Design, Implementation, Utilization, and Sustainability of a Fast Healthcare Interoperability Resources–Based Inpatient Rounding List

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Abstract

Objective We designed and implemented an application programming interface (API)-based electronic health record (EHR)-integrated rounding list and evaluated acceptability, clinician satisfaction, information accuracy, and efficiency related to the application.

Methods We developed and integrated an application, employing iterative design techniques with user feedback. EHR and application user action logs, as well as hospital safety reports, were evaluated. Rounding preparation characteristics were obtained through surveys before and after application integration. To evaluate usability, inpatient providers, including residents, fellows, and attendings were surveyed 2 weeks prior to and 6 months after enterprise-wide EHR application integration. Our primary outcome was provider time savings measured by user action logs; secondary outcomes include provider satisfaction.

Results The application was widely adopted by inpatient providers, with more than 69% of all inpatients queried by the application within 6 months of deployment. Application utilization was sustained throughout the study period with 79% (interquartile range [IQR]: 76, 82) of enterprise-wide unique patients accessed per weekday. EHR action logs showed application users spent −3.24 minutes per day (95% confidence interval [CI]: −6.8, 0.33), $p = 0.07$ within the EHR compared with nonusers. Median self-reported chart review time for attendings decreased from 30 minutes (IQR: 15, 60) to 20 minutes (IQR: 10, 45) after application integration ($p = 0.04$). Self-reported sign-out preparation time decreased by a median of 5 minutes ($p < 0.01$), and

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- medical informatics
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providers were better prepared for hand-offs ($p = 0.02$). There were no increased safety reports during the study period.

Conclusion This study demonstrates successful integration of a rounding application within a commercial EHR using APIs. We demonstrate increasing both provider-reported satisfaction and time savings. Rounding lists provided more accurate and timely information for rounds. Application usage was sustained across multiple specialties at 42 months. Other application designers should consider data density, optimization of provider workflows, and using real-time data transfer using novel tools when designing an application.

Background and Significance

Inpatient clinicians often spend 30 to 60 minutes creating a "rounding list" daily. This process requires reviewing a variety of electronic health record (EHR) data, including vital signs, medications, laboratory, and imaging results.[1–3] Creation of a rounding list is necessary to understand a patient's clinical condition, their progress during the admission, to formulate plans for the day, and to coordinate discharge. More than one-third of daily EHR usage is in chart review tasks,[4,5] and providers often print or transcribe these data to paper.[1,6–8] Clinicians prefer daily printed lists for rounding for portability despite electronically available resources.[6,9]

Transcribing this data can lead to inadvertent omission, inaccurate, or incorrect data.[6,10] One study showed that 22% of data were missing from prerounding notes.[10] Additionally, nearly 40% of laboratory data were inaccurately communicated from prerounding notes, and only 7% of these inaccuracies were identified during rounds.[6] Other studies have described the use of inpatient and/or automated rounding lists but were usually available only to a local institution and had limited integration at other sites given lack of interoperability.[3,11–17] Other applications, such as List Runner or Rounds List, offer digital-only solutions for patient list management, but to our knowledge, published literature regarding enterprise-wide adoption, long-term sustainability, and EHR-integration of these tools is lacking. Furthermore, these tools seemingly require data entry by the clinician into a secondary application often increasing documentation burden, whereas, most clinicians require immediate data. Similarly, other lists are created outside the EHR in a word processing or spreadsheet document without a direct interface with the EHR. These lists are often housed in unsecured "shadow" databases on hard drives, networks, or in the cloud which serve as a source of liability.[8] Although most EHRs have rounding and hand-off functions, these reports can produce a single page per patient, require configuration, may lack necessary data, and are not user customizable.

This study aimed to (1) design and implement a secure, robust, clinician-friendly, user-customizable rounding list application embedded within a complex commercial EHR to automatically generate rounding lists using an API based approach; (2) evaluate EHR-reported provider chart-review time before and after application integration; and (3) evaluate self-reported provider satisfaction, application usage, provider chart review time, and data accuracy before and after application integration.

Methods

Ethical Approval

This study was approved by the Institutional Review Board (identifier: IRB00073502).

Application Design, Development, and Integration

The creation of the application was intended to automatically generate an inpatient rounding list by pulling data from the EHR. Specific application programming requirements were determined by the application programming team and previously utilized by other developers.[18–20] Requirements include that it generates a short 1- to 2-page list, displays laboratories in the same format as used on paper lists, condenses patient information, is real time and accurate, and is user customizable.

We used agile development principles for the design and integration of the application into the EHR at a tertiary care academic medical center, consisting of 1,535 system-wide beds, 60,023 inpatient admissions and observations per year, and 19,220 system-wide professionals, including more than 700 residents and fellows. This architecture allows for application portability across Epic hospital instances. Initial data elements, including patient demographics, location, diagnosis, 24-hour vital sign ranges, diet, intake and output, laboratory, imaging, procedure, and hand-off fields were included. Metabolic and blood count data were displayed in standardized shorthand "fishbone" diagrams.[21] Medications were programmed to display conventional names but allowed an individual user to further customize. (For example, "0.9% sodium chloride" is the order name in the EHR. The application displays as "NS," but is customizable to "Normal Saline" or "Saline," or any other designation written by the user). Graphical displays were iteratively developed by physicians and the technical team until data were displayed in a user friendly and compact format.

The application was α-tested by the two physician developers to ensure the application was functioning as intended. After numerous bug fixes and user-interface updates, the application was β-tested by 371 users in July 2017. The application was released enterprise wide on August 21, 2017.

To test the initial design, β-users were recruited through "word-of-mouth" and were also able to sign-up for β-use when clicking on the application-launch button embedded within the EHR prior to enterprise-wide application deployment. We sought β-users to provide feedback on unseen barriers and challenges 6 weeks prior to enterprise-wide application integration. The application was integrated into the inpatient EHR for clinicians and displays within an embedded window in the EHR and can be printed on paper. We leveraged the Health Level 7 (HL7) Fast Healthcare Interoperability Resources (FHIR)[22] standard RESTful Application Programming Interface (APIs). When FHIR APIs were not available for a needed data element, we leveraged Epic RESTful APIs. The application design required a hybrid design approach as the APIs utilized changed over time as they matured. Please see supplementary table (►**Supplementary Table S1**, available in the online version) for additional details about the APIs leveraged.

A β-user-feedback mechanism was built into the application for point of use feedback for which messages were routed to two physician developers and the application developer. From β-user feedback, 48-hour laboratory value trends, portrait, and landscape orientation, font size, list sharing functions, multiple list creation by a single user, and integration of commonly used phone numbers were designed and integrated. An example inpatient rounding list shows pertinent data for inpatient rounding (►**Fig. 1**). Sensitive diagnoses, for example, HIV and psychiatric disorders, can be obscured and replaced with "Ø." List customization was considered an essential component of application adoption. Hence, all printed data elements can be customized by the end user (►**Fig. 2**). Customizations exist for hospital units, medications, rooms, procedures, studies, laboratory values, and EHR-specific structured data capture (i.e., vital signs, intake/output, ventilator settings, pain scales, nursing documentation, and others).

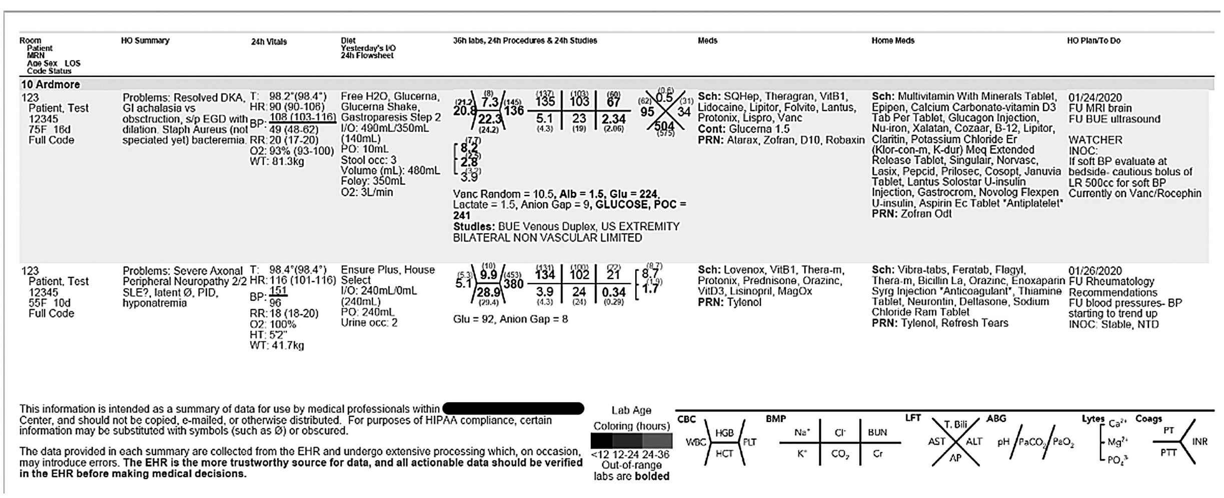
Data Collection

Electronic Health Record User Action Log

The EHR user action logs recorded user actions at 2-week intervals, from June 2017 to February 2018 which was 2 months prior to and 6 months after application integration for all EHR users with provider inpatient security access, regardless of application utilization. We extracted the user ID, action type (description of the user action within the EHR), and action instant (date–time stamp). Analytic datasets were created to evaluate the amount of time users spent within the inpatient EHR functions, including reviewing medications, orders, laboratory results, the amount of time writing notes, and the total amount of time spent within the EHR between the hours of 6 to 10 a.m., as this is when inpatient rounds typically occur. Provider demographics and hospital census by day were obtained from the EHR.

Application Utilization

We evaluated application utilization through total cumulative number of users, active number of users per day, number of lists generated per day, total number of patients accessed per day, and total number of unique patients accessed per day across the health system at months 1 through 6 after application integration, and also at month 42. Due to a database issue, two weeks of utilization data (January 23, 2018–February 4, 2018) are missing and could not be used in the evaluation. Eight outliers were removed from the data due to a programmatic flaw that allowed for lists to be generated for outpatients.



Room / Patient / MRN / Age Sex LOS / Code Status	HO Summary	24h Vitals	Diet / Yesterday's I/O / 24h Flowsheet	36h labs, 24h Procedures & 24h Studies	Meds	Home Meds	HO Plan/To Do
10 Ardmore							
123 Patient, Test 12345 75F 16d Full Code	Problems: Resolved DKA, GI achalasia vs obstruction, s/p EGD with dilation. Staph Aureus (not speciated yet) bacteremia.	T: 98.2°(98.4°) HR: 90 (90-106) BP: 108 (103-116) / 49 (48-62) RR: 20 (17-20) O2: 93% (93-100) WT: 81.3kg	Free H2O, Glucerna, Glucerna Shake, Gastroparesis Step 2 I/O: 490mL/350mL (140mL) PO: 10mL Stool occ: 3 Volume (mL): 480mL Foley: 350mL O2: 3L/min	20.8 (21.2) 7.3 (8) 22.3 (24.2) 136 (145); 135 (137) 103 (103) 67 (60) / 5.1 (4.3) 23 (19) 2.34 (2.06); 0.5 (0.6) 95 (62) 34 (31) 504 (575); 8.2 (7.7) 2.8 (2.5) 3.9 (3.2) Vanc Random = 10.5, **Alb = 1.5, Glu = 224**, Lactate = 1.5, Anion Gap = 9, **GLUCOSE, POC = 241** **Studies:** BUE Venous Duplex, US EXTREMITY BILATERAL NON VASCULAR LIMITED	**Sch:** SQHep, Theragran, VitB1, Lidocaine, Lipitor, Folvite, Lantus, Protonix, Lispro, Vanc **Cont:** Glucerna 1.5 **PRN:** Atarax, Zofran, D10, Robaxin	**Sch:** Multivitamin With Minerals Tablet, Epipen, Calcium Carbonate-vitamin D3 Tab Per Tablet, Glucagon Injection, Nu-iron, Xalatan, Cozaar, B-12, Lipitor, Claritin, Potassium Chloride Er (Klor-con-m, K-dur) Meq Extended Release Tablet, Singulair, Norvasc, Lasix, Pepcid, Prilosec, Cosopt, Januvia Tablet, Lantus Solostar U-insulin Injection, Gastrocrom, Novolog Flexpen U-insulin, Aspirin Ec Tablet "Antiplatelet" **PRN:** Zofran Odt	01/24/2020 FU MRI brain FU BUE ultrasound WATCHER INOC: If soft BP evaluate at bedside- cautious bolus of LR 500cc for soft BP Currently on Vanc/Rocephin
123 Patient, Test 12345 55F 10d Full Code	Problems: Severe Axonal Peripheral Neuropathy 2/2 SLE?, latent Ø, PID, hyponatremia	T: 98.4°(98.4°) HR: 116 (101-116) BP: 151 / 96 RR: 18 (18-20) O2: 100% HT: 5'2" WT: 41.7kg	Ensure Plus, House Select I/O: 240mL/0mL (240mL) PO: 240mL Urine occ: 2	5.1 (5.3) 9.9 (10) 28.9 (29.4) 380 (453); 134 (131) 102 (100) 21 (22) / 3.9 (4.3) 24 (24) 0.34 (0.29); 8.7 (8.7) 1.7 (1.9) Glu = 92, Anion Gap = 8	**Sch:** Lovenox, VitB1, Thera-m, Protonix, Prednisone, Orazinc, VitD3, Lisinopril, MagOx **PRN:** Tylenol	**Sch:** Vibra-tabs, Feratab, Flagyl, Thera-m, Bicillin La, Orazinc, Enoxaparin Syrg Injection "Anticoagulant", Thiamine Tablet, Neurontin, Deltasone, Sodium Chloride Ram Tablet **PRN:** Tylenol, Refresh Tears	01/26/2020 FU Rheumatology Recommendations FU blood pressures- BP starting to trend up INOC: Stable, NTD

This information is intended as a summary of data for use by medical professionals within [redacted] Center, and should not be copied, e-mailed, or otherwise distributed. For purposes of HIPAA compliance, certain information may be substituted with symbols (such as Ø) or obscured.

The data provided in each summary are collected from the EHR and undergo extensive processing which, on occasion, may introduce errors. **The EHR is the more trustworthy source for data, and all actionable data should be verified in the EHR before making medical decisions.**

Lab Age Coloring (hours) <12 12-24 24-36 Out-of-range labs are **bolded**

CBC: WBC, HGB, HCT, PLT — BMP: Na+, Cl-, BUN, K+, CO2, Cr — LFT: T. Bili, AST, ALT, AP — ABG: pH / PaCO2 / PaO2 — Lytes: Ca2+, Mg2+, PO4 — Coags: PT, PTT, INR

Fig. 1 Example of inpatient rounding list. List generated using Health Level 7 (HL7) fast healthcare interoperability resources (FHIR) standard RESTful application programming interface (APIs) and EHR-vendor specific APIs. Sensitive diagnosis is obfuscated for the second patient. Notable features include data density and laboratory trends. Customizations exist for hospital units, medications, rooms, procedures, studies, laboratory values, and EHR-specific structured data capture (i.e., vital signs, intake/output, ventilator settings, pain scales, nursing documentation, etc.). EHR, electronic health record.

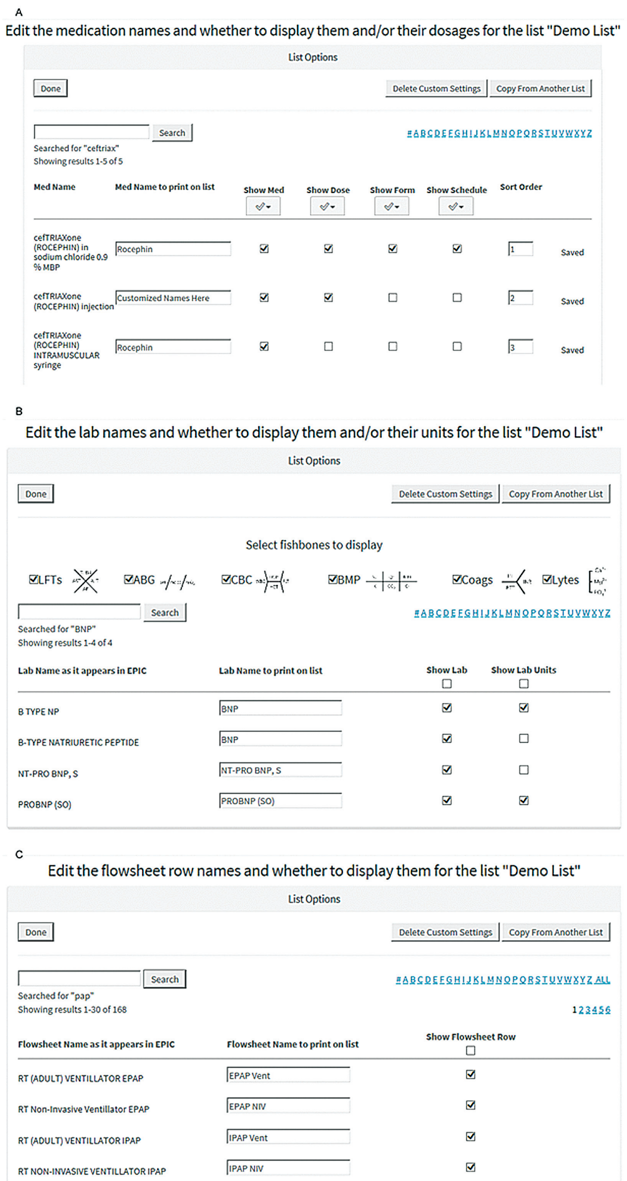


Fig. 2 Configuration of list customization features for medications and labs. (**A**) Printed list medication name can be user-customized. The dose, form, and schedule are also customizable. Medications can be sorted per user preferences. (**B**) Laboratory names can be customized to commonly used provider short-hand nomenclature, such as "BNP" rather than "B type NP" or "B-Type Natriuretic Peptide." The laboratory result, as well as unit display, can be customizable. Shorthand "fishbone" diagrams can be configured to display commonly ordered laboratories. (**C**) All flowsheet rows available in the EHR can be displayed with list-level customization features, such as vent settings.

Survey Data

To evaluate usability, all providers with inpatient security access, including medical and surgical residents, fellows, and attendings were surveyed using REDCap[23,24] 2 weeks prior to and 6 months after enterprise-wide EHR application integration (►**Supplementary Table S2**, available in the online version). The survey was redistributed to all nonresponders after 2 weeks. The first survey question asks if the respondent provides inpatient care; if the response was "no," the survey was completed. User demographics, provider-reported task completion time, and printed list characteristics were obtained. The burden of preparing for rounds and rounding tool satisfaction were measured on a 0 to 100 continuous scale, with lower numbers indicating low burden, or low satisfaction, respectively. Estimated percent of inaccurate data and patient harm instances were obtained through the questions "Roughly what percentage of the time are there inaccuracies on your printed list due to transcription errors or information that has not been updated?," "Can you recall any times when inaccuracies on your inpatient list have results in nonharmful adverse effects on patient care?," and "Can you recall any times when inaccuracies on your inpatient list have resulted in patient harm?."

Safety Event Reporting

We queried our internal hospital safety event reporting system 6 months prior to and 6 months after application integration across the entire medical center. Reports are described by a care team member. The safety team reviews each entry and classifies by harm scores (i.e., no harm and harm) and safety event classification (i.e., moderate temporary harm and severe permanent harm).

Outcome Measures

Our primary outcome of interest was provider time savings as measured by user action logs. Secondary outcomes include self-reported provider time-savings, self-reported improvement in efficiency, satisfaction with prerounding data collection, impact of patient harm, and accuracy of inpatient rounding lists through survey data. These outcomes were measured through the survey given to the inpatient providers. Additional secondary outcomes included changes in the number of clinical safety events reported through our institution's safety event reporting system during the study period. Time 0 is defined as enterprise-wide application deployment.

Statistical Analysis

Baseline characteristics were evaluated using the Wilcox's rank-sum test, Kruskal–Wallis equality of populations rank test, and median and interquartile range (IQR), as appropriate. Nonparametric test for trend across ordered groups was used for evaluation of application usage by month for the first 6 months; month was defined as a 30-day interval. Linear regression was leveraged to analyze application usage over the course of the study period with nonparametric variables transformed as necessary. To evaluate changes in provider EHR usage after application integration, we developed propensity scores to limit confounding by application usage. The propensity score included the users years of experience in the institution's EHR, user age in decades, primary versus subspecialty provider, user sex, and if user was a resident. An application user was defined as providers with >10 application uses, as this would indicate regular usage, rather than a user who launched the application out of curiosity, mistake, or because a colleague mentioned the rounding application. We used mixed effects linear regression with random

Table 1 Application utilization characteristics

	Month 1 Median [IQR]	Month 6 Median [IQR]	Month 42 Median [IQR]
Number of users per day	74 [48, 95]	108 [75, 133][b]	167 [119, 195]
Number of lists generated per day	188 [135, 218]	210 [142, 234]	264 [212, 312]
Number of unique patients accessed per day	575 [442, 608]	685 [597, 727][b]	782 [698, 875]
[a]Percentage of enterprise-wide unique patients accessed per weekday	62 [59, 65]	68 [65, 72][b]	75 [72, 76]

Abbreviation: IQR, interquartile range.
[a]The following outliers were removed from the data due to a programmatic flaw allowing for lists to be generated on outpatients (September 1, 2017–340.58%; September 8, 2017–124.75%; September 29, 2017–123.02%; October 30, 2017–113.64%; November 8, 2017–112.56%; November 10, 2017–122.88%; January 16, 2018–110.53%; January 17, 2018–104.32%). The programming flaw was corrected in February 2018.
[b]When comparing trends from month 1 through month 6, denotes statistical significance $p < 0.05$.

intercepts to test the association of provider time spent within the EHR before and after application integration through an interaction term and also adjusted for the daily inpatient census and propensity to use the application. Provider was a random effect. Statistical analysis was completed using Stata 16.1 and R version 4.0.5.

Results

Application Utilization

Application utilization had rapid adoption with a median number of active daily users of 85 (IQR: 80, 97) and 74 (IQR: 48, 95) on weekdays and all days, respectively, during the first month (►Table 1). Usage continued to increase over time and the overall positive trend in active daily user was statistically significant ($p < 0.01$). When adjusting for weekend and inpatient census, a median of 123 (IQR: 121, 136) active weekday daily users by month 6 and 191 (IQR: 185, 197) active weekday daily users by month 42 (►Fig. 3) were found. The association between number of active weekday daily users and months since deployment remained statistically significant ($p < 0.01$). Similarly, the number of lists generated also increased rapidly. There were a median of 188 (IQR: 135, 218) daily lists created within month 1. The number of daily lists increased to a median of 210 (IQR: 142, 234) by month 6, and 264 (IQR: 212, 312) by month 42. However, the increasing trend in number of lists generated per day was not found to be statistically significant ($p = 0.34$).

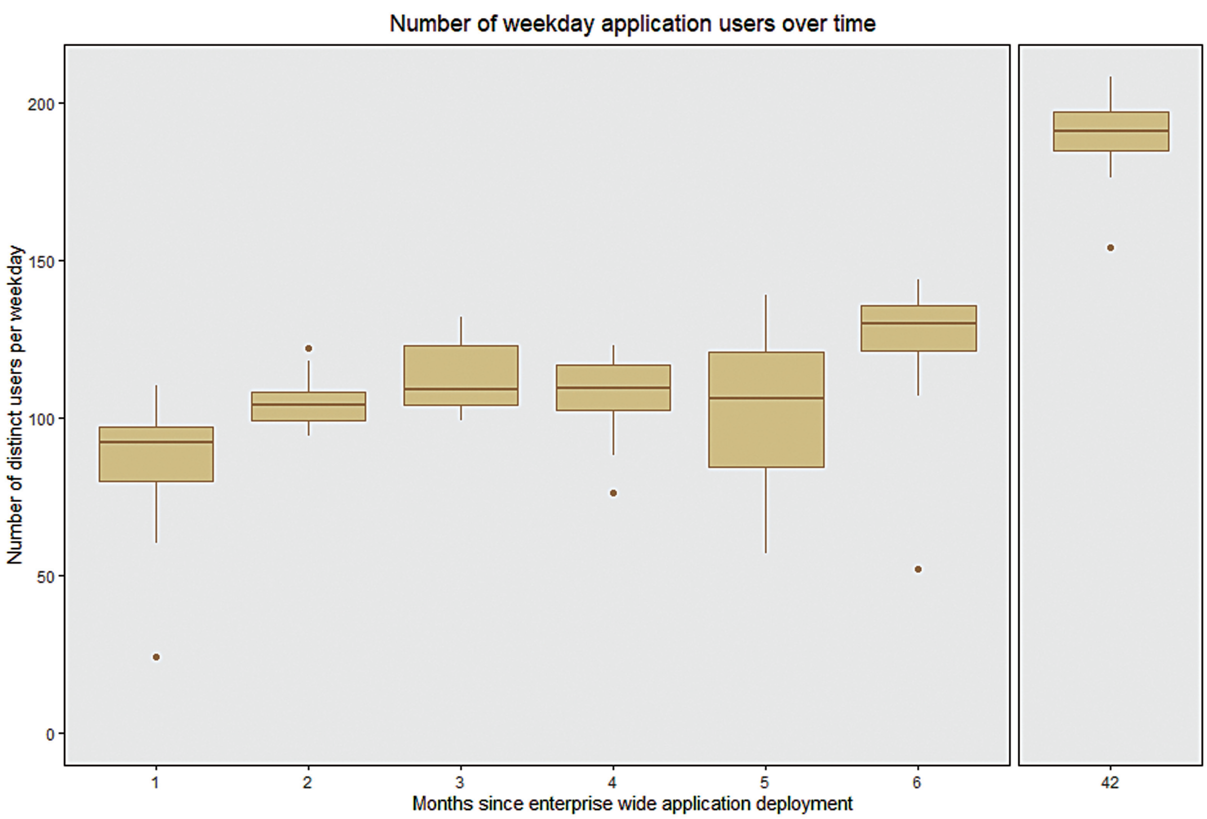


Fig. 3 Number of weekday application users over time. The number of weekday application users continued to increase over time.

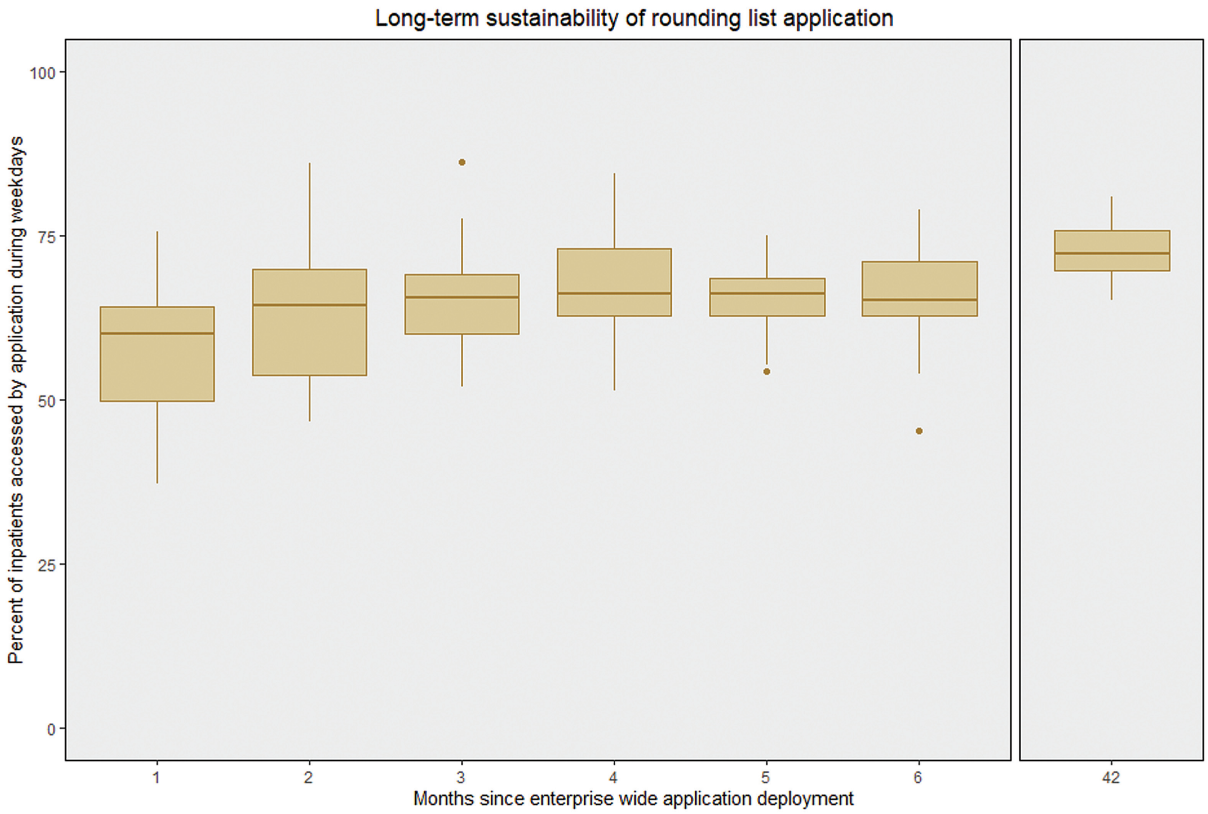


Fig. 4 Long-term sustainability of the inpatient rounding list application. The percentage of unique inpatients accessed by application during the weekdays increased and was sustained over time.

In addition, the percent of census patients queried by the application per day continued to significantly increase over time ($p < 0.01$). The median percentage of unique patients accessed by the application per weekday was 62% (IQR: 59, 65%) by month 1, 68% (IQR: 65, 72%) by month 6, and 75% (IQR: 72, 76%) by month 42. The percentage of patients accessed by the application significantly increased over time ($p < 0.01$; ►Fig. 4).

Electronic Health Record User Action Log

When accounting for application user characteristics and hospital census described as change in pre- and postimplementation (in the propensity score adjusted model), application users spent −3.24 minutes per day within the EHR after application integration (95% confidence interval [CI]: −6.8, 0.33), $p = 0.07$, indicating a trend toward time savings among application users.

Survey Data

Of the 2,962 and 2,964 surveys distributed before and after application integration, 280 (9%) and 317 (11%) were completed, respectively. The majority of surveys were completed by residents, fellows, or teaching service attending physicians (►Table 2).

Eighty percent of baseline respondents agreed or strongly agreed that a paper list was a necessary and vital component of patient care. Application usage was widely accepted by survey respondents, with the majority using the application-generated list rather than other lists including native EHR list functionality at 6 months. Of the application user survey respondents, 142 (69%) used the application more than 75% of the time when preparing for rounds. Median self-reported chart review time for attending providers decreased from 30 minutes (IQR: 15, 60) to 20 minutes (IQR: 10, 45) after application integration ($p = 0.04$). Among medical students, residents, and fellow trainees, there was a statistically significant decrease in overall chart review time ($p = 0.02$). Similarly, sign-out list preparation time decreased by a median of 5 minutes per provider ($p < 0.01$) and providers reported that they were better prepared for patient-care hand-offs ($p = 0.02$). Users also reported increased satisfaction of their rounding list ($p < 0.01$) and decreased burden of preparing for rounds ($p = 0.02$) after application integration. Respondents self-reported that application data were more accurate and there were fewer adverse events affecting patient care. Among application users, 93% recommend the application to a colleague and prefer it more than their prior rounding list.

Of the 17 medical students surveyed at 6 months, 15 (88%) felt that the application has made them significantly more or slightly more integrated into the medical team. The majority population (76%) think that they have assumed more responsibility within the care team because of this application.

Attending providers felt that the application facilitated learning through freeing up time for teaching and demonstration on the wards (37%); promoted laboratory interpretation and presentation skills (31%); demonstrated the natural flow of a patient presentation (26%); allowed

Table 2 User-reported survey data prior to and 6 months after hospital-wide application integration

	Baseline (*n* = 280) *n* (%)/median [IQR]	6 month (*n* = 317) *n* (%)/median [IQR]	*p*-Value
Clinical role			
Resident/fellow	100 (37)	123 (39)	0.46
Medical student	20 (7)	19 (6)	
Teaching service attending	99 (35)	94 (30)	
Hospitalist attending	15 (5)	16 (5)	
Pharmacist	14 (5)	14 (4)	
Physician assistant/nurse practitioner	29 (10)	42 (13)	
Other	3 (1)	9 (3)	
Current list[a]			
Application	N/A	205 (65)	–
EHR generated	252 (90)	182 (57)	
Word processor	32 (11)	28 (9)	
Spreadsheet	15 (5)	8 (2)	
Alternate database	11 (4)	0 (0)	
Other	10 (4)	13 (4)	
Nonattending,			
Chart review time	60 [45, 90]	60 [30, 75]	0.02
Orders time	20 [10, 30]	20 [10, 30]	0.69
Clinical notes time	60 [15, 80]	30 [10, 60]	0.10
Patient care time	60 [30, 100]	60 [40, 90]	0.58
Total prerounding time	120 [120, 180]	120 [120, 180]	0.74
Sign-out list preparation time	20 [10, 30]	15 [6, 30]	<0.01
Adequately prepared for handoff	148 (83)	205 (93)	<0.01
Current satisfaction	50 [27, 71]	74 [50, 85]	<0.01
Burden of preparing for rounds	60 [50, 70]	51 [30, 68]	0.02
Percentage of time inaccuracies on printed list	15 [5, 50]	10 [5, 30]	0.04
Times when inaccuracies resulted in...			
Adverse events	82 (30)	70 (22)	0.04
Patient harm	14 (5)	12 (4)	0.45
I would recommend WHIRL to a colleague	NA	188 (93)	–
I prefer WHIRL rather than old rounding list	NA	167 (82)	–

Abbreviations: EHR, electronic health record; IQR, interquartile range; NA, not available; WHIRL, Wake Health Inpatient Rounding List.
[a]Respondents were allowed multiple responses.

students to take a greater role of responsibility within the team (21%); and allowed a greater level and trust within the team (26%). The majority (85%) felt that having access to the application at a future place of employment was somewhat or very important.

Safety Event Reporting

When evaluating safety reports, there were 16 of 5,691 and 19 of 6,237 reports of severe patient harm before and after application integration, respectively ($p = 0.81$). “Rounds” was mentioned in 63 reports before and 54 reports after application integration, and there was no association of the application ($p = 0.18$).

Discussion

This study demonstrated the successful integration of a state-of-the-art rounding application embedded within an EHR using modern programming tools and interfaces; an application was able to be launched within the EHR within three clicks. There was trend toward significance when evaluating EHR user action log data. Provider surveys showed application users had an increase in both provider-reported satisfaction and provider-reported time savings. The application limited sensitive information and did not increase patient harm. Application users state the data provided by the rounding list were more accurate and timely for use during patient rounds. There was organic adoption despite minimal marketing or end-user training.

This application that was scalable across a diverse academic medical center, which included adult and pediatric providers, was translatable to multiple specialties such as generalists and surgeons, as well as subspecialties. Application usage was sustainable over time. Although we are unable to evaluate the precise percentage of inpatient medical center providers utilizing the list given that one team member could print multiple lists for other team members, the application queried the majority of patients across the medical center. Usage was sustained and continues to increase over time without the help of any marketing efforts or tools. Clinicians have chosen to use this application persistently without prompting or continued reinforcement to use the tool. Support and maintenance for the application were provided by the two physician developers and application developer. Initially, the volume of support and service requests were approximately 5 per week with a rapid attenuation approximately 3 months postimplementation.

Other studies have described the use of inpatient and/or automated rounding lists; some previous rounding lists were developed in the context of a "homegrown" EHR, limiting their potential for dissemination.[9,14] The rounding list described here has several notable features in comparison to previous literature. Historical rounding list applications required institution- and vendor-specific customized programming and home-grown interfaces.[11,12] However, our application uses standardized, interoperable FHIR HL7 APIs, with limited vendor-specific APIs. Our application demonstrates the precise use-case for standardized APIs as guided by the U.S. 21st Century Cures Act[25] to support electronic health information use, access, and exchange, to improve information exchange for providers, while also supporting software developers to create a health information application. Other studies also show that an application can result in time savings, improved patient safety, refined sign-out quality with a reduction in time spent transferring information, enhanced efficiency, and improved patient care.[1–3] However, there were some key differences in the rounding application in these studies. One rounding list required a manual entry of half of the data elements whereas our list uses standard data elements extracted from the EHR. Additionally, our design is efficient, usercentric, and customizable, whereas others were inefficient, lacked graphical data visualization such as a fishbone diagram, and did not easily integrate sign-out and progress note details. Previous studies have not detailed privacy considerations, such as obfuscation of sensitive information, as outlined by the HIPAA Privacy Rule.[26]

Limitations

This study has several limitations. First, this study was completed at a single institution. However, given that many academic institutions use the same market-leading EHR vendor and have comparable users, we think these results would be applicable to other academic institutions. Second, survey response rate was low. However, of the nearly 3,000 surveys sent, and 100 to 150 providers using the application, it is likely that those who did not complete the survey lacked regular inpatient responsibilities. Additionally, there have been concerns raised regarding changing sign-out practices, decreasing the time spent in rounding, and recopying patient data on patient safety. Although our application was unable to succinctly display culture and radiology results given their data models and reporting structures, the application was able to recognize these tests were performed and could prompt the user to further evaluate. In our study, we did not have the ability to thoroughly evaluate the role of the application on patient safety, but previous studies have shown that rounding lists do not jeopardize patient safety.[27]

Conclusion

We successfully integrated an inpatient rounding application into a commercially available EHR leveraging novel yet broadly available application interface resources. This application was well received by end users, demonstrating increased provider satisfaction, provider time savings, and accuracy of data on printed rounding lists. Application utilization was robust and sustainable. With improving rounding list data visualization, clinicians are able to shift from data gathering to information interpretation. Other application designers should consider data density, optimization of provider workflows, and using real-time data transfer using novel tools when designing an application.

Clinical Relevance Statement

This study demonstrates rapid and broad adoption of a production software application used in clinical care, leveraging modern informatics tools and implementation science strategies. Clinical time savings for clinical providers allow individuals to practice at the "top of their license," repurposing morning time spent gathering data to interpreting the data and/or more time with patients and/or educating learners. The software application allows for the ability to automate nonphysician/clinician level tasks as part of achieving the fourth aim of optimizing health system performance - improving the work life of healthcare providers, including clinicians and staff (Thomas Bodenheimer; Christine Sinsky; 2014; Annals of Family Medicine, "From Triple to Quadruple Aim: Care of the Patient Requires Care of the Provider").

Multiple Choice Questions

1. For inpatient rounding lists, most clinicians prefer:
   a. Transcribing electronic data to paper
   b. Using electronic databases outside of the EHR (i.e., MS excel, MS word, and Google sheets)
   c. Using EHR electronic databases without printing
   d. Daily printed rounding lists leveraging EHR data

Correct Answer: The correct answer is option d. More than one-third of daily EHR usage is in chart review tasks,[4,5] and providers often print or transcribe these data to paper.[1,6–8] Clinicians prefer daily printed lists for rounding for portability despite electronically available resources.[6,9]

2. Approximately what percentage of laboratory data are inaccurately communicated from pre-rounding notes?
   a. 5%
   b. 25%
   c. 40%
   d. 60%

Correct Answer: The correct answer is option c. Nearly 40% of laboratory data were inaccurately communicated from pre-rounding notes, and only 7% of these inaccuracies were identified during rounds.[6]

Protection of Human and Animal Subjects

This study involved human subjects are was reviewed and approved by the Wake Forest University Health Sciences Institutional Review Board (identifier: IRB00073502).

Conflict of Interest

A.D. and M.F. are the coinventors of WHIRL™. A.D., M.F., and Wake Forest University Health Sciences have an ownership interest in the WHIRL™ application. This research study utilizes the WHIRL™ application, which is licensed to IllumiCare, Inc.

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