Abstract
Errors associated with medication documentation account for a substantial fraction of preventable medical errors. Hence, the Joint Commission has called for the adoption of reconciliation strategies at all United States healthcare institutions. Although studies suggest that reconciliation tools can reduce errors, it remains unclear how best to implement systems and processes that are reliable and sensitive to clinical workflow. The authors designed a primary care process that supported reconciliation without compromising clinic efficiency. This manuscript describes the design and implementation of Automated Patient History Intake Device (APHID): ambulatory check-in kiosks that allow patients to review the names, dosage, frequency, and pictures of their medications before their appointment. Medication lists are retrieved from the electronic health record and patient updates are captured and reviewed by providers during the clinic session. Results from the roll-in phase indicate the device is easy for patients to use and integrates well with clinic workflow.

Introduction
Important medication errors often occur at handoffs in care because of changes in health status, discontinuity in providers, and gaps in patient information.\textsuperscript{1,2} Many errors are the result of discrepancies between prescriptions written at different times by the same or different providers for the same patient. Although initial studies suggest that processes directed at medication reconciliation may reduce discrepancies by up to 75\%,\textsuperscript{3,4} these benefits have been difficult to reproduce or implement.\textsuperscript{5} Some institutions use dedicated personnel such as pharmacists to identify medication changes,\textsuperscript{1} whereas others rely upon traditional clinic resources including the primary care provider,\textsuperscript{6} raising concerns about clinic productivity. Most providers struggle to reconcile fragmented lists in a time-sensitive manner, particularly when many patients have difficulty recognizing pills by name. One study showed that only 50\% of discharged patients could recall their medications by name within three days of hospitalization but over 75\% could accurately identify medications by indication.\textsuperscript{7} Thus, opportunities exist to create tools that improve patients’ abilities to provide a complete and accurate medication history.

The Portland Veterans Affairs Medical Center (PVAMC) attempted to improve the accuracy and sustainability of ambulatory medication reconciliation by developing the Automated Patient History Intake Device (APHID), a self check-in kiosk and reconciliation tool for the ambulatory care setting. The goals of APHID were twofold: (1) improve the accuracy of the medication history by showing patients digital pictures of their medications on record, and (2) integrate APHID into current business processes to promote use and minimize interruptions to workflow. The purpose of this manuscript is to describe our project design and implementation, review our preliminary findings on feasibility, and discuss the barriers to adoption encountered by the development team.
System Design and Data Management

The APHID consists of locally developed software accessed by patients using kiosks located in the clinic lobby. We used a client-server model managed by local information technology (IT) personnel and run on a closed virtual local area network (VLAN) (see Appendix, Fig 1, available as an online data supplement at http://www.jamia.org). A server hosting the software connects to kiosks, which are actually computer workstations comprised of a flash drive processor, touch-responsive monitor, keyboard, mouse, and magnetic stripe card reader. This set-up was selected for its cost-effectiveness, ease of installation, and nominal maintenance needs. A graphic user interface (GUI) written in Object Pascal allows patients to check-in for an appointment and review contact and billing information. The APHID also runs a medication history module for patients to review their medications. Each medication prescribed and dispensed by the VA is displayed along with a digital image of the pill. The pill images are stored in a separate database located on the server and mapped to prescriptions using the Food and Drug Administration’s National Drug Code (NDC) number. Patients indicate their compliance history (i.e., if and how they are taking their medications) using touch-screen buttons and entering additional comments about each drug in a free-text dialog box (Fig 1). Patients are also prompted to enter information about previously unknown prescriptions written by non-VA providers or report any over-the-counter medications. These non-VA medications can be transcribed by a staff member into the VA’s Computerized Patient Record System (CPRS). The names and doses of these medications can then be displayed by APHID on subsequent visits, although they are absent an NDC number and cannot be paired with an image.

The software also includes an interface written in MUMPS that connects to CPRS. Medical staff reviews patient-entered information using a specially designed health record note template. The template lists the patients’ VA prescriptions and compliance history entered using APHID (see Appendix, Fig 2). The APHID program does not overwrite any data in the health record, nor does it change any medication prescriptions. It is an expectation of all staff to validate information obtained via the kiosk and update the medical record.

Setting

The PVAMC is an integrated-care organization that supports prescribing and dispensing activities and archives all transactions in the Veterans Health Information System and Technology Architecture (VISTA) database. The primary care division manages 40,000 veterans across 6 clinic locations and completes an estimated 84,800 outpatient visits per year. Providers in these clinics use CPRS to retrieve both medication lists and dispense histories from VISTA. The Portland Campus, which employs 35 primary care providers and 45 residents, was selected for the first installation site because it is the largest volume primary care clinic and is centrally located in our care network. We installed four 0.9

Figure 1. Workflow process for primary care clinic with new process steps indicated in bold font.

Figure 2. Screenshot of APHID reconciliation survey using pill picture.
meters by 1.2 meters cubicles fitted with APHID terminals in the clinic lobby across from clerical staff workstations.

**Description of Project Implementation**

Our project team used health failure mode and effect analysis, a proactive model for system risk assessment, to understand VA primary care workflow and identify process steps to complete medication reconciliation. We observed sixteen providers and medical assistants (MA) to map out clinic throughput, common tasks, and existing reconciliation processes. The project team then generated a workflow diagram to highlight weak processes and outlined a “best practice” strategy using APHID technology (Fig 2). Finally, the team helped implement the new process by working with staff to define roles and responsibilities.

Process steps were delegated to several members of the care team to distribute workload, foster collaboration, and increase the understanding of a common goal towards medication reconciliation. Check-in staff were instructed to proctor workstations and encourage patient use of APHID. Medical assistants were required to generate the templated health record note using CPRS workstations in the examination room. Providers could review the note before entering the examination room or during the patient interview. Although consideration was given to interacting directly with the medication list, this would have required development of more complicated logic and an information model to interpret patient-entered data. We also wanted the provider to critically review patient responses before addressing discrepancies.

We observed patients using early versions of APHID and we collected field notes which informed subsequent designs. Next, we assembled patient focus groups to refine the software. The final product reflects the intersection of patient comments, task specifics, and technology limitations. A product roll-in phase was conducted over a 1-month interval using a convenience sample of 16 providers. Initially, several large-group training sessions were conducted with primary care staff and educational handouts were distributed. Throughout the roll-in phase, the APHID project team proctored workstations and assisted staff with clinical charting tasks. During weeks 1 and 2, feedback sessions focusing on information clarity and process design were held with providers using predefined structured questions. During weeks 3 and 4, a 6-item paper questionnaire adapted from a previously published software usability tool was handed to 75 consecutive patients immediately after using APHID (see Appendix Fig 3). The purpose of the questionnaire was to assess interface ease of use. Patients were asked to complete and return the form to a Proctor before leaving the clinic. We excluded patients with cognitive, sensory, or motor impairment. Patients with multiple appointments were surveyed only once.

Following the 1 month roll-in phase, kiosks were left in production for an additional six months to assess sustainability of the model. We recorded the number of patients checked-in by the program in comparison to the total number of patients with primary care appointments at the Portland Campus.

**Findings**

Workflow analysis showed that providers and support staff used a heterogeneous array of ad hoc processes rather than a systematic approach to medication reconciliation. Not all providers reviewed medications and only a few clinics used paper handouts or memory aids. A small number of providers reviewed medication fill activity or recently expired prescriptions to validate patient histories. Overall, clinics lacked a clearly defined pathway to reconcile medications and most providers believed that associated activities were unpredictable, redundant, and error-prone.

During the 1 month roll-in phase, 1,371 patients checked-in using APHID. Table 1 describes the demographic characteristics of this cohort. Patients using APHID were typical of a veteran population. Over the ensuing six months, an additional 8,170 of a potential 17,275 patients (47%) checked-in using APHID. The pattern of use showed high usage in the first month following implementation, but gradually decreased with time.

![Figure 3](image-url) APHID use statistics in the Portland primary care clinics.

**Table 1** Patient Cohort Demographics During Roll-in

<table>
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<th>Category</th>
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<tr>
<td>Mean age in years (sd)</td>
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<td>21–93</td>
<td>1371</td>
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<tr>
<td>Male gender (%)</td>
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<td>Average time at kiosk in minutes (patients adding new medications) (sd)</td>
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<td>Average time at kiosk in minutes (patients only reviewing previously documented medications) (sd)</td>
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<td>Average time at kiosk in minutes (patients without medications) (sd)</td>
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<td>Average number of medications reviewed (sd)</td>
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<tr>
<td>Average number of medications added (sd)</td>
<td>2.3 (2.1)</td>
<td>1–14</td>
<td>373</td>
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dropped to a nadir of 30% during the fourth month in production. By the end of the seventh and final month of tracking, APHID check-ins had shown improvement and increased to 50% (Fig 3).

Of the 75 patients surveyed, 69 completed and returned the usability questionnaire (see Appendix, Table 1). Even though many patients (51.5%) reported being unfamiliar with computers, the majority indicated that the product was both easy to use (75.4%) and easy to navigate (66.7%). Most patients thought the medical information was easy to understand (94.2%) and believed the program improved their medication recall (66.6%).

During the feedback sessions, most staff reported that the information provided by APHID helped with the task of history collection. However, many felt that the volume of medications to review and formatting of medication lists made it challenging to quickly identify important discrepancies needing action. Providers also felt overwhelmed with the new responsibility of medication reconciliation and tended to associate the increased workload with the software tool. Some clinicians were also reticent to address discrepancies that fell outside of their content area or prescribing responsibility.

**Lessons Learned**

Several conclusions can be drawn from our findings that may inform subsequent projects using consumer informatics to manage medication reconciliation. First, our preliminary observations suggest that patients with little to no computer experience can use an electronic kiosk to complete a medication history. The inclusion of pill pictures may improve patient recall, although this needs to be formally tested.

Second, the operational success of kiosk technology is largely dependent upon associated workflow processes and organizational behavior. Our statistics showed a fluctuating pattern of use over a seven month interval despite high patient usability scores. Several organizational characteristics might account for this finding. Initial administrative staff skepticism meant that terminals were left unattended and thus, less likely to be used by patients. Clinicians were not explicitly incentivized to participate in a process with added clinical responsibilities. Hence, providers could forgo reconciliation tasks if there were competing demands. Finally, the check-in procedures were very sensitive to clinic workflow patterns. During our observational period, the introduction of seasonal flu clinics changed the pre-existing check-in procedure and effectively bypassed the APHID terminals.

Third, infrastructure barriers made the design process more complex, limiting the scope of the project. We did not have access to a public domain pharmaceutical picture repository and were forced to assemble a local archive, which was very resource intensive. Furthermore, the fragmentation of health information systems prevented us from matching pictures to non-VA prescriptions. Therefore it would be challenging to reproduce this system outside the VA in any health organization that does not directly control medication distribution.

Several considerations may limit generalization of our results. First, APHID has only been tested in ambulatory clinics serving a veteran population. Second, we have not yet validated the accuracy of the kiosk history in comparison to traditional methods of data collection for medication reconciliation including paper forms and pharmacist interviews. Third, the feedback gathered from a convenience sample of providers may not be representative of all VA providers. Finally, we must test the system’s ability to influence provider reconciliation activities.

**Conclusions**

We believe that a consumer-based kiosk offers a feasible model to align the safety and efficiency needs of a health system by gathering a medication history and supporting clinic throughput. However, careful attention must be directed toward associated processes and staff buy-in to address the additional burden created by reconciliation activities. Sites considering use of kiosk technology are advised to dedicate resources to influence organizational culture. This may include development of local reconciliation policies and educational materials, securing stakeholder buy-in through clinician incentives, and identifying a priori measures to track performance.

**Next Steps**

For the purposes of quality assurance, it is crucial to assess functional performance of the device. Functional performance may be defined as the ability of a process to help improve organizational compliance with a practice or safety standard. Therefore, we intend to develop and track APHID performance metrics that map to Joint Commission accreditation safety goals.

It is also crucial to measure the accuracy of the medication history collected using APHID. The interface is analogous to a diagnostic test where performance characteristics should be measured in comparison to an accepted standard, such as a validated history or physician interview. We intend to measure the sensitivity and specificity of an APHID session when compared to a structured clinician pill review.

Finally, it is important to install and assess APHID at other facilities. This helps measure the reliability and interoperability of an information technology tool in disparate care environments. We, therefore, intend to conduct a series of test installations in sister VA hospitals over the forthcoming year.

**References**