The Institute for the Design of Environments Aligned for Patient Safety (IDEA4PS)

P30 Principal Investigators: Susan Moffatt-Bruce MD, PhD, MBA
Chief Executive Officer
Royal College of Physicians and Surgeons of Canada
774 Echo Drive
Ottawa, Canada, K1S 5N8
Phone: (613) 218-5384
Electronic mail: SMoffattBruce@royalcollege.ca

Ann Scheck McAlearney, ScD, MS
Professor, Family and Community Medicine
Executive Director, The Center for the Advancement of Team Science, Analytics, and Systems Thinking in Health Services and Implementation Science Research (CATALYST)
College of Medicine, The Ohio State University
460 Medical Center Drive
Suite 530 Columbus, OH 43210
Phone: (614) 293-8973; Fax: (614) 293-2715
Electronic mail: Ann.McAlearney@osumc.edu

Principal Investigators of Project and Cores:
Project 1: Emily Patterson, PhD, and Susan Moffatt-Bruce MD, PhD, MBA
Project 2: Courtney Hebert, MD, MS, Albert Lai, PhD, and Elisabeth Root, PhD
Project 3: Ann Scheck McAlearney, ScD, MS, and Timothy Huerta, PhD, MS
Core A: Susan Moffatt-Bruce MD, PhD, MBA, and Ann Scheck McAlearney, ScD, MS
Core B: Emily Patterson, PhD
Core C: Susan White, PhD, RHIA, CDHA

Co-Investigators: Larry Feth, PhD
Michelle Fenessy, PhD, MSN
Iahn Gonsenhauser, MD, MBA
Jennifer Hefner, PhD, MPH
Maryanna Klatt, PhD
Julie Mangino, MD
Susan Melsop, PhD
Alan Price, MFA

Additional Team Members: Alice Gaughan, MS
Mahmoud Abdel-Rasoul, MS, MPH
Thomas Bentley, MS
Maria Brancasio, MS
Santino Cua, RHIA
Danijela Cvjetinovic, MPH
Judy Edworthy, PhD
Gennaro Di Tosto, PhD
Morgan Fitzgerald, MPH, CHES
Jennifer Flaherty, MSN, RN
Natalie Gaines
Lakshmi Gupta
Christopher Hansen, MS

Michael Rayo, PhD
Milisa Rizer, MD, RN
Cynthia Sieck, PhD, MPH
David Woods, PhD
Todd Yamokoski, CNS
Lindsey Sova, MPH
Po-Yin Yen, RN, PhD
Daniel Walker, PhD, MPH
Jeremy Harper, MBI
Sarah MacEwan, PhD
Lauren Mansour, MS
Megan McHaney-Lindstrom, MA
Terri Menser, PhD
Austin Mount-Campbell, PhD
Seth Scarborough, MAS
Justin Smyer, MLS, MPH
Jacob Socha
Lindsey Sova, MPH
Robert Taylor, MA
Shonda Vink, MPH
Sean Yu
Chelsea Horwood, MD, MPH

Organization: The Center for the Advancement of Team Science, Analytics, and Systems Thinking in Health Services and Implementation Science Research (CATALYST) Departments of Surgery, Family and Community Medicine, and Biomedical Informatics The Ohio State University College of Medicine

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1. Structured Abstract.

**Purpose:** This study was designed to enable the integration of experts in systems engineering, design, human factors, organizational behavior, evaluation, and data analysis to explore the way that feedback of information is incorporated into the adaptation of work systems to enhance patient safety.

**Scope:** IDEA4PS assessed how all kinds of data collected at The Ohio State University Wexner Medical Center are leveraged to provide actionable information and how they are linked to patient outcomes.

**Methods:** Project 1 focused on telemetry alarms, seeking to improve what engineers call the signal-to-noise ratio, thereby allowing clinicians to focus on meaningful events over the din of background noise, leading to improvements in the safety and quality of patient care. The second project focused on hospital-acquired infections (HAIs). Despite the widespread use of electronic health records (EHRs), many hospitals continue to perform infection control surveillance retrospectively and often through manual review of records, which is both time consuming and labor intensive. We explored this problem and its potential solutions. Project 3 explored how the hospital-wide use of MyChart Bedside (MCB) – an inpatient EHR portal – impacted the provider work system and processes.

**Results:** IDEA4PS improved clinical practice by designing, testing, and exploring the type and kind of information flows resulting in adaptation of the health care work environment, as outlined below:

**Project 1** improved the signal-to-noise ratio, thereby allowing clinicians to focus on meaningful events over the din of background noise, leading to improvements in the safety and quality of patient care. This was accomplished by changing hospital policies to reduce false alarms; redesigning audio tones for telemetry alarms; identifying needs of patients and families to improve satisfaction with alarms; and assisting with making changes to tones for a new mobile phone platform with a Secondary Alarm Notification System (SANS) and a new hospital.

**Project 2** automated hospital-acquired infection (HAI) surveillance in order to provide results in near-real time to stakeholders as well as explore different visualizations for surveillance results. This was accomplished by creating a simple *Clostridioides difficile* (C. diff) algorithm that correctly identified all hospital-onset (HO) *Clostridioides difficile* infection (CDI) and by developing a demonstration C. diff interactive dashboard that used a map of the hospital as a form of visualization and building data infrastructure that takes into account space and time by leveraging geographic information systems (GIS) in order to better track infections within the hospital and that can be applied to other quality and safety outcomes that may benefit from localization within the hospital.

**Project 3** explored how the hospital-wide use of MyChart Bedside (MCB), an inpatient patient portal, impacted the provider work system and processes. Interviews with hospital staff indicated frustrations around MCB because of the lack of time in their workflow to provision tablets to patients upon admission and the need to deal with technology issues and training. Interviews also identified that clinicians developed workarounds to circumvent the Secure Messaging function of MCB. A health system-level committee was convened to serve as a means of translating findings from Project 3 into operational improvements, which involved hiring technology navigators to assist with MCB provisioning and training of both patients and clinicians. Many providers discouraged use of secure messaging in the inpatient setting because of difficulty in accessing messages and/or their preference for face-to-face
communications. Log file analysis showed that patients use MCB to send secure messages to providers to make requests, ask questions, and express gratitude. Messages from patients generally involve topics about symptoms, treatment plans, and pain.

**Conclusions:** The patient safety learning laboratory, the Institute for the Design of Environments Aligned for Patient Safety, provided foundational infrastructure to connect stakeholders across The Ohio State University and Wexner Medical Center to conduct rigorous research in the context of practice. This focus allowed research to inform operations in a cycle of continuous improvement in which clinicians and researchers, inclusive of health services experts, analysts, and information technology staff, worked together and improved operational excellence and performance management processes for patient safety.

**Key Words:** Telemetry, Hospital-Acquired Infections, Patient Portals, Hospitalization, Medical Informatics, Technology Adoption, Organizational Change, Behavioral Intervention, Human Factors, Alarm Fatigue.

2. **Purpose.**
This study, “The Institute for the Design of Environments Aligned for Patient Safety (IDEA4PS),” was designed to identify and explore how feedback of information can be used to inform the development of robust practices that lead to improved patient safety. Our Institute sought to improve clinical practice by designing, testing, and exploring the type and kind of information flows that result in adaptation of the health care work environment.

3. **Scope.**
The Institute for the Development of Environments Aligned for Patient Safety (IDEA4PS) aimed to use systems approaches to bring together multidisciplinary teams to generate new ways of thinking with respect to the design of feedback to the environment of care in alignment with systems dynamics. Given that much of the progress in patient safety has been on egregious and amenable threats, the three projects conducted by our Institute provided an opportunity to be more proactive, to envision the quality and safety of care that patients and providers would like to have, and to test innovative designs that had the potential to alter the status quo and shape a safer future rather than simply add a new patient safety practice on top of the existing system. Our projects were bound closely together by the costly harms associated with information problems. In Project 1, we focus on the information and signaling ecosystem that exists in the day-to-day environment of clinical care. In Project 2, we turned our attention to how retrospective data can be leveraged into prospective information about the spread of hospital-acquired infections. Finally, we investigated the challenge of integrating new sources of data, seeking to gain a more immediate and responsive understanding of the patient experience with an eye to leverage patient observation and engagement toward more rapidly identifying both exemplary practice and potential issues. The Ohio State University Wexner Medical Center offered an opportunity to evaluate these system interventions in a real-world clinical setting, with its full complement of facility design, equipment, people (patients, family members, and providers), new procedures and workflow, and organizational contextual features, as appropriate. By focusing on information as opposed to a specific patient safety challenge, we created generalizable experiential knowledge that is invaluable to improve both patient safety and the quality of care that health care organizations deliver.

Project 1: Telemetry and Alarms: The first project focused on the manner in which information is provided to clinicians. The volume of information that clinicians receive and interpret is overwhelming. A number of studies have spoken to this problem, suggesting that current systems create a significant amount of noise through which clinicians must identify particular signals that indicate clinically significant events. Project 1 focused on the signal-to-noise problem experienced by clinicians, seeking to improve what engineers call the signal-to-noise ratio, thereby allowing clinicians to focus on meaningful events over the din of background noise, leading to an improvement in the safety and quality of patient care. Such an effort required significant engagement with stakeholders and an exploration of the state of the tools and technology deployed in situ, with the project team exploring the needs of clinicians within the context of the existing social-technical factors (e.g., facility design features, equipment and technology, work processes and flow, and organizational, cultural, and contextual characteristics) that shape the clinical experience. The Human Factors and Design Core provided the expertise to evaluate, experiment, and explore alternative attention-focusing designs. The Informatics and Analytics Core worked with the project team to channel the data into experimental experiential systems through rapid prototyping.

Project 2: HAI Surveillance: The second project focused specifically on hospital-acquired infections (HAIs). Despite the widespread use of EHRs, many hospitals continue to perform infection control surveillance retrospectively and often through manual review of records, which is both time consuming and labor intensive. Although the development of automated surveillance algorithms has been shown to be feasible and accurate, systems that use real-time data to recognize concerning trends do not exist. Surveillance data is most commonly displayed in tabular format or simple charts, which are not ideal representations of complex data, especially for potential outbreak detection. The result is a significant delay in the use of surveillance data to implement timely and effective interventions and reduce the likelihood of a hospital-acquired infection. We proposed to explore this problem and its potential solutions. The Informatics and Analytics Core worked with infection preventionists (IPs) and quality improvement (QI) personnel to develop real-time results to recognize concerning trends sooner in order to implement timely and effective interventions through the use of tools like digital hotspotting. The Human Factors and Design Core worked with the Informatics and Analytics Core to support the development of visualizations, coupled with automated algorithms, to identify and illustrate the potential visual-spatial distribution of HAIs within the hospital from clustering of patients based on clinical disease states and acuity as well as the compliance with nursing processes and potential transmission of infection. Automating manual processes and visualizing these data in a hospital-wide interactive surveillance map may allow for earlier recognition of potential adverse patient quality and safety trends.

Project 3: Inpatient Portals and Information Flows: Finally, Project 3 was developed to explore how the hospital-wide use of MyChart Bedside (MCB) – an inpatient EHR portal – is impacting provider work systems and processes. MCB is a tablet-based technology used by inpatients, and the secure messaging feature is the main element that could affect information flow to the care team. Information overload has been identified as a threat to patient safety, and the goal of the project was to identify workflow modifications and potential changes to the MCB technology that could moderate the flow of secure messages from patients into the work system. This project team worked closely with the Human Factors and Design Core during the Design and Development phases and called on the Informatics and Analytics Core during Problem Analysis and during the iterative Evaluation phase.
5. Results.
The interdisciplinary approach of the Institute for the Design of Environments Aligned for Patient Safety (IDEA4PS) explored how feedback of information could be used to inform the development of robust practices that lead to improved patient safety. Our Institute improved clinical practice by designing, testing, and exploring the type and kind of information flows resulting in adaptation of the health care work environment.

Project 1 focused on telemetry alarms, seeking to improve what engineers call the signal-to-noise ratio, thereby allowing clinicians to focus on meaningful events over the din of background noise, leading to an improvement in the safety and quality of patient care. The principal findings of Project 1 are presented and discussed here.

- Changed policy in five hospitals to reduce the alarm burden from both bedside monitors and the Secondary Alarm Notification System (SANS) delivered on nurses’ phones. Policy changes included removing low-likelihood patient cohorts (Class III cardiac risk) from monitoring, lowering threshold defaults for pulse oximetry (SPO2 lo), and encouraging nurses to set patient-specific thresholds. Outcomes from intervention were lower ED boarding time, fewer alarms, fewer interruptions, shorter time when nurses were off the unit (monitored transport rate), and shorter nurse response times. A 15-59% reduction in response times for Code Blue was achieved. This was a clinically significant change in that Code Blue response times longer than 120 seconds changed from 63.5% (8256/12,999) to 19.9% (5544/27,822) in the cardiac hospital.

- Redesigned and replaced audio tones for cardiac and respiratory alarms delivered on SANS. Used human factors concepts of discriminability, masking, and usability (easy to learn, easy to localize); indicator encoding distinguishing human-initiated alarms (with digitized speech and earcons/auditory icons) from machine-initiated alarms; and orientation (beacon followed by repeated content sound) in tone design. Demonstrated improvements in laboratory study conducted on hospital unit to replicate authentic soundscape with hospital nurses in improved accuracy of detection and improved localization.

- Modified and standardized SANS escalation algorithms, including when and how long before escalation, delays before alarms sounded to reduce redundant alarms with bedside monitor, augmenting sounds with visually displayed information on phones without requiring logging in or navigation to information, and using visual displays instead of sounds for lower-priority alarms. Demonstrated 25% reduction in SANS alarms.

- Generated characteristics of ideal critical cardiac tones and patient-centered tones to support evaluations of anticipated transition to new SANS with different mobile device capabilities, sound options, and integration support with patient call system and electronic health record.

- Publicly sharable: We can share publicly one set of auditory alarm sounds that can be used in SANS systems. In addition, leveraged funding produced an alarm set that could potentially be shared upon request and that is compatible with the anticipated 2020 revision of the alarm standard, IEC/ISO 60601-1-8, with which the FDA requires compliance for bedside telemetry monitors. Both sets are accompanied by an ontology to support optional inclusion of individual tones rather than use of the full set. The ontology distinguishes origin of the alarm (clinician, patient, equipment), urgency (high, low), and clinical functions (e.g., respiratory system).

Project 2 focused on hospital-acquired infections (HAIs). Despite the widespread use of electronic health records (EHRs), many hospitals continue to perform infection control surveillance retrospectively and often through manual review of records, which is both time consuming and labor intensive. The results of surveillance are traditionally displayed to stakeholders in tables and charts
and are often weeks to months delayed. Project 2 studies focused on automating surveillance in order to provide results in near-real time to stakeholders as well as to explore different visualizations for surveillance results. The principal findings of Project 2 are presented and discussed here.

- Established demographic data on 2 years of adult inpatient admissions and discovered that there were over 65,000 patients in our initial cohort, with over 110,000 hospital encounters. Data from these encounters informed the basis of the retrospective database.
- Our simple *Clostridioides difficile* (C. diff) algorithm correctly identified all hospital-onset (HO) *Clostridioides difficile* infection (CDI) cases in 2015, with a PPV of 97.31%.
- Developed an initial version of a C. diff dashboard that uses a map of the hospital as a form of visualization. The user could change the time frame, select individual patients or groups of patients, and drill down to show where the patients moved within the medical center during their stay. It identifies the room where the patient was diagnosed with C. diff but also marks rooms that the patient was housed in while likely contaminating the environment.
- Performed user studies on the prototype dashboard with four subject matter experts. On the survey, all users “strongly agreed” that the dashboard would be a positive addition to Clinical Epidemiology and would allow them to present HAI information to others more effectively. All “agreed” or "strongly agreed" that they felt confident in manipulating the dashboard to demonstrate to others and that it was easy to learn and use. Respondents also suggested improvements to specific features, including improving the intuitiveness of changing the date ranges, adding isolation information, and showing present-on-admission CDI cases.
- Collaborated with colleagues in Geography to build data infrastructure that takes into account space and time by leveraging GIS. This allowed us to better track infections within the hospital and could be applied to other quality and safety outcomes that may benefit from localization within the hospital.
  - Created a survey of hospital rooms to identify room-level factors that may be associated with patient safety outcomes. We piloted this survey on 597 distinct rooms over 6 months.
  - Streamlined and improved the hospital room survey based on findings from this pilot and feedback from facilities personnel.
  - Created a crosswalk that allowed us to connect room-level data from the EHR and room-level data from our room survey to the hospital geographic files in order to create a hospital GIS.
- We hypothesized that exposure to more intra-hospital environments may increase the risk for HO-CDI. We performed a matched case-control (3:1) study to determine whether number of in-hospital transfers increased the risk for acquiring HO-CDI. Between December 1, 2013, through January 1, 2016, there were 386 cases of HO-CDI. Results of a multivariate logistic regression model adjusting for age, the Charlson comorbidity index, and antibiotic use suggest a significant relationship between HO-CDI risk and the number of in-hospital transfers. Each additional transfer increases the odds of HO-CDI infection by approximately 7%.
- **Automated surveillance and novel visualization:** Created an interactive dashboard that allowed spatio-temporal visualization of cases.
- **Visualization of hotspots:** We created a social network analysis to analyze in-hospital networks of HO-CDI cases. We used a GIS visual representation of the network structure to highlight rooms most associated with these cases.
- **Pilot study investigating the role of intra-hospital transfers on HO-CDI:** For each additional transfer, the odds of HO-CDI increase by 7%.
- **Pilot study to analyze data within a hospital GIS.** Using a logistic regression model with hospital fixed effects modeled the risk of HO-CDI as a function of patient and hospital room characteristics:
a. **Patient characteristics**: Antibiotic use was associated with an increased risk, and the comorbidity score was associated with a slightly decreased risk.

b. **Room characteristics**: Furniture and flooring factors as well as antibiotics in the room prior were associated with increased risks; hygiene factors and a computer in the room were associated with decreased risks.

Project 3 explored how the hospital-wide use of MyChart Bedside (MCB), an inpatient EHR-based patient portal, is impacting the provider work system and processes. The principal findings of Project 3 are presented and discussed here.

- Interviews with hospital staff about secure messaging have consistently identified work-arounds that clinicians have developed to circumvent the Secure Messaging function. This was addressed at the hospital level through additional training but has not resulted in increased usage of the secure message function. There is considerable concern among clinical staff that secure messaging could create communications issues. A health system-level committee was convened to serve as a means of translating findings from Project 3 into operational improvements.

- Interviews with hospital staff have indicated frustrations around MCB because of the lack of time in their workflow to provision tablets to patients upon admission and the need to deal with technology issues and training.

- Many providers discourage use of secure messaging in the inpatient setting because of difficulty in accessing messages and/or their preference for face-to-face communications.

- Patients are using MCB to send secure messages to providers to make requests, ask questions, and express gratitude. Messages from patients generally involve topics about symptoms, treatment plans, and pain.

- Patients and physicians identified strategies at the patient, portal, physician, and health system levels that could help each group navigate the portal to communicate via secure messages more efficiently.
  a. Patient-focused training strategies included multimodal materials addressing how to navigate portal features and direction on when, what, and how to message.
  b. Changes to the format of the messaging feature and pop-ups with communication tips were also frequently mentioned.
  c. Physician and clinic-level strategies focused on how the clinic and health system management could enhance physician training on the patient-facing portal features and how to manage patient care within the portal.

- Patients and care team members identified inpatient portal functions that they perceived to positively impact health literacy. These functions included providing patients access to health information, care plans, and educational materials as well as enabling patient communication with their care team.

- In patients who were concerned that their medical information would be compromised if it was sent electronically between providers, the odds of withholding information from their provider was three times that of patients without concerns. Conversely, for patients who were confident about the privacy of their medical information, the odds of keeping information from their provider was approximately half of those who were not confident.

- Black patients were generally more likely to withhold information than White patients were. Patients who were older, married, employed, and in good mental health and who had health care coverage were less likely to keep information from their provider.

- The perspectives of patients and care team members around the use of the inpatient portal generally converged. Three features – 1) ordering meals, 2) looking up health information, and 3) viewing the care team – were most commonly used; the secure messaging feature was less commonly used and of some concern to care team members. The inpatient portal benefited
patients in four main ways: 1) promoted independence, 2) reduced anxiety, 3) informed families, and 4) increased empowerment.

- Inpatient portals are recognized as a tool that can enhance the delivery of patient-centered care. In addition to empowering patients by increasing their sense of control, inpatient portals can support family members and caregivers throughout the hospital stay. Given the consistency of perspectives about portal use across patients and care team members, our findings suggest that inpatient portals may facilitate shifts in organizational culture that increase the patient-centeredness of care and improve patient experience in the hospital context.


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5. Patterson ES. “Addressing alarm overload with appropriate use of continuous cardiac monitoring.” Health and Rehabilitation Sciences, The Ohio State University Wexner Medical Center, Columbus, OH, Feb 19, 2016.


23. Moffatt-Bruce SD, Yamokowski T, Rayo MR. “Clinical Alarms: How Do We Keep it Safe?” IDEA4PS Learning Laboratory Lecture, The Ohio State University Wexner Medical Center, Columbus, OH, Mar 16, 2016.


28. Moffatt-Bruce SD, Hebert CL. “Hotspotting: Keeping Patients Safe in Real Time.” IDEA4PS Learning Laboratory Lecture; The Ohio State University Wexner Medical Center, Columbus, OH, Jun 29, 2016.


30. Moffatt-Bruce SD. “Concentrating specialized surgical care-why (not) and how (not)?” Erasmus Master Class in Anesthesia and Perioperative Care, Rotterdam, Netherlands, Mar 31, 2017.


32. Patterson ES. “Increasing the Efficiency of Nursing Documentation While Avoiding Unsafe ‘Copy Forward Workarounds.’” IDEA4PS Learning Laboratory Lecture; The Ohio State University Wexner Medical Center, Columbus, OH, Apr 26, 2017.


34. Moffatt-Bruce SD. “Clinical Transformation: What does it mean for our patients?” Thomas Jefferson University Hospital, Philadelphia, PA, Jun 1, 2017.


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49. Klatt M. Building a Culture of Wellness: An Interdisciplinary Panel Discussion With Q&A. OSUWMC, Columbus, OH, Mar 27, 2018.


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89. Reynolds ME, Morey DA, Rayo MF. Dispositioning machine answers: How data representation affects corroboration and reframing in human and machine teams. 2020 International