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Information and Data Visualization Needs among Direct Care Nurses in the Intensive Care Unit

Heidi L. Lindroth[1,2] Yuliya Pinevich[3,4] Amelia K. Barwise[5] Sawsan Fathma[3] Daniel Diedrich[3] Brian W. Pickering[3] Vitaly Herasevich[3]

[1] Department of Nursing, Mayo Clinic, Rochester, Minnesota, United States
[2] Center for Aging Research, Regenstrief Institute, School of Medicine, Indiana University, Indianapolis, Indiana, United States
[3] Department of Anesthesiology and Perioperative Medicine, Mayo Clinic, Rochester, Minnesota, United States
[4] Department of Anesthesiology and Intensive Care for Cardiac Surgery, Republican Clinical Medical Center, Belarus
[5] Division of Pulmonary and Critical Care Medicine, Mayo Clinic, Rochester, Minnesota, United States

Address for correspondence Heidi L. Lindroth, PhD RN, Department of Nursing, Mayo Clinic, 200 First Street SW, Rochester, MN 55905, United States (e-mail: Lindroth.heidi@mayo.edu; @minipixie26).

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Abstract

Objectives Intensive care unit (ICU) direct care nurses spend 22% of their shift completing tasks within the electronic health record (EHR). Miscommunications and inefficiencies occur, particularly during patient hand-off, placing patient safety at risk. Redesigning how direct care nurses visualize and interact with patient information during hand-off is one opportunity to improve EHR use. A web-based survey was deployed to better understand the information and visualization needs at patient hand-off to inform redesign.

Methods A multicenter anonymous web-based survey of direct care ICU nurses was conducted (9–12/2021). Semi-structured interviews with stakeholders informed survey development. The primary outcome was identifying primary EHR data needs at patient hand-off for inclusion in future EHR visualization and interface development. Secondary outcomes included current use of the EHR at patient hand-off, EHR satisfaction, and visualization preferences. Frequencies, means, and medians were calculated for each data item then ranked in descending order to generate proportional quarters using SAS v9.4.

Results In total, 107 direct care ICU nurses completed the survey. The majority (46%, $n = 49/107$) use the EHR at patient hand-off to verify exchanged verbal information. Sixty-four percent ($n = 68/107$) indicated that current EHR visualization was insufficient. At the start of an ICU shift, primary EHR data needs included hemodynamics (mean 4.89 ± 0.37, 98%, $n = 105$), continuous IV medications (4.55 ± 0.73, 93%, $n = 99$), laboratory results (4.60 ± 0.56, 96%, $n = 103$), mechanical circulatory support

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Georg Thieme Verlag KG, Rüdigerstraße 14, 70469 Stuttgart, Germany

devices (4.62 ± 0.72, 90%, $n = 97$), code status (4.40 ± 0.85, 59%, $n = 108$), and ventilation status (4.35 ± 0.79, 51%, $n = 108$). Secondary outcomes included mean EHR satisfaction of 65 (0–100 scale, standard deviation = ± 21) and preferred future EHR user-interfaces to be organized by organ system (53%, $n = 57/107$) and visualized by tasks/schedule (61%, $n = 65/107$).

Conclusion We identified information and visualization needs of direct care ICU nurses. The study findings could serve as a baseline toward redesigning an EHR interface.

Background and Significance

Time motion studies demonstrate that intensive care unit (ICU) direct care nurses spend approximately 22% of their shift completing tasks within the electronic health record (EHR).[1] This task completion is an intense cognitive process as nurses interpret and document both continuous (i.e., vital signs) and static (i.e., delirium detection) data formats.[2,3] A recent integrative review highlighted how the aggregation of data within the EHR has led to cognitive challenges in synthesizing, interpreting, and communicating pertinent clinical data.[2,4,5] These cognitive challenges may lead to inefficient workflows, miscommunications, and patient safety risks, particularly during the transfer of patient care.[2,4,6–8]

EHR use during the transfer of patient care, or "hand-off," has historically focused on form, structure, and consistency.[9,10] While hand-off is a routine communication, it requires both reporting and receiving nurses to rapidly absorb a large amount of data and synthesize an understanding of the plan.[11] Patient hand-offs are also fraught with miscommunication, which contributes to delays in tests and treatment, medication errors, and preventable adverse events.[12] A recent study found that direct care nurses use an informal narrative storytelling approach to convey what occurred in the past and present, largely focusing on communicating information (connected data that creates relation and meaning), data (raw facts), and knowledge (synthesizes, connects information).[11] These findings contrast with existing EHR workflows, which are developed using a hierarchical structure to exchange knowledge, then information, and lastly data.[4,13] This contrast highlights an opportunity to redesign how direct care nurses visualize and interact with the EHR during the transfer of patient care using a user experience conceptual framework.[4]

To our knowledge, previous studies focused on developing or implementing transfer of patient care tools did not employ a user experience conceptual framework, including user-centered design principles.[4] Recently, a similar analysis of physician clinicians' information needs was performed at Mayo Clinic in various settings such as neonatal ICU, operating room and post-anesthesia care unit, and hospital floor.[14–16] These findings are not transferable to direct care ICU nurses, due to their specific role and data needs. To begin to address this gap in knowledge, we deployed an anonymous survey to determine the information and visualization needs of direct care ICU nurses at patient hand-off.

Methods

We conducted a web-based anonymous survey across the geographically distributed hospitals (14 total units across four hospitals in Florida, Arizona, Minnesota, and Wisconsin, United States) of Mayo Clinic between September 2021and December 2021. The Mayo Clinic Institutional Review Board deemed the protocol exempt (21–002994). Consent was implied by survey completion.

Study Participants

The survey was distributed to all practicing direct care ICU nurses working in adult ICUs at Mayo Clinic. All ICU types were included (pediatric, medical, surgical, trauma, specialty, mixed) and use a single vendor EHR. There was a total of 1,303 possible survey participants.

Survey Development

Based on interviews conducted with key stakeholders, we developed a survey instrument consisting of 14 items related to EHR information and visualization needs at patient hand-off. The first set of data elements in the pilot survey were selected through the stakeholder interviews. For example, stakeholders indicated that "attending physician" was considered in their routine "hand-off" while "frontline clinician" was not. To ensure the face and content validity of the survey questions, a pilot version was tested in a sample of the target population ($n = 10$). Changes to the survey were made based on comments from this group. We considered the survey finalized when no substantial content-related recommendations for improvement were suggested. Questions were organized around three main topics: (1) EHR interaction and EHR data elements; (2) EHR satisfaction and usability issues, and (3) EHR nurse-centered visualization and interface expectations. The final version of the survey consisted of Likert Scale questions (5–high priority/completely necessary, 3–neutral, 1–low priority/completely unnecessary information), multiple-choice questions, open-ended questions and a rating scale question. The term "hemodynamics" was used to describe vital sign data per stakeholder feedback. Demographic information gathered included age, sex, primary role in ICU (staff nurse, charge nurse), ICU experience, and type of ICU. The anonymous survey distributed via Research Electronic Data Capture (REDCap) is shared in the **Supplementary Material S1** (available in the online version).

Data Collection

The survey was created using a web-based REDCap (Vanderbilt University, Nashville, Tennessee, United States) tool.[17] To recruit participants, the study team collaborated with nursing leadership for each ICU. Recruitment emails that contained an invitation to participate, information about the survey, and the survey link were distributed via email to ICU nurse clinicians by their designated leadership. Leadership also announced the invitation to participate at staff meetings (October–December 2021) and distributed flyers with QR codes on unit bulletin boards. Participants had opportunity to complete survey when inside organizational firewall. Reminder emails were sent 2 weeks after the initial email.

Outcome

The primary outcome was defined as the identification of primary EHR data needs for inclusion in future EHR visualization and interface development at patient hand-off for direct care nurses. These are termed "Big Picture" data points in the survey. This term was selected by the direct care ICU nurses that participated in the development of the survey. Big picture data points were defined as data elements supporting the direct care ICU nurses' development of a comprehensive picture that overviews the current patient situation and level of acuity. Secondary outcomes included current use of the EHR at patient hand-off, satisfaction with the EHR (0–100 scale), and visualization preferences. Current use of the EHR at patient hand-off was defined as the level of interaction between the direct care ICU nurses completing hand-off and the EHR. The question was framed as "How do you use the EHR during shift-to-shift hand-off?" with options as follows: (1) I rely on EHR-based hand-off tool/report; (2) I have my EHR opened during the hand-off and use it as a reference; (3) I open the EHR only when I need to verify information given (e.g., drug reconciliation); and (4) I rely solely on paper notes and verbal communication. I do not use the EHR during shift-to-shift hand-off.

Data Analyses

Survey responses were collected and tabulated via REDCap then exported to SAS v9.4 for analyses. Incomplete surveys were excluded from final analyses. The frequencies and means were calculated for each data item then ranked in descending order to generate proportional quarters. The data items that received a mean score >4.5 or a median score of 5 are reported, indicating "Big Picture" data items. Medians and interquartile ranges were examined and compared with the mean scores to identify variables that may have received a "neutral" mean score due to the occurrence of Likert scores on both ends of the scale (1 = strongly disagree, 5 = strongly agree) and were more aptly described with the median score. For this reason, both are reported. Differences in EHR information needs and visualization preferences were further examined by stratifying by ICU experience and ICU type to evaluate differences. Cumulative means and frequencies between years of ICU experience were compared using the Kruskal–Wallis test. Differences were considered significant between groups when a p-value ≤ 0.05 was generated. Data were summarized numerically and graphically. Distributions (frequencies) between survey items are reported.

Results

Baseline Participant Characteristics

A total of 147 direct care ICU nurses accessed the survey and 107 surveys were completed ($n = 1303$ emailed, 11% response rate). Demographic and clinical characteristics are summarized in ►Table 1. In brief, 76% ($n = 81/107$) of those who completed the survey were female and 47% ($n = 50/107$) were between 25 and 34 years of age.

Primary Outcome-Primary EHR Data Needs, "Big Picture" Items

The primary outcome is illustrated in ►Fig. 1. The top six "Big Picture" data elements indicated as completely necessary

Table 1 Summarizes demographics and clinical characteristics of survey participants

Demographics	Categories				
Age	18–24	25–34	35–44	45–64	
% (*n*)	9 (10)	47 (50)	29 (31)	16 (15)	
Identified sex	Female	Male	Prefer not to disclose		
% (*n*)	75 (80)	23 (24)	2 (2)		
ICU type	Medical	Surgical	Mixed	Cardiovascular	
% (*n*)	13 (14)	12 (13)	23 (25)	47 (50)	
Primary role	Staff nurse	Charge nurse	Both	Other	
% (*n*)	73 (77)	5 (5)	22 (23)	1 (1)	
Location	Minnesota	Arizona	Florida	Wisconsin (NW)	
% (*n*)	54 (58)	24 (26)	11 (12)	10 (11)	
Years of ICU experience	<1 y	1 to 2 y	3 to 4 y	5 to 6 y	≥7 y
% (*n*)	18 (19)	18 (19)	15 (16)	14 (15)	35 (38)

Abbreviation: ICU, intensive care unit.

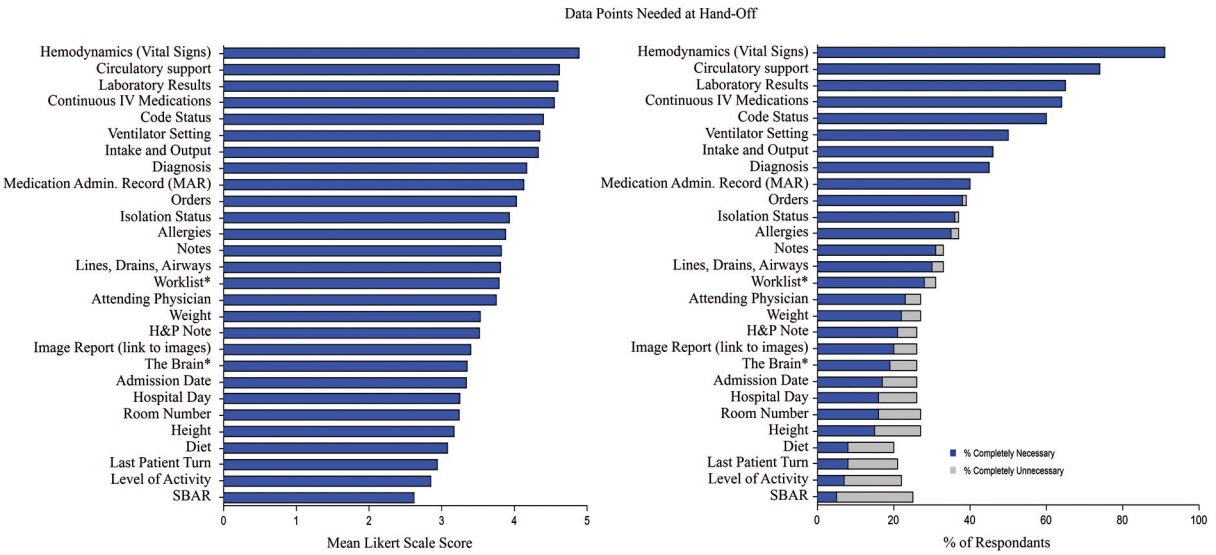

Fig. 1 Illustrates the ranking of "Big Picture" data elements that are needed at patient handoff. The Likert's scores (1–5) were averaged and ranked. These are displayed in the first bar graph panel. The mean values are displayed at the end of each bar. The second graph panel illustrates the percentage of items ranked as "Completely Necessary" (*blue*) and "Completely Unnecessary" (*gray*). *Indicates tools specific to the EHR system in use at the institution. Both are used to organize tasks.

in future EHR interface redesigns were hemodynamics (median: 5, mean [M]: 4.89 ± 0.37, 98%, $n = 105$), continuous IV medications (median: 5, M: 4.55 ± 0.73, 93%, $n = 99$), laboratory results (median: 5, M: 4.60 ± 0.56, 96%, $n = 103$), mechanical circulatory support devices (median: 5, M: 4.62 ± 0.72, 90%, $n = 97$), code status (median: 5, M: 4.40 ± 0.85, 59%, $n = 108$), and ventilation status (median: 5, M: 4.35 ± 0.79, 51%, $n = 108$). Items rates as neutral or somewhat unnecessary were time of next repositioning (median: 3, M: 2.94 ± 1.16, 33%, $n = 35$), activity (median: 3, M: 2.85 ± 1.04, 36%, $n = 38$), and diet (median: 3, M: 3.08 ± 1.13, 31%, $n = 33$). Those with more ICU experience (≥7 years) ranked the EHR "Brain" as an unnecessary "Big Picture" item compared with those with ≤2 years of ICU experience (Kruskal–Wallis, $p = 0.007$). The Epic "Brain" was a 2018 upgrade that is organized as a timeline and visualizes upcoming medications, tasks, and required documentation.

Secondary Outcomes

The mean satisfaction with the current EHR was 65 (standard deviation [SD] = ±21) and the median was 72 (IQR: 19) on a 1 to 100 scale, ►**Fig. 2**, and was significantly different based on years of ICU experience (Kruskal–Wallis, $p = 0.03$). Those with more years of experience reported a lower EHR satisfaction (median: 63, M: 55.92 ± 27.09 vs. median: 74, M = 73.95 ± 9.43). During shift-to-shift hand-off, 46% ($n = 49/107$) indicated that they open the EHR only when needed to verify verbal information being exchanged, such as during drug reconciliation. 65% ($n = 68/107$) indicated that the visualization of data within the EHR could be improved.

Future EHR visualization preferences included an EHR user-interface organized by system (53% $n = 57/107$) and data visualized in a schedule, or task-based, layout (61% $n = 65/107$). The most important characteristics of a future EHR interface was a "nursing tab" (28%, $n = 30/107$), a snapshot containing all relevant information to nurses in one spot nursing-specific tab, followed by the ability to hover over data instead of opening of different portions of the chart (19%, $n = 20/107$) and data entry and summary on the same screen (19%, $n = 20/107$).

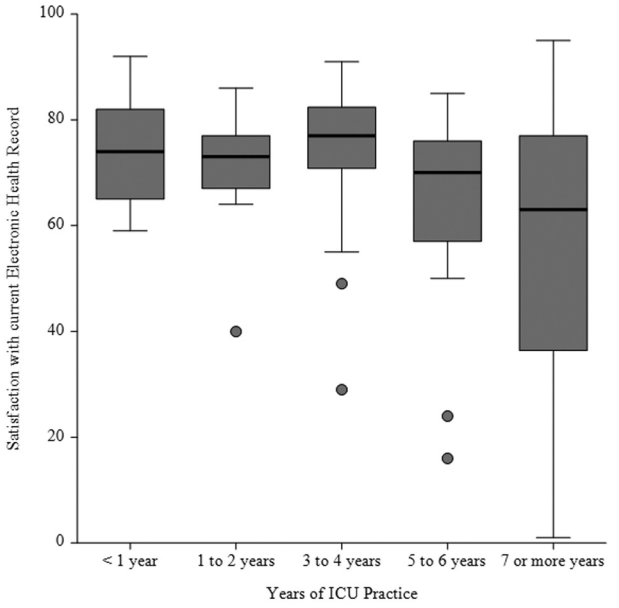

Fig. 2 Illustrates the median EHR satisfaction rating per years in practice. The EHR satisfaction scale ranged from 0 to 100, with 100 representing the highest satisfaction. The black line represents the median satisfaction score, each gray box shows the distribution of the data points between the 25th and 75th percentile points, and the "whisker bars" that emerge from each side of the gray box represent the boundaries of outliers within the data. Data points outside of these boundaries are indicated with gray circles. EHR, electronic health record.

The top usability challenges in the current EHR were redundancy in documentation (81%, $n = 87/107$), multiple sources are used to learn patient's history (80%, $n = 85/107$) and to review data at the start of shift (75%, $n = 80/107$), and updating or changing IV medications requires multiple screens (71%, $n = 76/107$). In current patient hand-off, the following EHR data were indicated as high priority (median score of 5 and M score of $\geq 4.0 \pm$ SD): continuous IV medications (4.70 ± 0.55, 75%, $n = 80/107$), laboratory results (4.57 ± 0.65, 64%, $n = 68/107$), hemodynamics (4.45 ± 0.94, 66%, $n = 71/107$), code status (4.38 ± 0.38, 64%, $n = 69/107$), medication administration record (4.29 ± 0.88, 52%, $n = 56/107$), and respiratory status/oxygen requirements (4.25 ± 1.01, 53%, $n = 57/107$). "New orders" had a mean score of 4.26 ± 0.79 (44%, $n = 47/107$), however, received a median score of 4 indicating somewhat necessary.

Discussion

Identifying data elements that are most valuable to direct care ICU nurses during patient hand-off is an essential first step in the process of redesigning an EHR interface to best support patient hand-off. The top six data elements identified as "Big Picture" items through an anonymous survey ($n = 107$) were hemodynamics, mechanical circulatory support status, laboratory results, continuous IV medications, code and ventilation status representing broad categories of granular data and conceptually overlap. Each item provides insight into current tissue perfusion, oxygen demands, hemodynamic support, and priority items to consider going forward. Each of these data elements informs the development of situational awareness for that patient, for that shift.

In the current EHR, the prioritized data points are in separate tabs and flowsheets, which may lead to the inability to fully develop situational awareness. Situational awareness is the ability to link task performance with complex mental models and is divided into three levels; perception, comprehension, and projection.[18,19] A recent study found significant challenges for nurses in navigating and integrating EHR data to successfully reach all three levels of situational awareness due to the fragmentation and presence of data silos.[3] As shown in previous studies, the inability to synthesize various data sources may lead to serious medication and communication errors.[20,21] Future studies should investigate how to synthesize various data sources within the ICU environment including EHR data, monitoring devices, sensor data, and verbal communication between team members and partner with the end user (direct care ICU nurses) to codesign effective visualization tools.

Forty-four percent of respondents indicated that they only use the EHR to verify information being exchanged during hand-off despite the availability of hand-off tools in the EHR. Current EHR tools designed to support patient hand-off are largely checklist based or provide an avenue for free text entry.[10–12] While these may have been built with the end-user in mind, they were built to support the existing EHR interface, not to support the development of situational awareness, to integrate and synthesize data to minimize mental load, or to support cognitive decision making. In previous studies, nurses have reported the inability to visualize the big picture of the patient and how unreliability of data during hand-offs can lead to verbal discrepancies.[4] The application of a user experience conceptual framework, outlining the five dimensions (function, physical, perceptual, cognitive, psychological and social) would help to develop an integrated, visual, user interface that supports how nurses conduct patient hand-off. Survey results substantiate the need for improvements in usability and data visualization of EHR data.

As several studies have suggested, ICU nurses' information needs, workflows, and information-seeking behavior are different from physicians' information requirements.[22–24] A recent systematic review, that summarized data on nurse well-being in relation to EHR, revealed a call for multi-level interventions to organize, synthesize, and visualize the information from the nurses' perspective.[25] Nurse-centered solutions, such as integrated graphical information displays, may improve the usability of ICU patient electronic records.[26] Future studies should consider using methods of cognitive engineering, computational ethnography, deep observation, user experience conceptual frameworks, user centered design principles and health informatics to design integrated, visual, and customizable solutions to support the complexity of ICU nurse clinician workflow.[3,4,11,27–30]

Strengths and Limitations

A survey assessing direct care ICU nurses EHR data information and visualization needs was the first step toward codesigning an updated EHR interface to support patient hand-off between nurses. We developed and pilot tested the survey with direct care ICU nurse stakeholders and deployed the survey across four geographically diverse hospitals at Mayo Clinic. Nonetheless, this study has several notable limitations. Generalizability of the survey is likely limited due to deployment at a single institution that uses the same EHR system, the sample size, and the inability to include local practices and culture that likely influence how the EHR is used. While the included sites use a single EHR vendor, the usage of the current EHR is limited to 4 years. It is likely that participants have experience with other EHR systems and varying experiences may introduce bias into the survey results. The response rate (11%) is low, which may be attributed to pandemic staffing, inability to complete survey off site, and competing clinical demands. Those direct care ICU nurses that are more tech-savvy may have been more likely to complete the survey, leading to a sampling bias. Further, participants may have interpreted and answered the survey questions differently. For example, participants may have ranked items based on their frequency of use or placed importance on data items that should not be neglected (i.e., code status). To adjust for these individual variances, we combined individual responses and examined the data at the population-level with calculated means and frequencies. Since the survey was anonymous, we are not able to evaluate characteristics of non-responders and it is likely that nurse clinicians who feel strongly about the EHR were more likely

to respond leading to response bias. There is a small risk that the survey was completed more than once by the same participant. The strength of capturing honest perspectives by anonymizing the survey outweighed the possibility of duplicate entries.

Conclusion

The findings from this anonymous survey provide insight into EHR information and visualization needs of ICU nurse clinicians during patient hand-off. Hemodynamics, mechanical circulatory support, laboratory results, and continuous IV medications were indicated as "big picture" items highly necessary to include in future EHR interfaces. Participants indicated that organizing this information by system and visualizing by schedules would improve usability of the EHR. Differences in current EHR satisfaction and the use of current EHR tools, such as the brain, differed significantly between years of ICU experience. Future studies will need to account for these differences while using user-centered design procedures.

Clinical Relevance Statement

Frontline intensive care unit nurse clinicians indicated future EHR interfaces organized by system and visualized that using schedules would improve the usability of EHR during hand-off. "Big Picture" information items that are highly important to communicate during patient hand-off include hemodynamics, mechanical circulatory support, laboratory results, and continuous IV medication use.

Multiple-Choice Questions

1. When designing an updated EHR interface to improve patient hand-off, what "Big Picture" data elements may be important to include?
   a. Patient level of activity, last patient turn, diet.
   b. Hemodynamics, circulatory support, laboratory results, continuous IV medications.
   c. Attending physician, code status, diagnosis, allergies.
   d. Worklist, H&P note, ventilator settings, hemodynamics.

   Correct Answer: The correct answer is option b. These were the primary findings reported from the multicenter anonymous survey completed by frontline intensive care unit nurse clinicians.

2. In the survey results, what preference did participants indicate for organization?
   a. By organ system
   b. By medication administration
   c. By task
   d. By timeline

   Correct Answer: The correct answer is option a. Participants indicated that organization by organ system would aid in visualization and communication of information during patient hand-off.

3. Current patient hand-off communication typically follows what type of format?
   a. EHR SBAR.
   b. EHR-based tool.
   c. Narrative storytelling.
   d. Hierarchical information given by going through EHR tabs and flowsheets.

   Correct Answer: The correct answer is option c. Recent studies examining current practice during nurse-to-nurse patient hand-off follows a narrative storytelling format and does not use the EHR tools. Results of the reported survey support these previous research findings.

Protection of Human and Animal Subjects

The study was performed in compliance with the World Medical Association Declaration of Helsinki on Ethical Principles for Medical Research Involving Human Subjects and was reviewed by the Mayo Clinic Institutional Review Board.

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None.

Conflict of Interest

None declared.

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