheet from a patient's record to "remember" that a walk-in patient has checked in. A relevant quote from the RN was: "Without a sheet of paper, I sometimes forget about an [unscheduled] patient–it's difficult to remember to check the computer periodically because I get caught up in other things."

3.4. *Sensorimotor preferences*

There were 15 cases of paper workarounds that related to a preferred sensory input and/or motor activity for a task. That

is, participants described a preference for the following: mobility; ability to "hear" something; hold something "tangible"; something concrete to "deliver"; and/or work with something that can be easily manipulated (e.g., hand notes). A relevant quote from a RN was: "I 'hear' the paper being dropped in my basket [indicating new unscheduled patient has checked in]. I also glance at the basket to make sure someone has not put a piece of paper in my basket." These sensorimotor preferences cannot currently be accommodated by the EHR with a high degree of realism.

In six of the cases, clinicians revealed that they are reluctant to use CPRS while with the patient. Instead, they commonly use printed copies of the current CPRS medication lists and handwritten notes. The notes are entered into CPRS later in the day, after the patient encounter. One physician's relevant quote: "I don't think it's [charting in CPRS during the patient encounter] conducive to having a good conversation. It also gives [poor] body language. If you were typing your notes [from this interview] right now I would say, 'Are you listening to me?"'

3.5. *Awareness*

We found 12 instances of the use paper to make clinicians aware of new information. In each case, paper was a workaround and contained the same information that was in CPRS. In one example, intake nurses recorded high blood pressure readings on a pink sheet and gave this to the patient. This way, the patient could hand the paper to the physician during his or her appointment, notifying the physician about the elevated blood pressure. Interviews also revealed an example where a RN created new progress notes in CPRS, printed them for physicians, and highlighted specific pieces of information for emphasis.

3.6. *Task specificity*

Interviews revealed 12 cases of paper-based workarounds that related to the need for specificity: in particular, the ability to customize data to a patient, group of individuals, provider, or department. In one case, a physician described how the computer alert system in CPRS lacked specificity, was not customizable, and resulted in too many alerts. The problem of alert overload or "fatigue", and/or alerts perceived as not being useful or clinically relevant, specifically in CPRS, has been documented in several other VA studies [17–24]. The physician also pointed out that the computer notifies her for labs that she ordered as well as labs ordered for that patient by any other physician. As a result, she had a nurse print only the lab results for tests that she ordered; these are placed in a special paper folder for her to review. Currently, there is no option in CPRS to request alerts only associated with orders from a specific physician.

3.7. *Task complexity*

There were nine instances where complexity required to perform a task was not supported by the routine workflow or CPRS functionality, resulting in the use of paper processes. One example related to oncology orders. A relevant quote from an IT specialist was: "Oncology does their orders on paper because they are very tailored to each patient. Each patient's orders are very complex. Each patient has complicated needs; different medications, different timings. CPRS is not designed to support this complexity; it is hard to track."

In other examples, nurses describe detailed routines they perform on paper to support work tasks that cannot be done in CPRS. One relevant RN quote was: "For the master schedule in the clinic, the first thing I do is highlight the patients' names that are mine. Then when they come in, I highlight them in green. If I talked to them I put a line through it. After charting [in CPRS], I make an 'X' through the patient's name. At the end of the day, all patients must have an 'X' through their name, or I follow-up to see what happened. If I don't have a patient checked, it reminds me to chart [document in CPRS]." While the RN relied on this paper process due to overall task complexity, this example was also comprised of elements coded as memory, awareness, and task specificity, due to the diversity and non-linear nature of the multiple tasks involved in the workflow.

3.8. *Data organization*

There were nine cases of paper use because the electronic data display was insufficiently organized. Clinicians needed to view the information differently to better support their work. In one case, the dermatology clinic manually recorded new data on a paper spreadsheet and entered it into CPRS in parallel. The paper spreadsheet allowed easy comparison of numbers; CPRS did not allow for this spreadsheet-formatted display. Another example involved a need to record serum dosage changes for allergy injections onto a single paper spreadsheet to look for changes in corresponding reactions, since CPRS did not allow the data to be viewed on a single screen.

3.9. *Longitudinal data processes*

We found nine examples of paper-based workarounds to CPRS when there was a need to track certain data metrics and look for trends over time. While a portion of these relate to the previous data organization category, all nine cases involved the need to view data longitudinally. One key example included a RN's paper notebook system for tracking international normalized ratios (INRs) for dosage changes across dates. INRs are used for reporting the results of blood clotting tests. A relevant quote from the RN was: "I add important footnotes–anytime the INR is too high, greater than 8.0. The primary care provider will think the INR was too high only this one time but I have the data in my notebook to show that it was too high three times." Three elevated INRs would likely change the provider's plan of action for the patient.

3.10. *Trust*

Interviews revealed one case of using paper instead of using the corresponding electronic process that was directly related to trust. In other words, one clinician believed that paper pro-

vided "proof" in a way CPRS could not. Note, this observation was obtained from an administrator who works in the file room, not a clinical provider. The administrator was describing others' use of paper. However, working in the file room makes that individual uniquely qualified to comment on clinicians' use of paper since these paper artifacts are archived in the file room by the participant.

3.11. *Security*

Finally, there was one case where an electronic system was not secure (i.e., not behind the VA electronic firewall); therefore, the participant used paper printouts instead. Many VA providers have dual university appointments and prefer to use their corresponding university email accounts instead of VA email. Transmitting certain information outside of VA IT systems or VA email, and thus outside of the VA electronic firewall, is not permissible. Our interviews revealed an example of an NP specifically printing information from CPRS to show to a physician rather than sending the information through email. In this case, the NP was aware that the physician only used a university email account.

4. Discussion

While EHRs may enhance how data is documented and organized, paper-based processes are not necessarily inefficient or inferior to corresponding computer processes in the EHR. Indeed, for many examples in this study, paper helped some clinicians be more efficient in their work. Campbell et al. notes that "paper often serves as a necessary, sometimes superior, cognitive memory aid" [3]. However, many of these processes circumvent the intended use of the computer system and increase the opportunity for losing clinical information. Further, workaround strategies may increase efficiency but create new potential paths to medical error [25]. Therefore, a well-designed EHR should support the use of important paper supplementation while minimizing the potential for gaps in EHR documentation.

4.1. *Actual and perceived efficiency*

Based on occurrence frequencies, there were many examples where paper-based workarounds enhanced the actual or perceived efficiency of workflow. Since this was a descriptive study, we do not have time data to support whether the reported examples resulted in actual efficiency gains or if the efficiency gain was illusory. Also, efficiency gains for one healthcare worker may have resulted in efficiency loss for others. The following are cases where efficiency gains were likely only illusory and/or where efficiency gain for one person caused potential efficiency loss for someone else:

- Physicians in the emergency department used paper orders because it was more "efficient" than ordering through CPRS. However, the physicians handed the paper orders to a nurse and the nurse handed the paper order to the clerk to enter into the computer. Thus the efficiency gain for the physician likely equated to efficiency losses for the nurse and the clerk. This example was documented in ambulatory care as well.
- A physician reported using a printed listed of medications instead of viewing the medication list in CPRS. "...the paper list...makes it easy to go through each one and say, 'this needs to be refilled, this doesn't." This efficiency "gain" is likely only illusory since the same list and process of going through each medication to see if it needed to be refilled can readily be done in CPRS. Although the physician may find it faster to work with a paper list, it may even be more efficient to do this task in CPRS, since each medication can simply be refilled in CPRS as the physician reviews the computer medication list.
- The following example was reported by an administrator: "Doctors tend to look at paper before seeing the patient, rather than looking at the last progress note in CPRS. They use paper in the clinics from beginning to end – they would rather kill a tree than look at CPRS every time." This perceived efficiency gain by using paper instead of CPRS is likely to be illusory, since CPRS is available in both the physicians' workspace and every patient exam room in primary care. This example was also coded in the 'sensorimotor preferences' category.

4.2. *Efficiency implications for EHR design*

Efficiency was tied for most frequent reason for use of paper workarounds, many of which related to ordering. The efficiency finding for paper persistence has two distinct implications. One is that the paper workaround phenomena indicated the EHR was not sufficiently designed and does not efficiently support clinicians' work and/or is not aligned with clinicians' natural workflow. Secondly, some paper workarounds replaced important EHR documentation or circumvented critical EHR-designed safety checks. These workarounds may lead to potential gaps in documentation and potential patient safety risks.

Each case of paper use with the EHR should be examined to understand the potential impact. For example, one physician noted that he relied on a printed medication list from CPRS during the patient encounter so that he could efficiently go through the list, make handwritten notations, and mark which medications needed to be refilled. This important documentation must also be entered into CPRS (including dosage and administration changes) at some point, presumably later in the day. Otherwise these changes would not be reflected in the active medication orders in CPRS for the patient. Ideally, these changes would be entered at point of care without the additional paper-based step to avoid any potential gaps or delays in the EHR documentation.

4.3. *Relationship of clinicians' knowledge of the EHR, computer skill, and usability*

There were also numerous examples of paper use related to participants' knowledge, skill, or the ease of use of CPRS in terms of finding needed information. Several of these cases involved CPRS training. Although well-designed EHRs and related health IT should not require extensive training, simply making clinicians aware of functions that can help facilitate their work is critical to avoid continued use of old or redundant paper processes. The VA often has formal work-

groups, including clinical end-users, who advise developers on design updates. This practice should be conducted routinely in healthcare organizations that use health IT, as design updates should not be implemented without corresponding involvement from the end-users. Similarly, new employees need a comprehensive demonstration or tutorial of EHR functions that are core to their work processes. One pharmacist noted: "Another issue I've seen is that there's not much education done on order entry. The doctors are left to learn this on the job."

In addition, clinicians' computer skill level seemed to be a factor in use of paper processes. One administrator noted: "For the older docs, it's just easier to jot something down", implying that the younger, computer savvy physicians are more likely to adopt computer processes. Poor ease of use, or usability, of CPRS and related heath IT also led to the use of paper. For example, in the acute dialysis unit, usability issues hindered a new computer process intended to automate patient vitals entry into CPRS, and has delayed future roll-out to the rest of the dialysis service. These types of cases, relating to knowledge, skill, and ease of use, were all grouped together in one category since many of these examples related to more than one component (e.g., computer skill level *and* CPRS usability).

4.4. *Paper as a cognitive memory aid*

Memory was a factor for several paper-based processes. Paper served as a reminder about old or existing information and supplemented CPRS. In the transition from paper to electronic medical records, the role of paper has changed from a long-term storage medium to an important, temporary memory aid and disposable display device [2]. In some cases, these paper processes support and enhance clinicians' work in critical ways and should not be viewed as circumventions to using CPRS. For example, one pharmacist, when working in the inpatient wards, made hand notes on printouts from CPRS and transferred the new handwritten data back into CPRS later in the day. "The hand notes help me remember. I do this for discharges and inpatients... There can be 6–12 discharges/day. It is not possible to make these types of notes in CPRS [in real time]. I don't know how you would do this in the computer... We need paper to do our job."

The above example differs from outpatient exam rooms, where it *is* possible and reasonable to enter information in CPRS in real time via dedicated computer workstations. Inpatient rooms do not have dedicated computer workstations for CPRS. In addition, for environments like the inpatient ward or emergency department, advances in technology such as light weight notebook computers and highly usable personal digital assistants (PDAs) still do not necessarily afford the same level of convenience or integration into clinical workflow as paper and pen.

4.5. *Working with the sensorimotor preferences of EHR users*

In several examples, the use of paper-based redundancies to CPRS seemed to relate to the need for clinicians and staff to have something "tangible" in front of them for certain tasks. That is, there seemed to be a preference to feel (sense) an object and/or physically respond (motor) to it. These 'sensorimotor' preferences relate to the core human factors principle of fitting technology and tasks to the human rather than trying to make the human adapt; in general, they should not be considered as negative circumventions to CPRS.

In addition, many physicians use paper because they prefer not to use the computer during patient encounters and favor focused interaction with the patient. This social norm was observed in previous research [6]. However, in the VA, CPRS and its associated decision support was designed to be accessed and used at point-of-care. Therefore, there is a clear conflict between the designers' mental model and some of the clinicians' mental model of how the system should be used in practice. Further research is needed to help clinicians find strategies to communicate and build rapport with patients effectively and efficiently while using a computer.

4.6. *The signal to noise ratio in the EHR*

Several of the paper-based workarounds identified in this study related to awareness of new information. Paper processes were used to notify, alert, or prompt a clinician to take action based on new information. Many of these paper processes were redundant to electronic processes in CPRS. Several of these paper processes were used instead of, not in addition to, electronic processes. This suggests that electronic processes were either insufficient in terms of a signal to noise ratio (i.e., ability to alert clinicians reliably and consistently), a problem documented in other VA studies [17–24], or there may have been distrust in the reliance of electronic systems for transmitting this information. Designers should consider strategies to increase the signal to noise ratio in the EHR, such as decreasing the overall number of EHR alerts to minimize clinicians' desensitization.

4.7. *Work complexity and EHR data organization*

Paper workarounds were employed when CPRS did not support the specificity or complexity of the clinical task. The processes used in these cases were necessary "workarounds" and provide excellent data on potential strategies to improve and innovate the EHR. For example, one RN participant described her paper process for prioritizing walk-in patients by how sick they were. She then assigned and wrote an acuity level on each patient's sheet printed from CPRS, and then sorted the patient list by acuity level. Her approach helped ensure that walk-in patients with the greatest needs were seen first by the providers. This type of task complexity could possibly be designed in CPRS to potentially save staff time. Another source of paper-based workarounds related to data organization within CPRS and a need to view data longitudinally, a function that was insufficiently supported by CPRS. Results from our small-scale study suggest that future CPRS design should better incorporate flowcharting capability and the ability to predict trends based on the patient's data.

4.8. *Trust and security*

Finally, there were distinct examples of paper workarounds related to issues of trust and security. The perception that

Table 3 – Predicted sources of paper generation mapped to categories of paper-based workarounds.

Human-technology integration factors from Fig. 1	Paper-based workarounds by category from Table 2
d. *Cumbersome EHR interface design* leads to handwritten notations on paper forms	Efficiency, data organization, knowledge/skill/ease of use, memory, awareness, task specificity, task complexity, longitudinal data processes
e. *EHR not well integrated into clinical workflow* leads to paper-based workarounds that align with clinical workflow	Efficiency, memory, sensorimotor preferences, awareness, longitudinal data processes
f. *Visual organization of data in EHR incompatible with clinicians' mental model* leads to manual transformation of patient data	Efficiency, data organization, task specificity, task complexity
Other	Knowledge/skill/ease of use, sensorimotor preferences, trust, security

paper provides "proof," where the electronic documentation does not, was limited to a single participant and thus likely not an issue that leads to excessive use of paper. Similarly, while we reported a case where computer security led to paper use, this finding was also not widespread in our study.

4.9. *Paper as a marker of resistance to change*

Paper use may also be due to a resistance to change. In this particular study setting, the EHR was implemented about 10 years ago, so there was perhaps less resistance to change in terms of moving to an EHR in general, and more of a resistance to change as it relates to certain components of the EHR, such as order entry and viewing certain results. For example, we reported a case where physicians viewed printed MRI results instead of the electronic report. This seems to be in part a training or EHR usability issue in that some physicians simply do not know how or where to view the MRI report in CPRS and instead rely on the nurse or office manager to print the report for them when it becomes available. Thus, the physicians who rely on the nurses to print the report for them may not have the motivation or need to access the report electronically themselves, perhaps for some of the reasons listed in Table 2, and these scenarios indicate a reluctance to change to electronic processes.

4.10. *Linking results to conceptual framework*

Linking our findings back to the predicted sources of paper generation in Fig. 1, we found elements of (d), (e), and (f) across our list of 11 emergent categories (Table 3). The human-technology integration factors in Fig. 1 broadly included poor EHR interface design, poor integration of the EHR into clinical workflow, and an incompatibility of clinicians' mental models for working with clinical data in the EHR. For example, paper-based workarounds related to 'efficiency', one of our most frequently occurring categories, included cases that involved all three human-technology integration factors outlined in Fig. 1.

There were also cases where a category only partially corresponded to one of the predicted sources of paper generation (e.g., sensorimotor preferences) or did not correspond at all (e.g., security). These are represented in the last row of Table 3 ("Other"). For example, 'sensorimotor preferences' is represented by (e), "not well integrated into workflow", in cases where participants used paper because they preferred having paper notes with which to walk into and use in the patient's room. However, the case where a nurse preferred to "hear" paper being dropped in her basket (indicating a new unscheduled patient had checked in) is not represented by the predicted sources of paper generation in Fig. 1. Since frameworks and models are place-holders in time to describe current knowledge, the 11 categories outlined in Table 2 give a more comprehensive and descriptive representation of factors that lead to the persistent use of paper with the EHR at the human-technology integration level. These factors help us understand workflow and cognitive reasons individuals use paper rather than the EHR; this knowledge is important for informing future EHR design.

4.11. *Limitations*

Limitations of this study should be taken into consideration when interpreting the results. For example, we studied a single VAMC; including other VA hospitals may have provided a richer understanding of paper-based strategies. For example, a multiple-site study would have allowed us to explore and compare other factors such as site-specific culture and user preferences that may contribute to the use of paper. We did not comprehensively interview all services in the hospital or all types of EHR users. We used a convenience sample; a random sample would have been a more rigorous approach to achieve better representation of the population. However, we purposefully recruited participants such that several different service areas of the hospital were represented. Generalizability of our results to non-VA hospitals may be limited due to the unique characteristics of the VA's EHR. However, since the VA's EHR and associated health IT are recognized to be one of the most comprehensive and widely integrated electronic health systems, the VA's EHR is arguably an ideal system to derive generalizable findings related to the persistence of paper with the EHR, since other organizations' heath record systems tend to be more of a blend of computerized and paper charting.

5. Conclusions

We identified 11 categories of paper-based workarounds when using the EHR. In several cases, paper served as an important tool and assisted healthcare employees in their work (e.g., as a cognitive memory and awareness aid). In some cases, paper use also circumvented the intended EHR design. It is possible that information may not be documented in the EHR in a timely fashion or may even be lost. Paper use is beneficial to employees but also a potential source for information gaps and errors. Individuals must carefully consider the reasons clinicians are using paper, as well as their workflow and cogni-

Summary points

What is already known on this subject?

- Paper use persists even after implementing a fully integrated EHR.
- Paper can serve as an important cognitive aid and temporary display device for information in the EHR.
- Paper-based processes are not always inefficient or inferior to corresponding computer processes. However, paper processes may circumvent the intended use of the computer system, increase the opportunity for losing clinical information, and create new potential paths to medical error.
- Previous research had identified three factors that may lead clinicians to generate paper-based workarounds while using an EHR: (1) poor EHR interface design; (2) poor integration of the EHR into clinical workflow; (3) and an incompatibility between EHR designers' and clinicians' mental models for workflow.

What this study added to our knowledge?

- This study identified 11 categories that represent distinct types of paper-based workarounds associated with the EHR.
- These categories advance our knowledge and provide a more comprehensive understanding of human-technology integration factors that promote paper persistence after EHR implementation. This knowledge also helps us understand workflow and cognitive reasons individuals use paper rather than the EHR.
- Specific cases of paper workarounds documented in this study provide an opportunity to innovate EHR design to better support clinical work. For example, current advances in technology still do not necessarily afford the same level of convenience or integration into clinical workflow as paper and pen, or work with the sensorimotor preferences of the clinicians during patient care tasks.

tive demands, before an attempt is made to implement an EHR redesign and reduce paper persistence or use of a "shadow" paper chart [26,27]. It is also important to note that while many of the examples of paper use presented in this paper related to EHR design or implementation problems, some persistent paper use may also simply be due to a reluctance to change. In conclusion, paper-based workarounds identified in this small-scale study provide some evidence to improve EHR design to better support clinical work by eliminating the need for a paper process, or to consider ways to support the use of important paper supplementation without introducing the potential for gaps in EHR documentation. Further research involving multiple healthcare organizations and EHRs is needed to advance our knowledge of the persistence of paper with the EHR on a broader scale.

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Appendix A. Interview script for semi-structured interviews

Note: The following questions served as starting points for more in-depth, unstructured, exploration of topics.

Questions for clinician interview script:

- Any there any paper forms that you are required to process and file as a matter of policy?
- Do you ever print information from CPRS? If so, what do you print and why?
- What paper-sources do you use in your clinical work?
- Do patients themselves bring paper notes that you sometimes work from and file or eventually discard?
- What paper sources do you file in your clinical work vs. destroy? (personal file versus permanent File Room in basement)
- Have you ever experienced frustration in viewing or combining information from CPRS (e.g., patient data) during your clinical work? If so, please give example(s).
- Have you ever manually transformed patient data from CPRS onto paper to better organize information during your clinical work? If so, please give example(s).
- Have you or others in your clinic developed "workarounds" to circumvent "poor" CPRS design? If so, please explain.
- What is your ideal workflow during your clinical work and how does it related to CPRS?
- How can CPRS be better designed to meet your needs?

Questions for administrator and computer support interview script:

- Are there certain paper forms that are required by policy to be collected and filed? Which forms are they and what is their purpose?
- How are patient records and forms that originate from outside the VA handled?
- Are there workflow improvements that you envision that could eliminate or reduce production and storage of some paper forms? Please explain.
- Are there CPRS improvements that you envision that could eliminate or reduce production and storage of some paper forms? Please explain.

- Are you aware of any "incompatible" software packages as part of CPRS or separate from CPRS that may cause paper generation as a result (e.g., printing from one package and scanning into the other)?
- Are you aware of any "workarounds" that are used to circumvent "poor" CPRS design? If so, please explain.

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