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Author manuscript

JAMIA Open. Author manuscript; available in PMC 2019 September 16.

Published in final edited form as:

JAMIA Open. 2018 July ; 1(1): 32–41. doi:10.1093/jamiaopen/ooy020.

Providers' assessment of a novel interactive health information technology in a pediatric intensive care unit**Onur Asan¹, Richard J. Holden^{2,3}, Kathryn E. Flynn⁴, Kathy Murkowski⁵, Matthew C. Scanlon⁵**¹Department of Medicine, Center for Patient Care and Outcomes Research, Medical College of Wisconsin, Milwaukee, Wisconsin, USA²Department of Medicine, Indiana University School of Medicine, Indianapolis, Indiana, USA³Indiana University Center for Aging Research, Regenstrief Institute, Inc., Indianapolis, Indiana, USA⁴Department of Medicine, Division of Hematology and Oncology, Medical College of Wisconsin, Milwaukee, Wisconsin, USA⁵Department of Pediatrics, Division of Critical Care, Medical College of Wisconsin, Milwaukee, Wisconsin, USA**Abstract****Objective:** To explore perceptions of critical care providers about a novel collaborative inpatient health information technology (HIT) in a pediatric intensive care unit (PICU) setting.**Methods:** This cross-sectional, concurrent mixed methods study was conducted in the PICU of a large midwestern children's hospital. The technology, the Large Customizable Interactive Monitor (LCIM), is a flat panel touch screen monitor that displays validated patient information from the electronic health record. It does not require a password to login and is available in each patient's room for viewing and interactive use by physicians, nurses, and families. Quantitative data were collected via self-administered, standardized surveys, and qualitative data via in-person, semistructured interviews between January and April 2015. Data were analyzed using descriptive statistics and inductive thematic analysis.

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CONTRIBUTORS
O.A. conceived and designed the study, obtained funding, participated in data collection, analysis, and interpretation, drafted and revised the manuscript, and approved the final version for submission. R.J.H. assisted with study conception and design and data interpretation, made critical manuscript revisions, and approved the final version for submission. K.E.F. assisted with study conception and design and data interpretation, made critical manuscript revisions, and approved the final version for submission. K.M. assisted with data collection, made critical manuscript revisions, and approved the final version for submission. M.C.S. assisted with study conception and design and data interpretation, made critical manuscript revisions, and approved the final version for submission.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *Journal of the American Medical Informatics Association* online.

Conflict of interest statement. None declared.

Results: The qualitative analysis showed positive impacts of the LCIM on providers' workflow, team interactions, and interactions with families. Providers reported concerns regarding perceived patient information overload and associated anxiety and burden for families. Sixty percent of providers thought that LCIM was useful for their jobs at different levels, and almost 70% of providers reported that LCIM improved information sharing and communication with families. The average overall satisfaction score was 3.4 on a 0 to 6 scale, between "a moderate amount" and "pretty much."

Discussion and Conclusion: This study provides new insight into collaborative HIT in the inpatient pediatric setting and demonstrates that using such technology has the potential to improve providers' experiences with families and just-in-time access to EHR information in a format more easily shared with families.

Keywords

collaborative health information technology; pediatric intensive care; human-computer interaction; family engagement

INTRODUCTION

The use of health information technology (HIT) has become integral to health care delivery,¹ necessitating biomedical informatics research on end-user perceptions, acceptance, use of, and ultimately, the costs and benefits of HIT.^{2,3} Research on these postadoption phenomena is important because, as stated by the "Field of Dreams" fallacy, implementing HIT does not guarantee its use.^{4,5} Actual HIT use and other outcomes of technology success depend a great deal on how users perceive the technology, whether they believe it meets their needs, and how they integrate it in their daily work routines.^{6,7}

Postadoption HIT research on commonplace clinical HIT, such as electronic health records (EHRs), has increased with the fast-paced spread of these systems, especially in light of providers' struggles with them.⁸ More research is needed on the next wave of technologies, whose use is less widespread and rarely mandatory but nevertheless important. Many of these are user-centered HIT systems, such as tethered personal health records, patient portals, in-room monitors or displays, and smartphone applications.⁹⁻¹¹ These technologies hold the promise of increasing health care quality by rendering care more patient-centered, collaborative, and team approach-driven.¹²⁻¹⁵ Systematic reviews support that such HIT systems do indeed improve clinical processes and patient outcomes, in addition to increasing aspects of patient-centered care such as shared decision making and responsiveness to patient needs and preferences.^{1,16}

A small but promising subset of nonmandated novel technologies are called "collaborative" HIT, or HIT used in parallel or in tandem by different stakeholders including providers, nurses, patients, or families, to support each party's contribution to health-related processes.^{9,10} Most collaborative HIT systems are designed for outpatient settings, for example, the oft-studied and putatively effective telehealth technologies.¹⁷ In contrast, HIT for inpatient or hospital settings, usually supports *either* the work of professionals *or* patients. EHR, computerized provider order entry (CPOE), and point-of-care barcoded medication

administration systems are examples of the former. The latter are largely newer patient- or family-facing adult inpatient technologies such as hospital room monitors providing patients access to their own data,^{13,18} mobile phone application providing dynamic information to emergency room patients,¹⁹ or tablet computers used by patients during a hospital stay.^{20,21}

In the present study, we examined a novel, collaborative HIT system in a pediatric intensive care unit (PICU). The technology, here referred to as the Large Customizable Interactive Monitor (LCIM) is a flat panel touch screen monitor that displays validated patient information from the EHR, including vital signs, laboratory results, medications, X-rays, and interventions. Unlike traditional HIT, the LCIM does not require a password to login and is potentially available in each patient's room for viewing and use by physicians, nursing and ancillary staff, patients, and patients' families. The study's objective was to understand the perceptions of PICU providers about the use of this novel technology in PICU setting, since they are the critical group accountable for patient care in PICU and make critical decisions in the treatment process.

The study addresses gaps in postadoption research on collaborative inpatient HIT systems and in pediatric settings. Pediatric settings are unique for many reasons, particularly the important information and decision-making roles played by both providers and family members.^{22–25} However, relatively few studies assess providers' novel HIT perceptions or acceptance in pediatric settings. Filling these gaps produces not only scientific knowledge about how providers perceive these emerging technologies but also practical guidance for their continued design, implementation, and daily use.

METHODS

The study design was a cross-sectional, concurrent mixed methods study of critical care providers' perceptions of the LCIM. Quantitative data were collected via self-administered, standardized surveys, and qualitative data via in-person, semistructured interviews. Data were collected from January to April 2015, with approval from the study hospital's institutional review board.

Setting and participants

The setting was the PICU of a freestanding children's hospital in a midsized city in Wisconsin, USA. The PICU is a 72-bed unit with three 24-bed floors, which provides highly specialized care to critically ill children and neonates and admits over 3000 patients a year.

There were 39 providers working in the PICU (92%), who were attending physicians and nurse practitioners, employed by the PICU full time and providing direct care. We recruited participants by attending provider meetings and through direct contact by a research coordinator. There are also residents and fellows working in the PICU, but they were not included in the study. Participants who completed the study were offered a \$45 gift card. We obtained verbal consent from each participant in the study.

LCIM technology

The LCIM is a commercially available product called Epic Monitor (v 2010, Epic Systems Corporation, Verona, WI, USA). It is a customizable touchscreen monitor and display, which receives data from the EHR. The LCIM is an interactive “view only” technology, with no ability to enter data except through the EHR (Figure 1). The interactive nature of the LCIM allows end users to “drill down” to see additional content behind the default panes. Upon touching a pane, all panes are moved to allow of an expanded view of the selected content. A scroll bar allows users to view additional data specific to any specific pane.

At the time of data collection, viewable data on the LCIM included discrete and trend vital sign information; the patient’s problem list; laboratory test results; a list of medications and infusions with doses, routes, frequency, and last administration time; documented fluid “ins and outs”; ventilator settings; and all indwelling lines, drains, and airways with date/time of placement. The content of the LCIM is customizable by hospital IT management but data must exist in the EHR to be displayed on the LCIM. *Unlike traditional HIT or the EHR system at the hospital, the LCIM does not require a log-in for each use.* It is activated upon the admission of the patient to the room and is always available for view and use by providers, patients, and their families.

The LCIMs were installed in patient rooms at the same time the study hospital implemented a commercially available EHR in November 2012. This installation of LCIMs was the third in the U.S. and the first in a pediatric setting. An LCIM was mounted on 1 wall in each patient room, though the specific mounting location varied as rooms were not standard and the monitors were installed after design of the physical space.

Data collection

Providers self-administered a brief standardized survey comprised of validated questions from the technology acceptance model (TAM). The questions covered perceived usefulness, perceived ease of use, satisfaction, training, and social norms and used an ordinal response scale from 0 (not at all) to 6 (a great deal). It has been validated and used previously for other HIT studies.^{8,26,27}

Interview and survey data collection were performed together in a private office in the PICU. We developed an interview guide based on specific study objectives and also following the TAM. (Supplementary Material Appendix 1).⁶ The interview guide was reviewed by 2 Human Factors Engineers (O.A., R.H.) and 1 methodologist (K.F.). It was then piloted with a pediatric intensivist (M.S.) for consistency, validity, and understandability. The interview guide was revised based on the feedback obtained in the pilot interview.

Data analysis

We used descriptive analysis to report the findings (means and standard deviations) of survey data. We used an inductive thematic analysis approach for the analysis of the qualitative interview data.²⁸ The 36 interviews were audiotaped and transcribed verbatim for analysis. The initial step, after reading 8 transcripts, was meeting as a team to discuss initial themes and define each theme. We developed a codebook to guide the coding process and

uploaded transcripts to Nvivo 10 (QSR International) to facilitate coding and analyses. Two independent coders conducted the main thematic coding process with a third coder to adjudicate any disagreements. The team refined preliminary interpretations throughout this process and added new themes when necessary. During team meetings, we reviewed the codes and text assigned to them and began to identify major categories. Appropriate revisions of the themes and codes were made until consensus was achieved between the coders. Reliability checks were conducted throughout the coding process and the 2 main coders achieved acceptable intercoder reliability of higher than 0.80 (range 0.80–0.91). Finally, we held a final meeting with all team members to discuss emergent themes and write the reports.

RESULTS

Providers' characteristics

The providers in this study consisted of 36 participants: 19 (53%) attending physicians and 27 (47%) pediatric nurse practitioners. Most participants were white, non-Hispanic (97%). Four (11%) were between 18 and 29 years old, 13 (36%) between 30 and 39, 11 (31%) between 40 and 49, 7 (19%) between 50 and 59, and 1 (3%) was older than 60 years. Participants' tenure in their current role was a median of 6 years (IQR 2.25–10.75). Some nurse practitioners had worked as “nurses” in the same institution, but we did not include that timeframe in the “current role” calculation. Additionally, participants had 8 years (mean) experience with EHR/CPOE systems, and approximately 3 years (mean) using the hospital's Epic EHR system. Each interview lasted 20–35 min (mean = 24 min).

Survey results

Figure 2 shows the responses for all survey items related to perceived usefulness of LCIM. Most providers indicated that LCIM did not decrease their effectiveness. Sixty percent of providers thought that LCIM was useful for their jobs at different levels, and almost 70% of providers reported that LCIM improved information sharing and communication with the family. However, a sizeable proportion, from 20% to 60% reported limited usefulness of the LCIM, particularly with respect to impact on personal job performance.

Providers responded to ease of use questions more positively. Most of the providers reported that the LCIM is easy to use, learn, and navigate, and is clear and understandable (Figure 3).

Figure 4 shows provider responses related to perceptions, satisfaction, and future intentions to use LCIM. The average overall satisfaction score was 3.38 on a 0 to 6 scale, between “a moderate amount” and “pretty much.” Further, almost 70% of providers believed LCIM improved family engagement to some extent. The survey data also showed that providers did not perceive receiving adequate or clear training.

Positive perceptions

Several providers pointed out the potential contribution of LCIM to family engagement and improving provider communication with families (Table 1). One provider described this as “I think they are more empowered to ask questions when using [LCIM],” and another

provider also emphasized “I think the dialogue between the parents and the providers is richer when the parents use the monitor. So the parents who use the monitor are going to ask more questions about the data sometimes or they might get the answers and ask less questions.” Further, some providers thought that families were better informed with LCIM, as stated by one: “Well I think the family feels like they’re better informed and then if you’re right there talking them through something they can ask you your reasoning behind it and you can explain your rationale.” Some providers also stated they used LCIM as a tool to educate and teach parents: “I try to use it just to teach or talk about what’s going on and show them maybe what I see in the vital sign trends that makes me think one thing or another, so that they have a better understanding of thought process.” In addition, some providers thought LCIM was particularly useful for parents of chronically ill children who stay longer in the unit: “I think some of the best things that have come up with it is with the medication reconciliation process that some of the—especially the chronic care kids—the families will pull up the active medication list and see that either we got it wrong or something’s missing or they’re wondering why one of their chronic meds went away and how did we replace it.”

Providers also described how LCIM aids their clinical work. Some pointed out that LCIM is an efficient reference point to quickly access data in the intensive care unit (ICU) room: “I think they’re a really nice quick reference point for me. They’re certainly easier than logging into Epic, especially when nurses are needing to document on their computers in the room.” Providers added that LCIM is particularly helpful when cross covering other providers’ patients: “When I’m cross covering my colleagues patients I don’t sometimes know their trends and medications intimately. And so when they’re all up on the screen [LCIM] and I walk into a patient’s room that someone has called me in to rapidly assess I can get a quick kind of ‘cliff-notes’ version of what I need to know. So from that standpoint I think it definitely helps me in my efficiency in assessing a patient.”

Furthermore, most providers reported that LCIM is straightforward, user-friendly and easy to use, as this provider stated “I think it’s really clear and easy to use and it’s a nice big monitor so I don’t have any problems with the design of it.” Some providers also emphasized transparency of LCIM being an advantage and might show parents nothing is being hidden from them.

Negative perceptions and concerns

Provider interviews revealed several negative perceptions and concerns, reported in Table 2. A major concern raised by providers was potential misinterpretation of the data by families: “I think it could be a problem having data displayed that family can see without anybody explaining to them.” Furthermore, some providers were concerned about the LCIM displaying too much information for some families, potentially adding anxiety for parents: “I think there are certain families that are naturally anxious or concerned than others, and the monitor can make them more anxious because there will be arbitrary red values that may have no medical significance, but it’s outside of the lab-reported norms, and they can’t distinguish what’s a concerning value and what’s not without having medical knowledge. So they become more and more alarmed.”

The analysis also yielded points regarding usability, issues with content, and technical problems. A frequently mentioned issue was some values not being shown in a format consistent with the desktop EHR display: “The disadvantage is that the data that it’s populating with doesn’t always correlate with some of the other data in Epic, like the ins and outs.... They’re correct, it’s just using a different time frame so you get a different net value.” Usability and technical issues, such as screen freezing or crashing of the monitors and unnecessary scrolling were also reported: “there’s all those empty parameters that I have to scroll through to get through all of the parameters that I want.” Finally, some providers highlighted privacy issues regarding patients’ names shown on the monitor, for example: “Probably the only really negative experience I had was a family member complaining about how their child’s name was on the monitor and everybody could walk by and see it. Like, she didn’t really care that much, but she just found it odd.”

Providers’ suggestions for improvement

Providers suggested potential improvements to make the LCIM more family-centered and more efficient for providers (Table 3). Family-centered suggestions included features or tutorials to help families interpret or understand data and displaying daily goals on the screen. As one physician stated, “If we get to the point where we have clear goals of care, it would be nice to have one component of this be able to click on and have almost the full screen do what the goals of care are for today.” Suggestions to improve the LCIM for providers’ use included customization based on providers’ interest or patient’s condition, eliminating some of the content, and adding data entry functionality, “It would be cool to be able to input things, like if you’re using it on rounds, like say you’re reviewing the problem list with the family, you know you could update it right there or if you want to put orders in right there. Just to make it more of a two-way street.” Most of the providers also highlighted the need for ongoing education regarding the LCIM.

DISCUSSION

As with the domains of safety and quality improvement, HIT has the potential to enhance patient and family engagement in the health care process.^{12,21,29} This may be even truer of those collaborative technologies that are used by both families and providers.^{9,22} This study identified a range of provider perceptions specific to one such technology that can be used collaboratively, the LCIM. This interactive display technology allows health care providers, patients, and families to view available EHR data ranging from medications to images to laboratory results. This study had particular strengths, including the novelty of the LCIM in ICUs, and particularly PICUs and the very high participation rate of providers. We also identified multiple perceptions and suggestions that can help us understand how the LCIM is being used and may inform the design and implementation of future collaborative technologies.

Both survey and interview data revealed that a majority of the providers perceive LCIM as mostly useful for their work without decreasing effectiveness, although majority of survey respondents also think there is no significant increase in productivity or organization for each patient. The comments on effectiveness may reflect that the monitors are available in

the patient room without requiring a user to login the system. Instead, both providers and families can immediately access information by touching the display. Of note, providers' perceptions of usefulness covered a range of activities including accessing data for direct care, information sharing with the entire care team, and information sharing with families. Some recent studies also reported that accessing information in inpatient settings might improve family/patient engagement and empowerment.^{21,22,30} The ability to access information is enhanced by the fact that the LCIM exists in each patient room in the PICU. Thus, multiple providers and/or family members can share the same view of data during discussions. This has the potential to improve the communication especially during the rounds, as reported in other recent studies.³⁰⁻³²

Beyond perceptions of usefulness, the LCIMs were largely perceived as easy to use. In both surveys and interviews, the majority of respondents reported that it is easy to navigate, learn, and use. Perhaps because the LCIM is consistent with other pervasive mental models for touchscreen devices, the majority of providers found the LCIM easy to learn and navigate. In addition, survey results also showed that almost half of the providers think that using it requires mental effort or takes too much time to find what you need. This is notable because there was no formal education process for any providers at the time of implementation regarding the content that might affect the familiarity level of each provider and might make it harder to find some data.

As with almost any technology, end-users reported a range of negative and positive perceptions. While some of these perceptions have already been highlighted in this discussion, several bear closer consideration. One category of negative perceptions could be interpreted as paternalistic. These include perceptions of information overload for families, creation of anxiety for families, and misinterpretation of data by families, as stated in another provider perception study on patients accessing information through portal in ICU.³¹ At least 1 participant expressed the need for providers to supervise families' use of LCIM. Further, a concern was expressed that the LCIM could generate "unnecessary questions" from families. While the tension between paternalism and engagement has been discussed for decades,^{33,34} our findings suggest a need to proactively address such provider concerns both before and during implementation of technologies intended to improve engagement. Furthermore, these perceived fears of creating information overload and anxiety, or the families not understanding the displayed data, should be formally validated or refuted through study of families' perceptions and use of this technology, and such work is currently ongoing.

Other negative perceptions reflect technical issues beyond the control of providers. These include LCIM failures or "crashes," the time frame in which certain data (fluid inputs and outputs) are displayed, and the speed of data retrieval, particularly from records of patients who have been hospitalized for a prolonged period. These technical and usability issues might impact providers' use frequency of LCIM negatively, as found in past studies of other HIT.^{35,36}

Additional negative perceptions reflected providers' misperceptions or lack of familiarity with the LCIM.³⁷ One example is the belief that the time of a laboratory test is unavailable

when the result is displayed. However, if users cannot easily find the data, their perception is validated, as the information is effectively unavailable to them. A second incorrect negative perception is the validity of the vital sign information, such as heart rate or oxygen saturation. This perception stems from the fact that vital sign data displayed on the LCIM is what is documented and validated by the bedside nurse, in contrast to raw physiologic data available to providers from other systems. Such perceived differences have always existed, whether nurses document on paper or with computers.^{38,39} It reflects an assumption that the recorded physiologic data is always more accurate than nurse recorded data because of the potential for nurse error. However, as it is not uncommon for heart rate to be inaccurately captured, for example respiratory rate in sick infants due to chest wall movement or pulse oximetry providing data even when not attached to the patient, this provider belief is partially correct at best. More importantly, such negative perceptions reveal the need for ongoing communication between providers and those overseeing the implementation of the technology.

Our study revealed a number of suggestions for future improvements to the LCIM. These suggestions are important for several reasons. First, they identify a potential tension regarding the LCIM's intended end-users. The vendor designed the LCIM primarily as a tool for providers and not for families. One other center has implemented the monitors with the requirement to enter a password, keeping data away from nonproviders. The decision to make data available to all inhabitants of a patient's room might improve transparency and engagement according to providers. Such transparency has been reported as a way to improve patient trust in past studies.^{31,40} The same PICU has implemented family-centered rounds and allowed 24-h family visitations for over 20 years. Thus, it is not surprising that the providers' suggestions include more patient-focused information such as parent name and contact information, as well as patient preferences. As the viewable display is limited, any addition of nonclinical content requires removal of clinical information that may otherwise be important for care decisions. In the same vein, providers have suggested a screen saver or dimming functionality so that data are not viewable unless someone is interacting with the LCIM. This functionality would conflict with some providers' positive perceptions related to the ability to peek in a room, glance at the LCIM, and quickly view physiologic trends. Both suggestions to optimize the LCIM content and functionality for family users may come at the cost of taking away clinical content that may improve care.

There are limitations to our findings. First, it is a study of a single site thus, some of the provider perceptions may have limited applicability to other organizations. Similarly, the decision to implement the LCIM without requiring a password to view content may not be consistent with other ICUs using similar technologies to the LCIM. Second, our data collection occurred 2 years after the implementation of the HIT, and it could be better to assess such technologies within the first year of implementation. Third, at the time of data collection, the hospital had no means of measuring "touches per LCIM" as a proxy for actual use. However, models of technology acceptance and use, such as TAM, would predict moderate use based on providers' perception of low-to-moderate LCIM usefulness and above average ease of use and satisfaction.^{6,8,26} Actual use is important and should be further assessed for the LCIM because it is a logical prerequisite to enhanced user engagement for this kind of technology. Finally, this study only focused on providers'

perceptions of LCIM, and family perceptions of the LCIM are needed to compare perceptions from both parties.

In conclusion, when implemented without requiring a password, the LCIM represents a collaborative HIT that was perceived primarily positively by PICU physicians and NPs, both for themselves and the patients and families for whom they provide care. This study provides new insight into collaborative HIT in the inpatient and pediatric settings and offers suggestions for improvements.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

ACKNOWLEDGMENTS

We would like to thank all participating providers for their valuable insight. We also thank to Yushi Yang and Laila Azam for helping in qualitative coding and Erica Wozniak for helping in quantitative analysis.

FUNDING

The financial support was provided by the Agency for Healthcare Research and Quality (Grant # 1R21HS023626-01) for this study.

REFERENCES

1. Crampton NH, Reis S, Shachak A. Computers in the clinical encounter: a scoping review and thematic analysis. *J Am Med Inform Assoc* 2016; 23 (3): 654–65. [PubMed: 26769911]
2. White A, Danis M. Enhancing patient-centered communication and collaboration by using the electronic health record in the examination room. *JAMA* 2013; 309 (22): 2327–8. [PubMed: 23757080]
3. Holden RJ. What stands in the way of technology-mediated patient safety improvements? A study of facilitators and barriers to physicians' use of electronic health records. *J Patient Saf* 2011; 7 (4): 193. [PubMed: 22064624]
4. Karsh BT, Weinger MB, Abbott PA, Wears RL. Health information technology: fallacies and sober realities. *J Am Med Inform Assoc* 2010; 17 (6): 617–23. [PubMed: 20962121]
5. Holden RJ. Physicians' beliefs about using EMR and CPOE: in pursuit of a contextualized understanding of health IT use behavior. *Int J Med Inform* 2010; 79 (2): 71–80. [PubMed: 20071219]
6. Holden RJ, Karsh BT. The technology acceptance model: its past and its future in health care. *J Biomed Inform* 2010; 43 (1): 159–72. [PubMed: 19615467]
7. Delone WH, McLean ER. The DeLone and McLean model of information systems success: a ten-year update. *J Management Inform Sys* 2003; 19 (4): 9–30.
8. Holden RJ, Asan O, Wozniak EM, Flynn KE, Scanlon MC. Nurses' perceptions, acceptance, and use of a novel in-room pediatric ICU technology: testing an expanded technology acceptance model. *BMC Med Inform Decis Mak* 2016; 16 (1): 145. [PubMed: 27846827]
9. Valdez RS, Holden RJ, Novak LL, Veinot TC. Technical infrastructure implications of the patient work framework. *J Am Med Inform Assoc* 2015; 22 (e1): e213–5. [PubMed: 25665705]
10. Valdez RS, Holden RJ, Novak LL, Veinot TC. Transforming consumer health informatics through a patient work framework: connecting patients to context. *J Am Med Inform Assoc* 2015; 22 (1): 2–10. [PubMed: 25125685]
11. Marceglia S, Fontelo P, Ackerman MJ. Transforming consumer health informatics: connecting CHI applications to the health-IT ecosystem. *J Am Med Inform Assoc* 2015; 22 (e1): e210–2. [PubMed: 25665702]

12. Prey JE, Woollen J, Wilcox L, et al. Patient engagement in the inpatient setting: a systematic review. *J Am Med Inform Assoc* 2014; 21 (4): 742–50. [PubMed: 24272163]
13. Wilcox L, Feiner S, Liu A, Restaino S, Collins S, Vawdrey D. Designing inpatient technology to meet the medication information needs of cardiology patients. In: proceedings of the 2nd ACM SIGHIT International Health Informatics Symposium; 2012.
14. Pell JM, Mancuso M, Limon S, Oman K, Lin C-T. Patient access to electronic health records during hospitalization. *JAMA Intern Med* 2015; 175 (5): 856–8. [PubMed: 25751393]
15. O’Leary KJ, Lohman ME, Culver E, Killarney A, Smith GR, Liebovitz DM. The effect of tablet computers with a mobile patient portal application on hospitalized patients’ knowledge and activation. *J Am Med Inform Assoc* 2016; 23 (1): 159–65. [PubMed: 26078412]
16. Finkelstein J, Knight A, Marinopoulos S, et al. Enabling Patient-Centered Care Through Health Information Technology [Internet]. Rockville (MD): Agency for Healthcare Research and Quality; 2012 (Evidence Report No. 206, Contract No. 290–2007-10061-I). <http://www.ncbi.nlm.nih.gov/books/NBK99854/> Accessed December 20, 2012.
17. Totten AM, Womack DM, Eden KB, et al. Telehealth: Mapping the Evidence for Patient Outcomes from Systematic Reviews. Rockville (MD): Agency for Healthcare Research and Quality; 2016 (Evidence Report). <https://www.ncbi.nlm.nih.gov/books/NBK379320/> Accessed February 10, 2017.
18. Wilcox L, Morris D, Tan D, Gatewood J. Designing patient-centric information displays for hospitals. In: proceedings of the SIGCHI Conference on Human Factors in Computing Systems; 2010.
19. Pfeifer Vardoulakis L, Karlson A, Morris D, Smith G, Gatewood J, Tan D. Using mobile phones to present medical information to hospital patients. In: proceedings of the 2012 ACM Annual Conference on Human Factors in Computing Systems; 2012.
20. Vawdrey DK, Wilcox LG, Collins SA, et al. A tablet computer application for patients to participate in their hospital care. In: AMIA Annual Symposium Proceedings; 2011.
21. Dalal AK, Dykes PC, Collins S, et al. A web-based, patient-centered toolkit to engage patients and caregivers in the acute care setting: a preliminary evaluation. *J Am Med Inform Assoc* 2016; 23 (1): 80–7. [PubMed: 26239859]
22. Kelly MM, Hoonakker PL, Dean SM. Using an inpatient portal to engage families in pediatric hospital care. *J Am Med Inform Assoc* 2017; 24 (1): 153–61. [PubMed: 27301746]
23. Lehmann CU, Weinberg ST, Alexander GM, et al. Pediatric aspects of inpatient health information technology systems. *Pediatrics* 2015; 135 (3): e756–68. [PubMed: 25713282]
24. Kim GR, Lehmann CU. Pediatric aspects of inpatient health information technology systems. *Pediatrics* 2008; 122 (6): e1287–96. [PubMed: 19047228]
25. Scanlon M, Holden R, Murkowski K, Karsh B-T. Complexity of medication administration in pediatric intensive care units: Implications for technology and patient safety. In: *Critical Care Medicine*; 2009.
26. Holden RJ, Brown RL, Scanlon MC, Karsh B-T. Modeling nurses’ acceptance of bar coded medication administration technology at a pediatric hospital. *J Am Med Inform Assoc* 2012; 19 (6): 1050–8. [PubMed: 22661559]
27. Holden RJ, Brown RL, Scanlon MC, Karsh B-T. Pharmacy workers’ perceptions and acceptance of bar-coded medication technology in a pediatric hospital. *Research in Social and Administrative Pharmacy* 2012; 8 (6): 509–22. [PubMed: 22417887]
28. Creswell JW. *Qualitative Inquiry and Research Design: Choosing among Five Approaches*. Thousand Oaks, CA: Sage Publications, Inc; 2006.
29. Tang C, Lorenzi N, Harle CA, Zhou X, Chen Y. *Interactive Systems for Patient-Centered Care to Enhance Patient Engagement*. The Oxford University Press; 2016.
30. Kaziunas E, Hanauer DA, Ackerman MS, Choi SW. Identifying unmet informational needs in the inpatient setting to increase patient and caregiver engagement in the context of pediatric hematopoietic stem cell transplantation. *J Am Med Inform Assoc* 2016; 23 (1): 94–104. [PubMed: 26510878]

31. Bell SK, Roche SD, Johansson AC, et al. Clinician perspectives on an electronic portal to improve communication with patients and families in the intensive care unit. *Annals Am Thorac Soc* 2016; 13 (12): 2197–206.
32. Patmon FL, Gee PM, Rylee TL, Readdy NL. Using interactive patient engagement technology in clinical practice: a qualitative assessment of nurses' perceptions. *J Med Internet Res* 2016; 18 (11): e298. [PubMed: 27836817]
33. Coulter A Paternalism or Partnership? *BMJ* 1999; 319: 719–20. [PubMed: 10487980]
34. Richards T, Montori VM, Godlee F, Lapsley P, Paul D. Let the patient revolution begin. *BMJ* 2013; 346: f2614. [PubMed: 23674136]
35. Yen P-Y, Bakken S. Review of health information technology usability study methodologies. *J Am Med Inform Assoc* 2012; 19 (3): 413–22. [PubMed: 21828224]
36. Middleton B, Bloomrosen M, Dente MA, et al. Enhancing patient safety and quality of care by improving the usability of electronic health record systems: recommendations from AMIA. *J Am Med Inform Assoc* 2013; 20 (e1): e2–8. [PubMed: 23355463]
37. Asan O, Holden RJ, Flynn KE, Yang Y, Azam L, Scanlon MC. Provider use of a novel EHR display in the pediatric intensive care unit. *Appl Clin Inform* 2016; 7 (3): 682–92. [PubMed: 27453191]
38. Fang H, Peifer K, Chen J, Rizzo J. Health information technology and physicians' perceptions of healthcare quality. *Am J Manag Care* 2011; 17 (3): e66. [PubMed: 21504261]
39. Yackel TR, Embi PJ. Unintended errors with EHR-based result management: a case series. *J Am Med Inform Assoc* 2010; 17 (1): 104–7. [PubMed: 20064810]
40. Asan O, Tyszka J, Fletcher KE. Capturing the patients' voices: Planning for patient-centered electronic health record use. *Int J Med Inform* 2016; 95: 1–7. [PubMed: 27697228]



Figure 1. LCIM Snapshot. ©2017 Epic Systems Corporation. Used with permission. LCIM: large customizable interactive monitor.

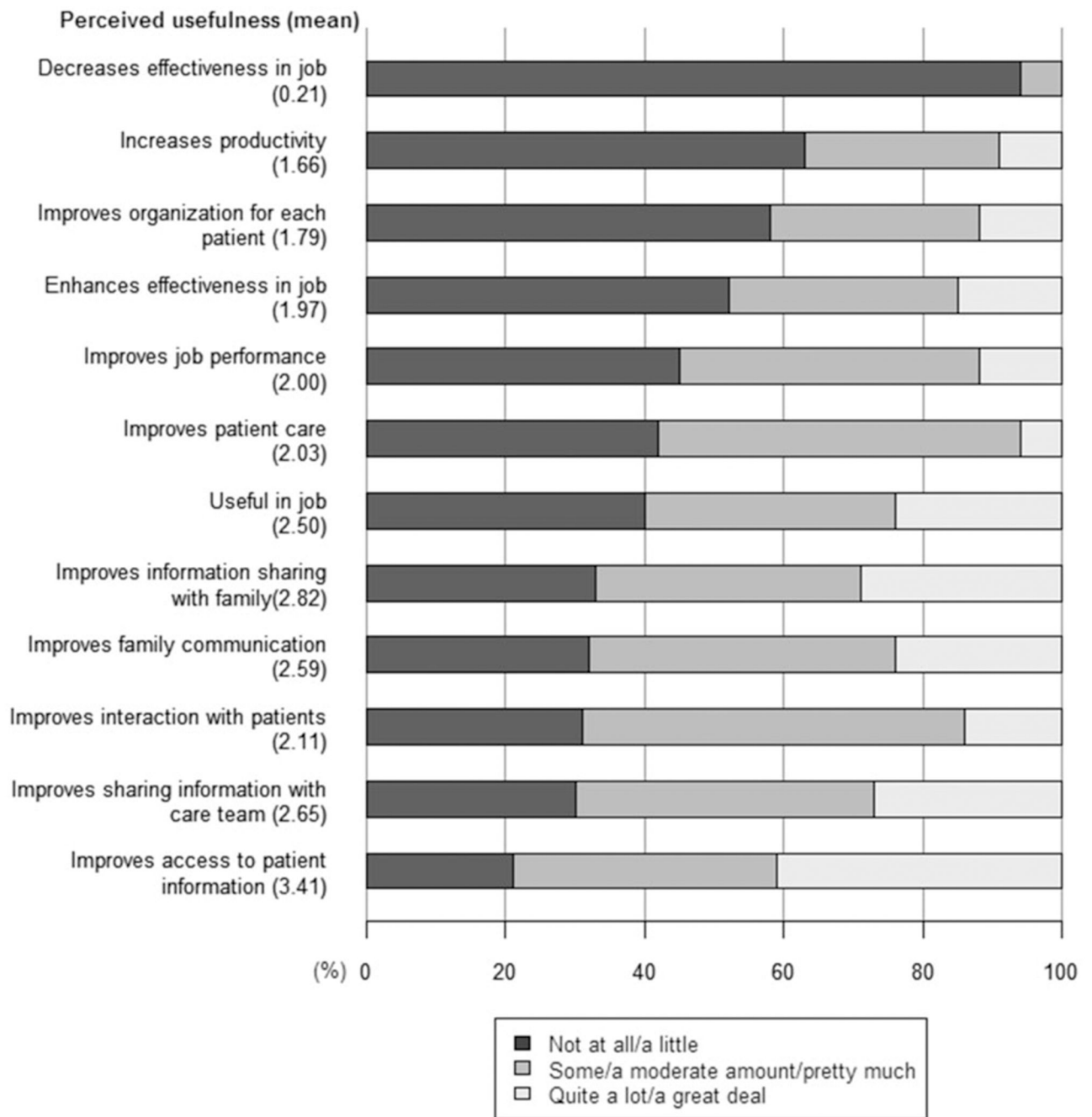


Figure 2. Perceived usefulness of LCIM. LCIM: large customizable interactive monitor.

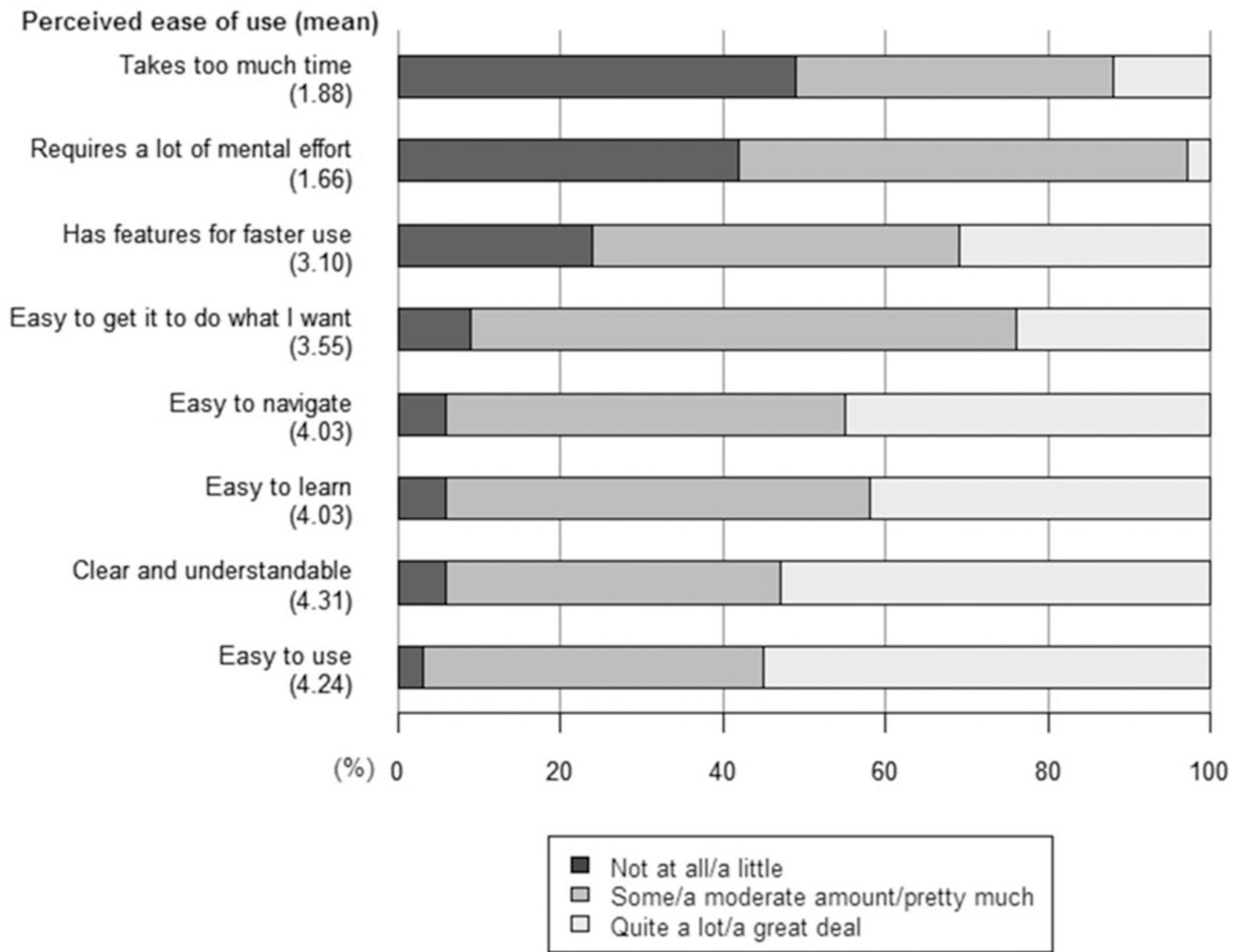


Figure 3. Perceived ease of use of LCIM. LCIM: large customizable interactive monitor.

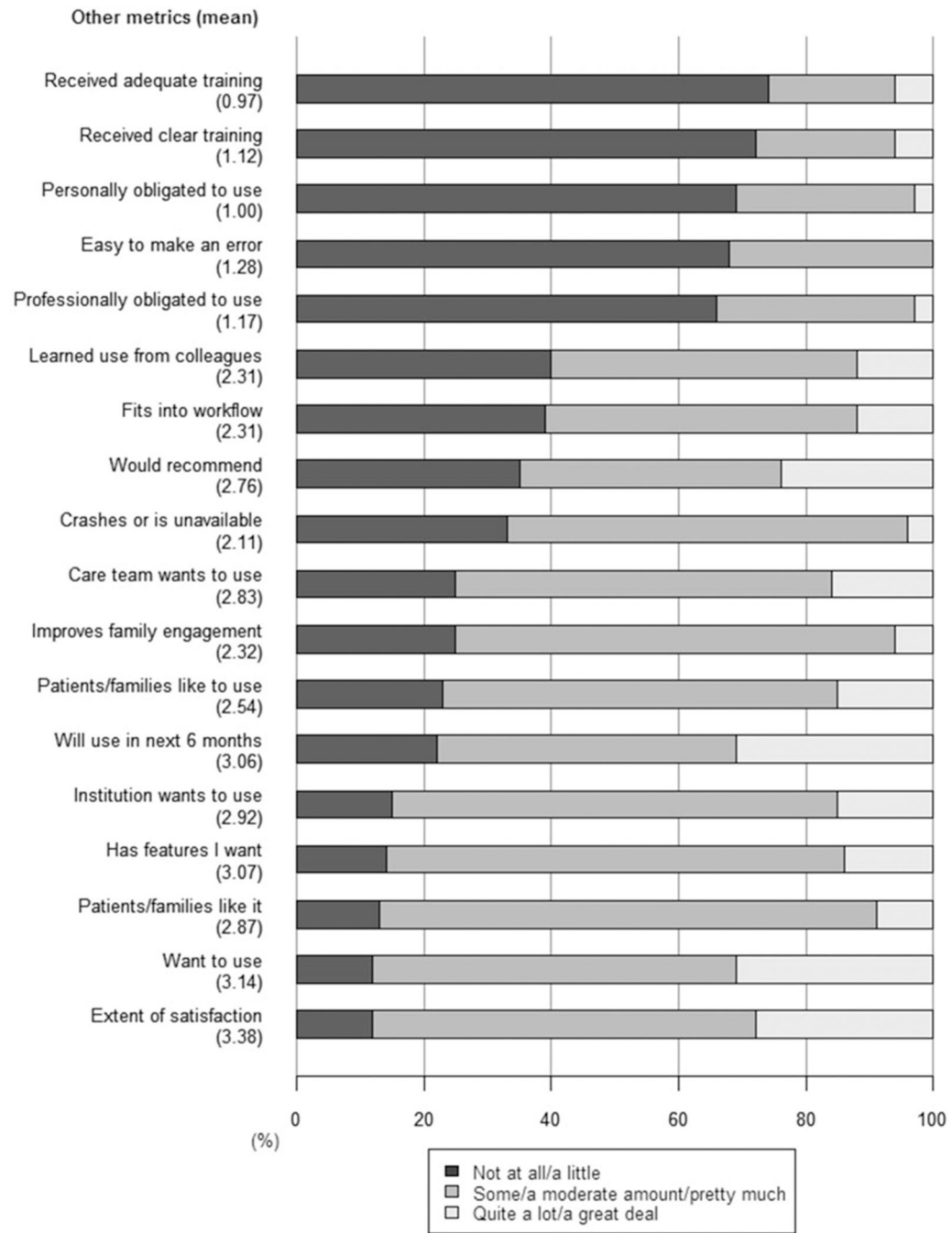


Figure 4. Other metrics for evaluation of LCIM. LCIM: large customizable interactive monitor.

Table 1:

Themes and subthemes of providers’ positive perceptions of LCIM

Impact on family engagement and communication

- Helps improve provider-family communication if families use it
- Can be used to educate/teach parents about their child’s health
- Might lead to conversations with families if they are interested in learning more
- Helpful for overnight providers when they respond to the questions of families
- Helps providers to explain context and rationale of data, especially lab and vital trends
- Visual info on LCIM facilitates parents’ understanding of the displayed data/info
- Families look at data and start formulating questions if they see abnormal values
- Families might feel more empowered to ask questions when they use it
- Helps with medication reconciliation process with families especially for chronic kids
- Chronic childrens’ families like it more, due to the continuous access
- Might help parents to develop some medical expertise and interpret the data
- Helps providers to be transparent with families showing them the data they want to see
- Might make families more involved in the rounds and feel comfortable to ask questions
- Families can see the progress of their kids and access new info without asking the providers
- Parents accessing all data providers see/access might influence trust in a positive way

Impact on their work, including workflow, productivity, and data access

- Quick access to data, no password, and snapshot of patient status might save time
 - Might give a better sense of information to improve the decision-making process
 - When provider walks in the room, they can glance and see what patients’ night looked like
 - It is most helpful when providers’ cross cover for their colleague’s patient
 - Helpful in explaining providers’ thought process to the families
 - Can eliminate the time looking at desktop so more time to talk to parents at bedside
 - Helpful during the rounds, several people can look at it at the same time
 - No need to worry about printing lab reports while having a dialogue with parents
 - The information provider is looking for is generally there with an easy access point
 - Helpful when all computers in the room are occupied
 - Information on LCIM serves as memory aid for providers such as patients’ name or basic info
 - Might be a nice teaching tool for providers to teach nurses in the room
 - Helpful for providers to teach trainees how to use vital signs to make decisions
 - Providers can eyeball information quickly from LCIM and see any abnormality
-

LCIM: large customizable interactive monitor.

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Table 2.**Themes and subthemes of providers' negative perceptions of LCIM**

Concerns on interaction with families

- Information overload/too much information for some families
- Red values [outside of lab-reported norms] might create additional/unnecessary anxiety for families
- Potential misinterpretation of data if not supervised by a provider/not properly interpreted
- Families might be too involved with LCIM without understanding the meaning of displayed data
- It might be hard to understand some data for families with low health literacy level
- Data on the LCIM might prompt unnecessary questions from the families
- May created additional burden/disturbance for providers due to the family questions prompted
- Informed family members can be concerned about medical team not accurately responding to problems
- Highly involved families with LCIM give clinical suggestions, places more burden on the providers
- Providers make decisions that are not always based on the data seen on LCIM, which can be questioned by families

Display/data related

- Time frame for “ins and outs” (12 AM–12 AM) is different from EHR (7 AM–7 AM)
- Weights and age did not update appropriately in the past (this was fixed)
- Garbage in/Garbage out (ie if nurses make an error in data entry, it can lead to medication errors)
- Lab results are not updated frequently
- LCIM does not show dates of when labs were taken (eg is it from 3 h ago or 3 days ago?)
- The data on LCIM are based on validation of nurses, so if providers need more data they go to desktop
- Providers cannot view orders in LCIM

Comparison with other technologies in the room

- LCIM does not accommodate the features of flowsheet used in the past
 - Vital sign information is less accurate in the LCIM than Bedmaster for second intervals
 - Duplication of information on LCIM with other current technologies in the room (eg ventilator)
 - For some providers, viewing the labs in desktop is easier
 - LCIM provides good snapshot of trends, but you cannot see longer trends, as you do in the desktop
 - For some providers, their workflow is more efficient with using desktop rather than LCIM
 - Some providers do not see any difference using the desktop/computer rather than LCIM
-

LCIM: large customizable interactive monitor.

Table 3.

Providers' suggestions for improving the LCIM

Improvements for families
Providers should interpret medical info to families in patient room when needed
Show accurate and updated problem list to families
The creation of tutorials for families to use and understand LCIM
Simplified data display for families
Display data in an analog format and show trends
Incorporate features of white boards into the LCIM: writes goals of the day, have space for parents to write down their phone number, patient preferences, parent questions for rounds, and parent concerns
Improvements for providers
Eliminate unnecessary content
Update problem list more frequently, since parents are concerned when old information is listed
Graph lab values over time
Customization of displayed medications based on the units
Display parents' name on LCIM
Have functions of input orders
Insert the function of pulling up the assessment and recommendation from the consult
Customization of features based on interest of attending physician
LCIM should have a screen saver mode, which reverts to pictures of patients' medical team
Pull up real-time information as opposed to nurse-verified information
A feature of having 2 trends shown at the same time
Medications should be classified after being clicked, such as antibiotics, diuretics, inotropes, and how long they have been prescribed
Functionality showing interventions and how they affected vital signs on a trended scale
Synopsis view on the screen so people can track what happens for changes
Inform potential users of LCIM about why it was implemented
LCIM should have a setting where they can dim down or shut off as a power save mode at night

LCIM: large customizable interactive monitor