Final Progress Report to AHRQ

Project Title: NYU Patient Imaging, Quality and Safety Laboratory

Principal Investigator: Leora Horwitz, MD, MHS

Team members:

Project PIs
Soterios Gyftopoulos, MD
Danil Makarov, MD
Eric Aaltonen, MD
Saul Blecker, MD
Stella Kang, MD

Additional Team Members
James S. Babb, PhD - Statistician
Wei-Yi Chung, RN – Data Analyst
Eduardo Iturrate, DO – Co-Investigator
Erin McCaffrey, RN – Co-Investigator
Jordan Swartz, MD – Co-Investigator
Silas Smith, MD – Co-Investigator
Emma Simon – Project Coordinator
Cathy Santos, MPH – Research Data Associate
Kira Gary, MPH – Research Data Associate
Isomi Miake-Lye, PhD – Consultant

Organization: NYU Grossman School of Medicine

Inclusive Dates of Project: 09/30/2015 – 08//31/2020

Federal Project Officer: David Rodrick

Acknowledgment of Agency Support: The project was funded by the Agency for Healthcare Research and Quality. Results are solely the responsibility of the authors and do not necessarily represent the views of the AHRQ.

Grant Award Number: P30 HS24376-01

Structured Abstract

Purpose: To create a Patient Safety Learning Laboratory on the theme of improving radiology-related quality and safety

Scope: Imaging-related care in the outpatient, emergency department, and inpatient settings

Methods: We used design thinking, human factors engineering, and implementation science principles to realistically characterize existing practices, conduct deep problem analyses, identify key areas for improvement, brainstorm and prioritize interventions, implement and iterate interventions, and evaluate final outcomes. We conducted three distinct projects: one focused on optimizing ordering of CT pulmonary angiography for the detection of pulmonary emboli in the emergency department; one focused on optimizing interventional radiology procedures for inpatients, with particular attention to handoffs between IR and inpatient teams; and a third focused on management and follow-up of incidental radiologic findings, with specific focus on incidental pulmonary nodules.

Results: We identified numerous process failures and opportunities for improvement in all three focus areas, including lack of routine calculation of risk of PE, lack of standard policies and procedures for pre- and post-IR care, and inconsistent reporting of incidental findings. Inadequate communication and handoffs between providers was a consistent theme across all three projects. We conducted a number of interventions, including autocalculation of risk scores, audit and feedback reports, peer comparison dashboards, institution of new work procedures, standardization of policies, training sessions on optimal pain and sedation management, creation of new templated notes in the electronic health record, and macros for radiology reports.

Key Words: Radiology, communication, handoffs, incidental findings, pulmonary embolism, informatics, decision support

A. Purpose

The goal of this grant was to create the NYU Patient Imaging Quality and Safety Laboratory (PIQS Lab): a dynamic learning environment focused on improving safety and quality for patients undergoing radiologic imaging or procedures. The PIQS Lab was composed of three synergistic, interdisciplinary projects. Though related in scope, each of the projects had a distinct research team, methodology, and focus. Project 1 focused on maximizing appropriate utilization of diagnostic imaging in the ambulatory setting, Project 2 focused on improving the safety of inpatient vascular interventional radiology, and Project 3 ensured appropriate follow-up of radiological test results.

Each project included distinct specific aims. Nearly all are now complete, though some evaluations (Aims 3) are still in progress.

Project 1: Maximizing appropriate utilization of diagnostic imaging in the ambulatory care setting

Aim 1: To examine and characterize the sequence of events and interacting systems within the ambulatory imaging ordering process in order to define the potential sources of failure leading to inappropriate imaging in the ambulatory setting.

Aim 2: To use design thinking to generate, develop, and test solutions to ameliorate the potential sources of failure during the imaging ordering process in the ambulatory setting.

Aim 3: To evaluate the effect of interventions on improving imaging quality and safety in the ambulatory care setting.

Project 2: Improving the safety of inpatient vascular and interventional radiology procedures

Aim 1: To comprehensively study and characterize failures in inpatient procedural consultation between referring clinical teams and the Vascular and Interventional Radiology (VIR) section.

Aim 2: To use a design and engineering approach to improve the safety of inpatient VIR procedural consultation by addressing failures in shared sensemaking and in aspects of the underlying sociotechnical system.

Aim 3: To evaluate the effect of systemic improvements to inpatient VIR procedural consultation on patient safety outcomes including case delays, near-miss/inappropriate procedure rates, and repeat visits.

Project 3: Ensuring appropriate follow-up of radiological test results

*Aim 1***:** Perform problem analyses to identify the causes of inappropriate follow-up of radiological test results

Aim 2: Design, develop, and implement solutions of inappropriate follow-up of radiological test results

Aim 3: Evaluate the effect of systemic improvements while considering unintended consequences

B. Scope

Background and Context (adapted from original grant application)

The NYU Patient Imaging Quality and Safety Laboratory (PIQS Lab) is focused on improving safety and outcomes for patients undergoing radiologic imaging or treatment. This multidisciplinary laboratory connects experienced clinicians in the NYU Departments of Radiology, Emergency Medicine, Medicine, Orthopedics, Surgery, and Urology with operations researchers and improvement staff at NYU Langone Medical Center (NYULMC), the NYU Department of Population Health, the NYU Wagner School of Public Policy, and NYU Stern School of Business and with design experts at the world-famous design firm IDEO. The PIQS Lab will be jointly housed in the NYULMC Center for Healthcare Innovation and Delivery Science (CHIDS) and the NYU Department of Radiology. Together, we will comprehensively redesign our systems to improve the quality and safety of diagnostic and therapeutic radiology.

Every year, 400 million radiology tests are performed in the United States at a cost of over $100 billion,[1] making radiology a central feature of both inpatient and outpatient healthcare. Done well, radiological studies assist in the timely and accurate diagnosis of disease, helping patients avoid prolonged symptoms or more invasive testing. Interventional radiology is now also an important option for diagnosis and treatment of acute illness, replacing more invasive and risky surgical procedures and shortening recovery time. However, radiologic imaging and intervention also carry risks. In the **short term**, patients risk allergic reactions to contrast material (0.2-0.7% for CT contrast;[2,3] <0.1% for MRI contrast[4,5]), contrast extravasation,[2] anesthesia-related complications (0.2% for hemodynamic instability[6]), and injury from metallic objects in MRI machines (very rare). In the **medium term**, patients risk CT contrast-induced nephrotoxicity (likely rare[7,8]) and major procedural complications, such as bleeding or infection (variable; as high as 10% for percutaneous drainage procedures[9]). Most worrisome, in the **long term**, patients risk cancer (up to 2% of all cancers in the United States may be attributable to CT scan radiation),[10,11] nephrogenic systemic fibrosis (a rare but potentially fatal condition caused by MRI contrast),[12] missed diagnosis or treatment from lack of follow-up, and, most commonly, identification of incidental findings (12-30% of studies[13-15]) that create a cascade of often unnecessary further imaging or interventions. Many of these risks have been demonstrated to be avoidable or ameliorable through systems-based improvements.[16-21] In addition, all are greatly compounded by overutilization: 20-50% of radiologic results do not change clinical management, potentially unnecessarily exposing patients to substantive risks for no benefit.[22-24]

Opportunities for error exist at every point along the process of radiologic evaluation: ordering the study or intervention,[22,25,26] performance,[2,27] interpretation and recommendation,[28,29] and follow-up.[30] Indeed, the very fact that radiology is so central to modern medicine makes it also a key locus for failures in teamwork, communication, cognition, workflow, technical skill, and information technology. To address these issues and develop efficient, scalable, generalizable solutions, we propose the PIQS Lab. The PIQS Lab will improve patient safety and reduce risks of radiologic imaging through three synergistic projects (**Figure 1**), in collaboration with a group of systems experts and design experts and supported by common administrative and information technology cores.

In the **first project**, we will examine and redesign the radiology ordering process. Unlike surgeries or medications, which are ordered by the same clinicians who perform or administer them, radiology studies uniquely are ordered by clinicians who are typically not expert in radiology and often have little knowledge about the best test or intervention to order. Little to no decision support is available to the ordering clinician in most environments, and direct communication with the expert radiologist is a rarity. Clinicians are often unaware of prior similar tests ordered by other providers or of cumulative radiation doses received by the patient. Radiologists, in turn, may be unaware of crucial contraindications to imaging, such as allergies, impaired renal function, or embedded metallic objects. This multidisciplinary project will redesign the ordering process to ensure patients receive the correct test the first time without adverse consequences or unnecessary duplication. The **second project** will focus on interventional radiology procedure ordering and conduct for hospitalized patients.

Like ambulatory patients, hospitalized patients are at risk of undergoing an inappropriate or redundant intervention because of failures in the ordering process. Moreover, their acuity of illness coupled with the dynamically changing pace of inpatient medicine adds several more layers of complexity to the system. Inpatients undergoing interventional procedures may be clinically unstable; may be receiving medications that need to be altered or held in anticipation of the procedure; may have coagulation disorders requiring identification and management prior to an invasive procedure; may need to be prepared for the procedure by withholding food and drink; may need to be monitored or receive treatments during or after the procedure; and must be appropriately counseled to provide informed consent. This project will apply lessons learned from ambulatory ordering redesign to improve the ordering process for inpatients and will explore safety risks unique to this acutely ill population. The **third project** will connect these two populations by focusing on the aftermath of the test: ensuring that, once the right study is performed, the results are reported in the most timely and usable fashion and that both the results and the patients themselves are followed up appropriately. We and others have found that radiologists are not consistent in their recommendations and often do not follow evidence-based guidelines;[29] that their reports are not optimally helpful to the ordering clinicians;[31] and that clinicians do not consistently perform recommended follow-up – either by over-aggressively following up benign findings or by missing necessary follow-up for worrisome findings.[30] Lost follow-up is of greatest concern in cases in which the radiologist identifies an "incidental" but important finding that may need longer-term follow-up, particularly in cases in which the clinician who should be responsible for long-term follow up (i.e., a primary care physician) is not the one who ordered the initial radiology test (i.e., an emergency physician).[14,15] This third project will identify challenges to appropriate follow-up in both ambulatory and hospitalized patients and will test a number of interventions to improve patient safety after a radiology study or procedure is performed.

Setting

This project took place entirely within the NYU Langone Health System, a large quarternary care health system in New York City. Project 1 was focused on the emergency department setting (four distinct EDs); project 2 was focused on interventional radiology at the main hospital campus and its interactions with the internal medicine service; project 3 was focused on both the inpatient and ambulatory settings.

Participants

Studies conducted as part of this large center grants included as participants the patients undergoing radiology studies/procedures, nurses, physicians, transporters, housekeeping, and IT staff. Specific inclusion criteria differed by study but in general included any patient or staff involved in the radiology process.

Incidence

The incidence of relevant radiologic studies varied by study. Approximately 1.8% of all ED patients underwent a CT pulmonary angiogram (>3,500 patients included in the study). Approximately 22% of pulmonary CT scans were found to have an incidentally identified pulmonary nodule (>1,000 patients included in the study). There were approximately 1,500 interventional radiology cases per year (>4,500 patients included in the study).

C. Methods:

Study Design

We conducted a variety of studies as part of this grant, each of which used a slightly different design. However, a common theme across all projects was an overall approach to systems redesign.

For all projects, we sought to develop successful shared sensemaking[32,33] – a collective ability to make sense of complicated, dynamic, and ambiguous information without oversimplifying or ignoring discordant data – and wholesale system redesign: alterations in workflow, skills, culture, staffing patterns, equipment, incentives, and information technology. Our approach to systems redesign was based on process-based theories of change, which emphasize accounting for complexity; involving all stakeholders; tightly linking interventions to an in-depth problem analysis; taking a sequential rather than wholesale approach; starting with easier, low-impact interventions; iterating and rapidly abandoning failures; and using data to monitor progress and reassess interventions.[34-37] This theoretical model has been very successfully adapted by the design company IDEO, which partnered with us for all three projects to apply design thinking to radiology safety.[38-40]

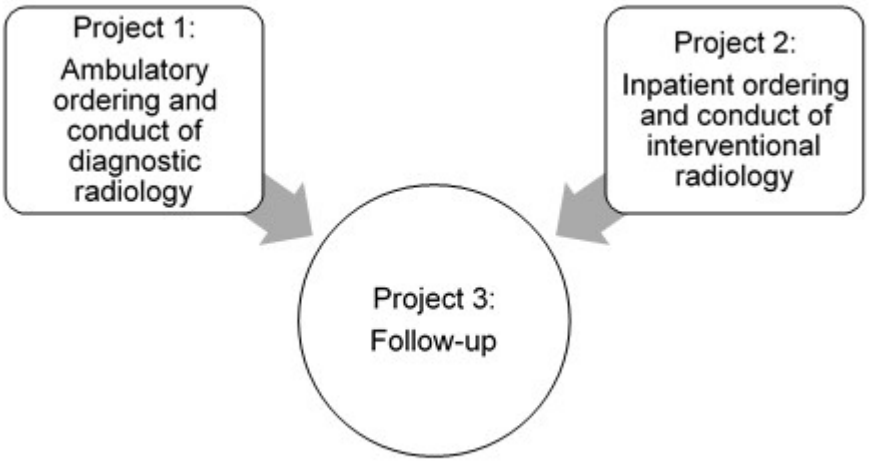

Figure 1: Schematic of the three PIQS Lab projects

Accordingly, first, we spent time understanding radiology diagnostic and intervention processes through direct observation, 360° interviews, chart reviews, adverse event reviews, and root cause analyses. Second, we created concepts for possible interventions using techniques from design firms (e.g., brainstorming, storyboarding, and creating composite, representative characters) and from operations management (i.e., service blueprinting). We made it a particular priority to include all relevant stakeholders in the design phase, including attending physicians and trainees in radiology and relevant specialties, nurses, radiology technicians, front desk staff, and our patient advocates. Then, we developed prototype interventions and tested and revised them on a small scale. For several projects, we then implemented the revised interventions to scale across the health system. Then, we conducted evaluations appropriate to the nature of the intervention, making full use of quality improvement and program evaluation methods, from qualitative analysis to quasi-experimental designs.

Data Sources/Collection

Data for these projects were largely drawn from the electronic health record at NYU Langone Health (Epic Systems, Verona, WI) as well as from the adverse event reporting system, interviews and focus groups, and surveys of staff and patients. We also collected phone log data and pager data to track communication events, and obtained patient experience survey results.

Interventions

We conducted a series of interventions, including:

1. an automatic calculation of the Geneva Score for risk of pulmonary embolism
2. a best practice alert in the EHR tied to the auto-calculated score that triggered on order of a CTPA
3. a monthly audit and feedback report to ED clinicians
4. a quality dashboard in Tableau illustrating CTPA quality-related outcomes on the provider and patient level
5. a natural language processing tool to identify CT scans with incidental pulmonary nodules
6. an automatic guideline concordance calculator for CTPA
7. a standardized note template for interventional radiology consult

8. a standardized note template for post-IR procedure reporting
9. a dedicated IR consult position
10. a push notification to clinicians for IR procedure acceptance and for scheduled event
11. incorporation of scheduled IR events into unit nurse workflow for easy visualization
12. standardized scripting for transporters
13. low health literacy-suitable frequently asked questions brochures for every major IR procedure
14. pre/peri/post procedure music for patients via headphones for relaxation
15. a standardized macro for reporting of incidental findings
16. a dedicated dashboard for tracking of incidental findings
17. direct phone calls to patients with high priority incidental findings to ensure follow-up

Measures

Measures for the projects in this grant included:

1. proportion of CTPA that were guideline-concordant
2. yield of CTPA
3. D-dimer order rate per capita
4. CTPA order rate per capita
5. proportion of pre- and post-procedure notes that included all key elements
6. frequency of calls to IR with questions about procedure or timing
7. use of pain and sedation medications during procedure
8. pre/post procedure patient anxiety as measured by a standard instrument
9. frequency and type of adverse event reports

Results

This grant has generated numerous problem analyses and subsequent interventions. We have conducted dozens of qualitative interviews, reviewed hundreds of adverse event reports, spent over 100 hours in direct observations, led four half-day design charrettes, and implemented half a dozen interventions. Examples of some of the most important results the program has generated are:

Assessment of the frequency of non-guideline concordant CTPA ordering in the ED

We assessed 212 consecutive ED encounters with CTPA ordered and found that the frequency of guideline-discordant studies ranged from 53 (25%) to 79 (37%) depending on the scoring system used; 46 (22%) were guideline discordant under all three scoring systems. Of these, 18 (39%) had at least one patient-specific factor associated with increased risk for PE but not included in the risk stratification scores (e.g., travel, thrombophilia). These findings were reported in the *Journal of the American College of Radiology*.[41]

Development and implementation of a clinical decision support tool to promote guideline-concordant CTPA ordering

This tool combines risk stratification and lab results to generate a recommendation to the provider if, and only if, they are attempting to order a guideline discordant exam. To determine a patient's level of risk, we developed an autocalculated version of the risk stratification. The results of the development and validation of this autocalculated version of the revised Geneva score were published in *Academic Emergency Medicine*.[42] Providers may decide to override the BPA; however, they need to acknowledge a reason for doing so before proceeding.

Development and implementation of a CTPA dashboard

The CTPA dashboard provides personalized and comparative ED-wide data on various CTPA ordering metrics. In addition to these generalized metrics, the dashboard also presents patient-specific data for providers to review. The dashboard is complementary to the CDS tool above, because it provides a consistent source of data that can be accessed by ED physicians at any time.

Development and implementation of an audit and feedback email intervention

The monthly audit and feedback emails acts as a way to provide physicians with a concise version of the data seen in the CTPA dashboard by pushing this information directly to their inbox. Providers who have ordered guideline-discordant exams receive an email that includes personalized data on their ordering behavior. The emails also contain a link to their CTPA dashboard so that they can easily review the cases discussed.

Collectively, the three interventions above were applied to 1,910 patients undergoing CTPA, who were compared to 1,677 patients in the pre-intervention period. Guideline concordance increased significantly ($p<0.001$) from 66.9% (1122/1677) to 77.5% (1480/1910). CTPA order rate and D-dimer order rate also increased significantly (from 17.1 to 18.4 per 1,000 patients, $p=0.035$, and 30.6 to 37.3 per 1,000 patients, $p<0.001$, respectively). Percent yield showed no significant change (12.3% pre- vs.10.8% post-intervention; $p=0.173$). SPC analysis showed sustained special-cause variation in the post-intervention period for guideline concordance and D-dimer order rates, temporary special-cause variation for CTPA order rates, and no special-cause variation for percent yield. A paper reporting these findings is under review.

Assessment of adverse events associated with peri-procedural handoffs

We reviewed 375 adverse event reports related to vascular interventional radiology over a 6-year period. More than half (207, 55.2%) of reports involved no harm to patients; one (0.3%) involved severe permanent harm, and six (1.6%) involved death. Reports were filed from radiology (183, 48.8%), medical specialties (90, 24.0%), surgical specialties (52, 13.9%), and six other major specialties (50, 13.3%). The most commonly reported adverse events were procedural complications (109, 29.1%), many of which had implications for post-procedure care. Additional types of adverse events particular to peri-procedural handoffs included treatment or transfer delays (47, 12.5%), pre-procedure optimization failures without delay (7, 1.9%), unanticipated changes in clinical condition following transfer (13, 3.5%), performance/near performance of the incorrect procedure (13, 3.5%), and multiple transfers for procedures because of poor coordination (2, 0.5%). Results of this study informed several of our subsequent interventions; an associated manuscript is under review.

Development and implementation of standardized documentation and communication for vascular interventional radiology

In our problem analyses, we identified a significant need for standardized communication between VIR and the referring specialties that included the key information needed by both sides. We implemented two standardized notes, which utilize a smartphrase within the EHR to delineate helpful pieces of information for the referring provider. We developed one note for pre-procedure communication and another for post-procedure communication. Audits demonstrated a mean of 3.5 key elements included in pre-procedure notes prior to standardization compared with 15.3 post-intervention ($p<0.001$) and 4.7 key elements in post-procedure notes compared with 15 in post-intervention notes ($p<0.001$); these results were stable over a 1-year post-intervention period.

Pre-intervention staff surveys showed that 52.9% of non-VIR staff lacked confidence in knowledge of how to prepare patients for VIR procedures, compared with 30% after (p=0.40). Incoming phone calls to VIR decreased from 19,625 in the 6 months pre-intervention to 9,370 in the 6 months post-intervention (p<0.001); this work was presented at the Society of General Internal Medicine annual meeting and the American Medical Informatics Association meeting.

Development of patient education materials for vascular interventional radiology procedures

In qualitative interviews with patients, we identified a need for proactive communication between providers and patients, who are often too ill to take the initiative to ask key questions. To address this issue, we developed a series of frequently asked question documents specific to each procedure. Each was reviewed by a patient literacy team to ensure appropriate language level, was standardized with other patient communication materials, and was embedded into the procedure order to ensure consistent receipt. Full implementation of these materials into routine workflow is ongoing.

Vascular interventional radiology staff and medicine staff training

Qualitative interviews with patients identified inadequate pain control to be a consistent problem during procedures; interviews with staff identified discomfort with pain and sedation dosing during conscious sedation procedures as a major barrier. We therefore held multiple in-services with VIR nurses and doctors with improved sedation outcomes. In addition, referring providers expressed a desire to learn more about VIR itself. To address this, we held in-services for referring providers on the basics of VIR and reasons to order a VIR consult.

Randomized trial of pre-/intra-procedure music for relaxation

We conducted a randomized trial of giving patients music to listen to before and during their procedure to determine whether it influenced anxiety scores and total pain and sedation medication use. We enrolled 126 patients (61 in intervention, 63 in control). We found no significant difference in mean dose of pain medication or sedation.

Development of a natural language processing tool to identify incidental pulmonary nodules

Using a tool developed at NYU, we trained and validated a natural language processing tool to identify incidental pulmonary nodules from unstructured radiology reports. The sensitivity and specificity of the algorithm was 96% and 86%, respectively. This algorithm was published in the *Journal of the American College of Radiology*.[43]

Direct outreach to patients newly identified with incidental pulmonary nodules

We conducted a pilot intervention to contact patients immediately after hospital discharge who had newly diagnosed pulmonary nodules requiring long-term follow-up. We created a registry and dashboard within the EHR to which patients were automatically added once a nodule was identified. Using a central coordinator based in the Cancer Center, we contacted patients by phone after discharge. Those who did not already have a plan for follow-up were referred to a dedicated nodule clinic established for the purpose. Of 45 patients with new nodule diagnoses over 3 months, we reached 29, of whom 10 were not aware of the diagnosis. The program was halted because the small numbers per week could not justify the staff allocation.

Publications and Presentations

Publications

1. Gyftopoulos S, Smith SW, Simon E, Kuznetsova M, Horwitz LI, Makarov DV. Qualitative study to understand ordering of CT angiography to diagnose pulmonary embolism in the emergency room setting. J Am Coll Radiol. Epub 2017 Oct 19; S1546-1440(17)31016-5. PMCID: PMC5908756
2. Koziatek, CA, Simon E, Horwitz LI, Makarov DV, Smith SW, Jones S, Gyftopoulos S, Swartz JL. Automated pulmonary embolism risk classification and guideline adherence for computed tomography pulmonary angiography ordering. Acad Emerg Med. 2018 Sep;25(9):1053-1061. Epub 2018 Apr 30. PMCID: PMC6133740
3. Simon E, Miake-Lye IM, Smith SW, Swartz JL, Horwitz LI, Makarov DV, Gyftopoulos S. An evaluation of guideline discordant ordering behavior for CT pulmonary angiography in the emergency department. Journal of the American College of Radiology. 2019 Aug;16(8):1064-1072. Epub 2019 Apr 29. PMCID: PMC6984630
4. Kang S, Garry K, Iturrate E, Kim D, Horwitz LI, Swartz J, Moore W, Blecker S. Natural Language Processing for Identification of Incidental Pulmonary Nodules in Radiology Reports. Journal of the American College of Radiology. 2019 Nov;16(11):1587-1594. Epub 2019 May 24. PMCID: PMC7686874.
5. Gyftopoulos S, Simon E, Swartz JL, Smith SW, Santos C, Babb JS, Horwitz LI, Makarov D. Efficacy of a multi-modal intervention on CT pulmonary angiography ordering behavior in the emergency department, under review.
6. Horwitz LI, McCaffrey EC, Kuznetsova M, Simon E, Reyes D, Miyake-Lye IM, Aaltonen ET. Adverse events associated with peri-procedural handoffs, under review.

Oral presentations

1. Horwitz LI. Patient “Imaging Quality and Safety Laboratory (PIQS Lab).” Patient Safety Learning Lab Annual Conference, Sep 2017, Rockville, MD.
2. Improvement Stories for Informatics Professionals. Society for Imaging Informatics in Medicine Annual Meeting, June 2017, Pittsburgh, PA.
3. Horwitz, L.I. “Patient Imaging Quality and Safety (PIQS) Lab: Increasing guideline concordant utilization of CT pulmonary angiography in the emergency department.” Presented at: NYU Langone Health HealthTech Symposium, June 2018, New York, NY
4. Horwitz, L. I. “Disruption.” Presented at Engineering High Reliability Learning Lab Critical Junctures Session, Feb 2018, Boston, MA.
5. Horwitz, L. I. “Patient Imaging Quality and Safety Laboratory.” Presented at National Clinical Scholars Program Annual Meeting, Nov, 2018, New Haven, CT.
6. Makarov D, Gyftopoulos G, Horwitz LI, Aaltonen E, Blecker S, Kang S. “Patient Imaging Quality and Safety Laboratory.” Presented at PSLL Webinar series, Apr 2019.
7. Chung R, Garry K, Horwitz L, Iturrate E, Swartz J, Moore W, Li D, Kim D, Blecker S, Kang S. “Natural Language Processing for Identification of Incidental Lung Nodules.” Annual meeting of the Radiological Society of North America, Nov 21, 2018, Chicago, IL.
8. Simon E, Miake-Lye IM, Smith SW, Swartz JL, Horwitz LI, Makarov DV, Gyfopoulos S. An evaluation of guideline-discordant ordering behavior for CT pulmonary angiography in the emergency department. American College of Radiology 2020 Annual Meeting, May 2019.

Posters

1. Qualitative Analysis of the Current State of CT Pulmonary Angiography Ordering in the Emergency Department at NYULMC. Poster presented at NYU Langone Health Quality & Safety Day, June 2017, New York, NY.

2. Assessing the Utilization of CT Pulmonary Angiography in the Emergency Department at NYULMC. Poster presented at NYU Langone Health Quality & Safety Day, June 2017, New York, NY.
3. Patient Imaging Quality and Safety (PIQS) Lab: Improving Safety of the Inpatient Interventional Radiology Process. Poster presented at NYU Langone Health Quality & Safety Day, June 2017, New York, NY.**
4. Improving the Interventional Radiology Patient Experience. Poster presented at NYU Langone Health Quality & Safety Day, June 2017, New York, NY.**
5. Swartz, J.L., Gyftopoulos, S., Makarov, D.V., Horwitz, L.I., Iturrate, E., Smith, S.W., Miake-Lye, I.M, Li, D., Mentor, S.M., Simon, E., Santos, C.. Implementing an audit and feedback dashboard for CT pulmonary angiography in the emergency department. Poster presented at: NYU Langone Health Quality & Safety Day, June 2018, New York, NY.
6. Koziatek, C.A., Swartz, J.L., Makarov, D.V., Gytopoulos, S., Horwitz, L.I., Smith, S.W., Miake-Lye, I.M., Li, D., Mentor, S.M., Simon, E., Santos, C. Developing an automated assessment of guideline adherent ordering of CT pulmonary angiography. Poster presented at: NYU Langone Health Quality & Safety Day, June 2018, New York, NY.
7. Aaltonen, E.T., Horwitz, L.I., McCaffrey, E.C., Li, D., Miake-Lye, I.M., Kuznetsova, M., Simon, E. Standardization of electronic documentation for inpatient interventional radiology procedures. Poster presented at: NYU Langone Health Quality & Safety Day, June 2018, New York, NY.**
8. Abbott, H., Simon, E., Horwitz, L.I., Aaltonen, E.T., McCaffrey, E.C., Li, D., Miake-Lye, I.M. Improving outcomes for moderate sedation use in interventional radiology: an educational intervention. Poster presented at: NYU Langone Health Quality & Safety Day, June 2018, New York, NY.
9. Blecker, S., Kang, S.K., Horwitz, L.I., Iturrate, E., Swartz, J.L, Chung, R., Miake-Lye, I.M., Li, D., Garry, K.E. Automated identification of incidental pulmonary nodules using natural language processing. Poster presented at: NYU Langone Health Quality & Safety Day, June 2018, New York, NY.
10. Gyftopoulos, S., Makarov, D.V., Swartz, J.L., Smith, S.W., Simon, E., Santos, C., Mike-Lye, I.M., Li, D. Interventions to improve guideline concordant ordering of CT pulmonary angiography in the emergency department. Poster presented at: NYU Langone Health HealthTech Symposium, June 2018, New York, NY.
11. Gyftopoulos, S., Makarov, D.V., Swartz, J.L, Smith, S.W., Simon, E., Santos, C., Miake-Lye, I.M., Li, D. Developing an automated assessment of guideline adherent ordering of CT pulmonary angiography. Poster presented at: NYU Langone Health HealthTech Symposium, June 2018, New York, NY.
12. Aaltonen, E.T., Horwitz, L.I., McCaffrey, E.C., Simon, E., Kuznetsova, M., Miake-Lye, I.M, Li, D. Standardization of electronic documentation for inpatient interventional radiology procedures. Poster presented at: NYU Langone Health HealthTech Symposium, June 2018, New York, NY.
13. Horwitz, L.I., Blecker, S., Kang, S.K., Iturrate, E., Swartz, J.L, Garry, K.E., Simon, E., Chung, R., Miake-Lye, I.M., Li, D. Automated identification of incidental pulmonary nodules using natural language processing. Poster presented at: NYU Langone Health HealthTech Symposium, June 2018, New York, NY.
14. Miake-Lye, I.M., Kuznetsova, M., McCaffrey, E.C., Aaltonen, E.T., Horwitz, L.I.. Problem solved or protracted? A qualitative analysis using organizational learning theory to understand potential system solutions in Vascular and Interventional Radiology. Poster presented at: AcademyHealth Annual Research Meeting, June, 2018, Seattle, WA.
15. Simon S, McCaffrey EC, Kuznetsova M, Horwitz LI, Aaltonen E. Utilizing standard documentation to improve the clarity and efficiency of periprocedural communication for inpatient vascular interventional radiology procedures. Poster presented at: Society of General Internal Medicine Annual Meeting, May 2019, Washington, DC.

**Designated a Meritorious Project

References

1. Swensen SJ. Patient-centered Imaging. *The American Journal of Medicine.* 2012;125(2):115-117.
2. Cochran ST, Bomyea K, Sayre JW. Trends in adverse events after IV administration of contrast media. *AJR Am J Roentgenol.* 2001;176(6):1385-1388.
3. Mortele KJ, Oliva MR, Ondategui S, Ros PR, Silverman SG. Universal use of nonionic iodinated contrast medium for CT: evaluation of safety in a large urban teaching hospital. *AJR Am J Roentgenol.* 2005;184(1):31-34.
4. Prince MR, Zhang H, Zou Z, Staron RB, Brill PW. Incidence of immediate gadolinium contrast media reactions. *AJR American journal of roentgenology.* 2011;196(2):W138-143.
5. Aran S, Shaqdan KW, Abujudeh HH. Adverse allergic reactions to linear ionic gadolinium-based contrast agents: experience with 194, 400 injections. *Clin Radiol.* 2015;70(5):466-475.
6. Chang B, Kaye AD, Diaz JH, Westlake B, Dutton RP, Urman RD. Complications of Non-Operating Room Procedures: Outcomes From the National Anesthesia Clinical Outcomes Registry. *J Patient Saf.* 2015.
7. Weisbord SD, Mor MK, Resnick AL, Hartwig KC, Palevsky PM, Fine MJ. Incidence and outcomes of contrast-induced AKI following computed tomography. *Clin J Am Soc Nephrol.* 2008;3(5):1274-1281.
8. McDonald JS, McDonald RJ, Comin J, et al. Frequency of acute kidney injury following intravenous contrast medium administration: a systematic review and meta-analysis. *Radiology.* 2013;267(1):119-128.
9. Wallace MJ, Chin KW, Fletcher TB, et al. Quality improvement guidelines for percutaneous drainage/aspiration of abscess and fluid collections. *Journal of vascular and interventional radiology : JVIR.* 2010;21(4):431-435.
10. Brenner DJ, Hall EJ. Computed tomography--an increasing source of radiation exposure. *The New England journal of medicine.* 2007;357(22):2277-2284.
11. Smith-Bindman R, Lipson J, Marcus R, et al. Radiation dose associated with common computed tomography examinations and the associated lifetime attributable risk of cancer. *Arch Intern Med.* 2009;169(22):2078-2086.
12. Wertman R, Altun E, Martin DR, et al. Risk of nephrogenic systemic fibrosis: evaluation of gadolinium chelate contrast agents at four American universities. *Radiology.* 2008;248(3):799-806.
13. Lumbreras B, Donat L, Hernandez-Aguado I. Incidental findings in imaging diagnostic tests: a systematic review. *The British journal of radiology.* 2010;83(988):276-289.
14. Kelly ME, Heeney A, Redmond CE, et al. Incidental findings detected on emergency abdominal CT scans: a 1-year review. *Abdom Imaging.* 2015.
15. Samim M, Goss S, Luty S, Weinreb J, Moore C. Incidental findings on CT for suspected renal colic in emergency department patients: prevalence and types in 5,383 consecutive examinations. *Journal of the American College of Radiology : JACR.* 2015;12(1):63-69.
16. Rosenkrantz AB, Doshi AM. Continued evolution of clinical decision support tools for guiding imaging utilization. *Acad Radiol.* 2015;22(4):542-543.
17. Johnson E, Sanger J, Rosenkrantz AB. Important nonurgent imaging findings: Use of a hybrid digital and administrative support tool for facilitating clinician communication. *Clinical Imaging.* 2015.
18. Doshi AM, Kiritsy M, Rosenkrantz AB. Strategies for Avoiding Recommendations for Additional Imaging Through a Comprehensive Comparison with Prior Studies. *Journal of the American College of Radiology : JACR.* 2015.
19. Medverd JR, Cross NM, Font F, Casertano A. Advanced medical imaging protocol workflow - A flexible electronic solution to optimize process efficiency, care quality and patient safety in the national VA enterprise. *Journal of Digital Imaging.* 2013;26(4):643-650.
20. Vartanians VM, Sistrom CL, Weilburg JB, Rosenthal DI, Thrall JH. Increasing the appropriateness of outpatient imaging: effects of a barrier to ordering low-yield examinations. *Radiology.* 2010;255(3):842-849.
21. Ip IK, Schneider L, Seltzer S, et al. Impact of Provider-led, Technology-enabled Radiology Management Program on Imaging. *The American Journal of Medicine.* 2013;126(8):687-692.
22. Lehnert BE, Bree RL. Analysis of Appropriateness of Outpatient CT and MRI Referred From Primary Care Clinics at an Academic Medical Center: How Critical Is the Need for Improved Decision Support? *Journal of the American College of Radiology.* 2010;7(3):192-197.

23. Hendee WR, Becker GJ, Borgstede JP, et al. Addressing overutilization in medical imaging. *Radiology.* 2010;257(1):240-245.
24. Dunnick NR, Applegate KE, Arenson RL. The Inappropriate Use of Imaging Studies: A Report of the 2004 Intersociety Conference. *Journal of the American College of Radiology.* 2005;2(5):401-406.
25. Obara P, Sevenster M, Travis A, Qian Y, Westin C, Chang PJ. Evaluating the Referring Physician's Clinical History and Indication as a Means for Communicating Chronic Conditions That Are Pertinent at the Point of Radiologic Interpretation. *Journal of Digital Imaging.* 2014.
26. Bautista AB, Burgos A, Nickel BJ, Yoon JJ, Tilara AA, Amorosa JK. Do Clinicians Use the American College of Radiology Appropriateness Criteria in the Management of Their Patients? *American Journal of Roentgenology.* 2009;192(6):1581-1585.
27. Lee YH, Yang J, Suh JS. Detection and Correction of Laterality Errors in Radiology Reports. *Journal of Digital Imaging.* 2015.
28. Margolis NE, Rosenkrantz AB, Babb JS, Macari M. Frequency of recommendations for additional imaging in diagnostic ultrasound examinations: Evaluation of radiologist, technologist, and other examination-related factors. *Journal of clinical ultrasound : JCU.* 2015.
29. Rosenkrantz AB, Kierans AS. US of incidental adnexal cysts: adherence of radiologists to the 2010 Society of Radiologists in Ultrasound guidelines. *Radiology.* 2014;271(1):262-271.
30. Blagev DP, Lloyd JF, Conner K, et al. Follow-up of incidental pulmonary nodules and the radiology report. *J Am Coll Radiol.* 2014;11(4):378-383.
31. Rosenkrantz AB, Kiritsy M, Kim S. How "consistent" is "consistent"? A clinician-based assessment of the reliability of expressions used by radiologists to communicate diagnostic confidence. *Clin Radiol.* 2014;69(7):745-749.
32. Weick KE. The Collapse of Sensemaking in Organizations: The Mann Gulch Disaster. *Admin Sci Quart.* 1993;38:628-652.
33. Weick KE, Sutcliffe KM, Obstfeld D. Organizing and the process of sensemaking. *Organ Sci.* 2005;16(4):409-421.
34. Bartholomew LK, Parcel GS, Kok G, Gottlieb NH. *Intervention Mapping: Designing Theory and Evidence-Based Health Promotion Programs.* New York: McGraw-Hill; 2001.
35. Ferlie EB, Shortell SM. Improving the quality of health care in the United Kingdom and the United States: a framework for change. *The Milbank quarterly.* 2001;79(2):281-315.
36. Grol R, Wensing M. Effective Implementation: A Model. In: Grol R, Wensing M, Eccles M, eds. *Improving Patient Care; the Implementation of Change in Clinical Practice.* Oxford: Elsevier; 2005:41-48.
37. Kotler P, Roberto E. *Social Marketing Strategies for Changing Public Behavior.* New York: Free Press; 1989.
38. Kelley T, Littman J. *The Art of Innovation: Lessons in Creativity from IDEO, America's Leading Design Firm.* New York: Currency Books; 2001.
39. Moen R. A Review of the IDEO Process. 2001; http://www.rwjf.org/content/dam/web-assets/2001/10/a-review-of-the-ideo-process. Accessed January 31, 2014.
40. OpenIdeo Blog. 7 Tips on Better Brainstorming. http://www.openideo.com/blog/seven-tips-on-better-brainstorming. Accessed January 31, 2014.
41. Simon E, Miake-Lye IM, Smith SW, et al. An Evaluation of Guideline-Discordant Ordering Behavior for CT Pulmonary Angiography in the Emergency Department. *J Am Coll Radiol.* 2019;16(8):1064-1072.
42. Koziatek CA, Simon E, Horwitz LI, et al. Automated Pulmonary Embolism Risk Classification and Guideline Adherence for Computed Tomography Pulmonary Angiography Ordering. *Academic Emergency Medicine.* 2018.
43. Kang SK, Garry K, Chung R, et al. Natural Language Processing for Identification of Incidental Pulmonary Nodules in Radiology Reports. *J Am Coll Radiol.* 2019.