Abstracts of the 50th Anniversary Association of Pathology Chairs Annual Meeting: Pathology and Population Health

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Education

E001. Residents and Fellows Comprise the Inspection Team for a CAP Self-Inspection: An Effective Way to Teach Lab Management, Promote Interprofessional Collaboration, and Prepare Residents for Practice

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We report our experience at the University of Florida in which residents and fellows served as the inspection team for a College of American Pathologists self-inspection. To prepare for the inspection, we provided a series of 4 lunchtime seminars, covering numerous laboratory management topics relating to inspections and laboratory quality. Preparation for the inspection began approximately 4 months prior to the date of the inspection. The intent was to simulate a College of American Pathologists (CAP) peer-inspection, with the exception that the date was announced. The associate residency program director of clinical pathology served as the team leader. All residents and fellows completed inspector training provided by CAP and the team leader completed the team leader training. A 20-question pretest and posttest was administered; additionally, an anonymous survey was given after the inspection. The residents’ and fellows’ posttest scores were an average of 15% higher than on the pretest (P < .01). The survey as well as subjective comments showed that this experience was a useful tool to learn accreditation and laboratory management.

E002. Pathology Residents on Rounds: What Are You Doing Here?

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Consultation with colleagues in other departments regarding test selection and interpretation of results, understanding laboratory processes, and interprofessional collaboration in activities such as root cause analyses and quality improvement projects are some of the most common and important components of the job of a medical director. As such, many of the milestones set by the Accreditation Council for Graduate Medical Education focus on these activities. We felt that the conventional method of clinical pathology training, which involved spending the majority of time on the bench in the laboratory or self-directed learning, did not enhance these skills. Therefore, we created a new rotation in which the resident serves as a director for the microbiology, virology, hematology, chemistry, point-of-care, and electrophoresis laboratory test results under mentorship. Several components of the curriculum aide in fostering collaboration with clinical services:
1. The resident attends clinical rounds once per week on a service of the resident’s choice (with direction from the faculty) and can tailor it to his/her specific interests. The resident can choose to attend the same service’s rounds each week in order to integrate themselves into the clinical team or choose different services each week to meet a variety of clinicians and learn about a wide variety of patients. A clinical pathology faculty member often accompanies the resident on rounds. One of the most common reactions when pathologists introduce themselves to the team is a polite but perplexed question, “What are you doing here?” which is followed by a brief explanation of our consultative services and then a warm welcome from the team.

2. The resident attends infectious disease (ID) clinical case conferences and grand rounds. When laboratory-related questions come up, the resident is able to offer his or her input related to the topic or case. It is not unusual for the ID fellow who is presenting a case to ask for microscopic or gross photos which the resident can provide prior to the presentation.

3. He or she leads a multidisciplinary plate rounds conference in the microbiology laboratory, which is an interactive seminar with trainees and staff from the departments of ID, infection control, and epidemiology, pharmacy, and pathology. Laboratory methods and processes are described, usually in the Socratic method and as an illustration of a few patient cases.

4. The resident reviews all miscellaneous test requests. This often involves contacting the physician to discuss the appropriateness of the test order, possible limitations of the test, and any possible alternatives.

5. The resident holds a day pager that is accessible by any clinician or laboratory technologist.

Residents are sometimes hesitant to serve in the consultative role. However, they are reminded that it is always appropriate to state whether you are unsure of the answer to a question but will look into it and follow up later. The above activities have led to substantial collaboration among clinicians and pathologists and are generally enjoyed by our residents.

E003. Enhancing Clinical Translation in an Experimental Pathology PhD Training Program
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The graduate program in the molecular and cellular basis of disease (MCBD) at the University of Virginia (UVA) confers the PhD degree in experimental pathology. The program was established in 2004 with a stated purpose of providing a graduate training experience with a strong focus on translational research. The MCBD program draws on the unique environment provided by the combined clinical and research missions of the UVA department of pathology to support a unique curriculum that weaves a disease-centric thread through the entire training predoctoral training experience.

Students matriculate into the MCBD program near the end of their first year at UVA, after completing core coursework and research rotations as members of the umbrella program in Biomedical Sciences (BIMS). Molecular and cellular basis of disease is one of the 9 degree granting programs that accept students from the BIMS umbrella. As an interdisciplinary program, MCBD considers students who are training with mentors holding primary appointments in any basic science or clinical department, as long as their proposed research includes a disease focus. Our current roster of 26 students includes trainees working with mentors in 7 basic science departments and 4 clinical departments/divisions throughout the School of Medicine and the department of biology.

Once a student has elected to train through MCBD, we devise an individualized training plan based on his/her research interests. Some aspects of the training program are quite conventional, including an advancement to candidacy examination consisting of a written grant proposal and oral defense. The didactic coursework required for our trainees is designed such that the lectures and discussions focus on disease topics, each led by a team composed of a clinician and basic scientist. The students learn about each disease from these 2 perspectives, gaining an appreciation for how the disease is diagnosed and treated and the challenges of caring for the patients as well as an understanding for the state-of-the-art in the scientific study of the disease.

However, the cornerstone of our curriculum is the rotations in diagnostic and interventional medicine, during which each student completes 4-week long rotations. Selections are made with the research interests of the individual student in mind, though all students are expected to spend at least 1 week in surgical pathology. While on each rotation, the students are immersed in the daily activities of the service. While educational in their own right, these rotation experiences also allow students to establish relationships with our clinical faculty who then serve as resources for later discussions. Students are encouraged to include these faculty members on their advisory committee.

Since its inception, MCBD has graduated 17 students with the PhD in experimental pathology. Many of our alumni have secured successful postgraduate training opportunities in competitive academic postdocs or, in the case of our MD/PhD trainees, residencies, and fellowships leading to faculty positions. Others have launched careers in industry, science communication, and teaching. Although long-term outcomes will require additional time, we contend that these students have likely benefited from unique training opportunities that set our graduates apart from their peers.

E004. The Role of Quality Management in Quantitative Literacy Training
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Models of informatics training in medical school, pathology residency, and informatics pathology subspecialty assume quantitative literacy, but this often is not the case in our
society. Even though pathology and laboratory data analysis can provide public health information comparable to that of large planned studies, our involvement in public health studies is limited by innumeracy. Development of numeracy cannot rely solely on theoretical instruction or on practice with simulated data. It requires the handling of actual data as well as expertise in the subject matter. In this study, we present examples of quality improvement projects carried out with pathology resident participation. They illustrate the educational opportunities provided by laboratory and pathology information, as they require data extraction from different sources, cleanup, use of exploratory data analysis, and the graphic and tabular communication of results, conclusions, and actions. Similar data-focused projects can be leveraged within the PIER framework.

1. Hypokalemia might help detect primary hyperaldosteronism, yet it is difficult to detect due to interference by hemolysis. After analysis of phone call data, patient and experimental results, the hemolysis index measured by chemistry instruments was used to cancel spurious K results and to add warnings of potential hypokalemia-masking hemolysis to laboratory test reports. This reduced all critical result calls by nearly one-fourth while making notification of hyperkalemia more meaningful.

2. Exactitude in the hemoglobin A1c test (HgbA1c) is essential. Its imprecision is generally estimated by the coefficient of variation (CV) of quality control (QC) results, which should not exceed 1 of 3 of the 6% total error allowed. Increased imprecision (CV 1.8%-2.0%) had placed the method in borderline category. We performed exploratory data analysis of 11 453 HgbA1c QC results spanning 6 months and found long-term fluctuations and high prevalence of outliers. This perspective brought attention to the frequent interruptions of testing and test repeats caused by these out-of-control events, and the A1c instruments were promptly upgraded.

3. The partial thromboplastin time (aPTT) test is used for the therapeutic monitoring of intravenous unfractionated heparin (UFH). Target aPTT intervals are established for each UFH lot using regression analysis of aPTT versus antiactivated factor X (aXa) test results. Evaluation of these data revealed that 28.6% of 234 aPTT results would misclassify patients as being within the 0.3 to 0.9 U/mL aXa therapeutic interval. That fraction could be not reduced enough by manipulating aPTT cutoffs. This led to the partial replacement of the aPTT by the aXa test for UFH therapeutic monitoring in the institution.

We have thus demonstrated that rigorous mentoring of pathology residents on data-intensive quality improvement projects can hone their numeracy, the foundation of informatics training, and eventually lead to a creative role in the Learning Healthcare System of the future, while familiarizing them with the complexities of clinical laboratory operations and effecting favorable outcomes in the delivery of patient care.

E005. Strategic Approach to Restructuring Surgical Pathology Resident Education in a Subspecialty Practice Model

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Background: To keep pace with new developments and subspecialized nature of clinical practice, many academic pathology departments in the country have transitioned to a subspecialized practice model in surgical pathology (SP). We found that this transition posed challenges when structuring the residency education program in SP. The strategic approach adopted by our institution to manage this issue is discussed.

Design: At University of Wisconsin Madison, we instituted an SP Education Committee, comprised of SP faculty, director of SP, residency program director, laboratory staff, and resident members, tasked to devise an educational program to meet resident’s needs in the new model. To match subspecialty (SS) practice, a 2-year didactic curriculum was designed to supplement resident learning. Conference evaluations were implemented to provide rapid feedback to faculty. Subspecialty curricula with slide study sets and examinations specific to each specialty area were developed to support self-learning and complemented by voluntary evening conferences. Most challenging was the balancing of resident service needs within acceptable duty hours. This was met by (1) creation of a unit system for busier subspecialties to limit the number of large cases grossed by the resident, (2) implementation of a separate tumor board (TB) rotation to avoid previewing and sign-out interruption for SP residents, and (3) limiting biopsy sign out to 3 d/wk and utilizing the remaining 2 days for frozen sections and added preview/study time. Modules for laboratory management education in SP were implemented. Recently, we introduced a frozen section block for our senior residents. To maintain renewed interest and resident motivation, we implemented formal year-end teaching sessions conducted by senior residents with an interest in SP.

Results: The immediate impact of these changes showed improved resident morale and faculty satisfaction of resident performance. Restructuring the grossing and minimizing interruption during preview and sign-out enhanced the overall quality of work performed by the residents. Faculty evaluations on the TB rotation reflected high confidence by majority of the residents with improved organization and presentation skills. We observed improvements in our Resident In-Service Examination (RISE) scores and Accreditation Council for Graduate Medical Education reviews. However, we believe that the true impact of these changes will be evident over time.

Conclusion: Moving to an SS practice model impacts residency education in SP. Adopting a strategic approach to understanding the issues and restructuring resident education in this
model has shown promising results within our department. We believe that discussing such educational strategies at national forums, leading to an exchange of ideas, can help advance the quality of SP education in an increasingly common SS setting.

**E006. Demystifying Transfusion Medicine for Internal Medicine residents**

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**Purpose:** Transfusion medicine should not simply be viewed as an isolated branch of medicine. In this discipline, specialists in internal medicine, surgery, and anesthesiology interact with the blood bank staff (technicians, trainees, and clinical pathology attendings and nurses). The main goal of this relationship is to coordinate the delivery of optimal patient care, often for a complex and critically ill patient population. Based on our experience and review of the literature, we recognized a deficit in some basic knowledge concepts of transfusion medicine among internal medicine residents rotating in our blood bank. These deficiencies can lead to improper use of blood products and miscommunication between blood bank staff and clinical teams. Additionally, can cause delays in urgent patient care and could potentially result in serious patient harm. Our long-term goal for this project is to include targeted transfusion medicine education modules in orientation for internal medicine, surgery, and anesthesiology residency programs. This will foster a better understanding of appropriate utilization of blood products, basic immunohematology, and recognition of transfusion reactions, with a secondary goal of improving communications between clinical teams and blood bank staff.

**Methods:** Thirty-two internal medicine residents from first and second year of the Internal Medicine Program of Penn State Hershey Medical Center agreed to participate in this study. PGY-3 residents did not participate in the lectures and, therefore, were excluded from the assessment. Four educational modules focusing on blood products, identification of red blood cell antibodies, ABO/Rh compatibility, and transfusion reactions were specially developed for internal medicine residents. The 30-minute modules were presented during noon conference on 2 consecutive days. An anonymous online-based survey (SurveyMonkey) with multiple choice questions was sent 3 days prior and 15 days after the lectures. \( \chi^2 \) distribution analysis was utilized to estimate the statistical significance of the results.

**Results:** All residents (32 of 32) answered the pre- and post-lecture assessments. The results showed a statistically significant improvement in the knowledge of blood products and their use \( (P = .023) \), red cell antibody identification \( (P = .024) \), and ABO/Rh compatibility \( (P = .004) \). There was a trend toward adequate knowledge of transfusion reactions. Anecdotally, participants in the educational intervention note improved utilization of blood products in their clinical practice.

**Conclusion:** Our data suggest that training incoming residents with brief modules targeting specific blood bank and blood transfusion principles results in significant improvement in medical knowledge. The participants note increased confidence in blood utilization and smoother communication with the blood bank. Future studies are necessary to determine the outcome on improving patient care, reducing unnecessary blood product utilization and errors caused by miscommunication.

**E007. Objective Structured Pathology Examination (OSPE): Novel Curricular Tool for the Evaluation of Residents in Anatomic Pathology**

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**Introduction:** The Accreditation Council for Graduate Medical Education’s (ACGME) next accreditation system demands greater accountability for postgraduate education on the part of training programs. Objective structured clinical examinations (OSCE) have become a mainstay in undergraduate and graduate medical education, particularly in the evaluation and assessment of clinical skills as they relate to continuum of training. As the criterion-based milestones have been clearly delineated by the ACGME, pathology residency programs are in need of new assessment tools that can be used to objectively evaluate resident performance. Predominately relying on direct observation of clinical responsibilities will fall short of truly evaluating a resident’s competence in practice. In the ACGME pathology residency milestones, one of the suggested methods of evaluation is simulation, but there is little literature on the development and implementation of OSCE in the pathology residency-training forum. Simulations allow for the evaluation of learners and can be used to show developmental progression for both common situations as well as for uncommon situations not readily encountered in a clinical setting. These examinations can also identify areas of weakness such as in system-based practice that are hidden from routine rote evaluations. We developed and conducted 5 interactive case-based objective structured pathology examinations twice a year over 2 years that are linked to the ACGME pathology milestones and evaluate residents formatively with immediate feedback.

**Methods:** Objective Structured Pathology Examination (OSPE) was created by a group of pathologists and clinicians according to the OSCE blueprint model developed by Zabar et al. The interactive structured simulation event sessions were conducted with an attending pathologist (associate program director) and a resident role-playing in mock clinical scenarios. See figure for an example of an OSPE session blueprint. Detailed instructor notes were written to guide the attending pathologist so that the assessments of the goals of the interaction were addressed with each resident. A milestone-linked evaluation matching the learning
Introduction: Contrary to the clinical pathology training which does not require the residents to take calls until the second year, the residents start to take anatomic pathology (AP) calls* shortly after their training begins. However, due to the limited exposure to AP prior to residency, the PGY-1 residents generally have no concept of routine surgical pathology workflow, no experience of proper grossing techniques, and no clear idea of how essential the accurate and efficient pathologic diagnoses are on patient-care decisions. Therefore, it is not uncommon that mistakes can be made by new residents during evening and weekend calls. In turn, this will increase the anxiety for new residents to take calls. Therefore, we initiated this pre-AP call simulation workshop.

Methods: During a 3-hour workshop, 26 scenario-based simulation-style questions that were likely encountered during AP calls were presented to PGY-1 residents and appropriate guidelines for responding to these clinical situations with detailed explanation were offered and discussed. A field trip to the labs was also included to demonstrate how to handle the specimens when facing the urgent calls. Meanwhile, a 10-question survey was given to answer pre- and postworkshop, so as to determine whether the workshop was helpful in decreasing their anxiety level and increasing their appropriate response in taking the actual calls.

Conclusion: Based on the statistical analysis of the workshop, it appears to be an efficient way to prepare the PGY-1 residents for their on-coming AP calls, including improving their understanding and expectation of the AP calls, self-confidence of taking calls properly, and avoiding errors that might arise in taking calls. The workshop has been adopted as part of the training courses for PGY-1 residents routinely.

Note: *AP calls for PGY1 resident reflect the extended work hours (up to 10 PM when covering after-hour-frozen sections). After 10 PM, the PGY2 to 4 residents cover the AP calls.

E009. Integration of Technological Tools in Resident and Fellow Education: the University of California at Davis Health System Experience

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Increasing time constraints and educational expectations for all residents and fellows have created curricular challenges for training programs. These challenges include an escalating pressure to incorporate newer disciplines (eg, molecular pathology) into an already saturated curriculum, as well as an increasing need to educate residents and fellows in pathology and other medical specialties on the role that the pathologist should play in patient care. Technological tools allow for an efficient means of enhancing our teaching of these concepts in the residency and fellow training environment.

At the University of California Davis Health System, we have pathology residents, hematopathology fellows, and hematology/oncology fellows regularly rotating on our hematopathology service. In addition to regular one-on-one teaching sessions at the microscope and white board, we use our virtual hematology atlas as a self-learning tool in the hematopathology rotation for all trainees. This digital hematology atlas is available online and as a free iPhone/iPad app to orient residents and fellows to the basics of hematology (eg, vocabulary, cellular morphology) prior to and during the hematopathology rotation. We have also included several self-assessment modules within this digital atlas to allow residents and fellows to test their knowledge before, during, and after each rotation. These tools include randomly generated multiple choice quizzes on peripheral blood and bone marrow and matching quizzes that assess the user’s basic hematology knowledge, along with a novel virtual slide assessment tool that allows for review of the hematopoietic elements in a rapid, efficient manner. The material in the atlas can then be reviewed with the trainees during a didactic session, with inclusion of discussion about the roles played by the pathologist at different stages in providing excellent patient care.

Another example of the use of technology in our curriculum is the use of audience response software in our board review sessions. Our faculty pathologists have collaborated in the design and implementation of a board review curriculum based on recommendations and public domain data from the American Board of Pathology (ABP), the College of American Pathologists, and the Accreditation Council for Graduate Medical Education.

The utilization of this new board review curricular approach allows for a consistent, systematic review of topics on the ABP board certification examination, while also offering participants an opportunity to test their own knowledge and receive “just in time” teaching and feedback. To maximize the practical applicability of these sessions, the discussion held after each question also explores practical issues, such as the role of the pathologist in the patient’s care for a specific condition,
recommendations that could be made to optimize patient management and how to approach communication about sensitive issues with clinical colleagues. These audience response lecture sessions have been well received by our trainees, and we intend to refine and improve these further based on resident and fellow feedback.

**E010. Weekly Clinicopathologic Conferences as a Means of Teaching Gastroenterology Fellows About the Pathologist as Consultant**

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Regular education of clinicians on the consultant role of the pathologist is clearly essential, particularly as our collective medical knowledge exponentially expands in an increasingly complex health-care system. As at many academic medical centers, the pathologists at the University of California at Davis Health System have a long-standing tradition of contributing to the medical education of our clinical colleagues and trainees. One such example of this is our weekly gastrointestinal clinicopathologic conference, in which our gastroenterology fellows select several interesting cases to review at the multiheaded microscope with a gastrointestinal pathologist. Other regular attendees of this conference include gastroenterologists on faculty, internal medicine residents rotating on the gastroenterology service, medical students rotating on the gastroenterology or pathology service, and interested pathology residents and fellows. Each case begins with the gastroenterology fellow presentation of the patient’s clinical history, physical examination findings, laboratory and imaging results, and endoscopy findings. This is followed by the pathologist-led description of the histopathologic findings, with specific questions asked by the pathologist of the gastroenterology fellows to increase fellow preparedness for the gastroenterology board certification examination. Perhaps, most important is the subsequent, often robust discussion and analysis of the clinical and pathological differential diagnoses and where they overlap. When cases are particularly challenging—whether due to an unusual or complex patient presentation, a significant discrepancy in the clinical and pathological differential diagnosis, or technical challenges in the procurement and processing of tissue—this provides fertile ground for a discussion on the best approach to consulting both anatomic and clinical pathology. We also use this weekly forum to remind our gastroenterology fellows of several key issues at the interface between gastroenterology and pathology, including the need to provide all relevant clinical history on the requisition form, the importance of procuring sufficient tissue from the correct location to establish the diagnosis (e.g., numerous deeper biopsies are needed to evaluate for invasion in potentially malignant masses or how biopsies of an esophageal ulcer bed are best to evaluate mesenchymal cells for cytomegalovirus infection), how to approach the grouping and labeling of tissue biopsies by container to balance cost to the health-care system with the gastroenterologist’s need for accurate information, how to submit more complex specimens for the most informative results (e.g., pinning out and orienting endoscopic mucosal resections), and a review of the expected time course and steps involved in the processing and diagnosis of tissue specimens. In addition, we discuss issues particularly relevant to clinical pathology, including the best approach to submitting specimens to microbiology or hematopathology and caveats in the interpretation of laboratory results such as liver “function” tests and autoimmune disease panels. Although this conference does require an investment of pathologist time and effort, we have found that this repeated and reinforced emphasis on how best to use pathology in consultation to be very helpful in reducing the number of problematic cases, enabling us to be more helpful still in the evaluation of our shared patients.

**E011. Transfusion Medicine Education for Medical Students**

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**Background:** Transfusion of blood products is the most common procedure performed at hospitals and medical facilities, most often under the supervision of physicians without subspecialty training in transfusion medicine. There are already established curricula delineating which topics should be included in transfusion medicine education. How this information is distributed is not clear. Surveys have shown that many trainees receive 1 to 2 transfusion medicine lectures, and some programs do not include transfusion medicine in their formal training.

**Discussion:** At our university, we offer a comprehensive and multifaceted curriculum given throughout their time as medical students, ranging from didactics to interactive hands-on simulations. In year 1 to 2 of medical school, there are 3 distinct lecture sessions. The lectures and small-group sessions cover introductory topics including red cell antigens, antibody characteristics, fundamental blood bank testing, transfusion indications, and possible complications, as well as coagulation concepts.

In year 2 of medical school, students participate in a small-group simulation of a transfusion reaction. A high fidelity simulator is utilized, and the students assess the “patient” and determine the need for a transfusion. An acute hemolytic transfusion reaction occurs, and the students work to diagnose the reaction and manage the patient appropriately. Discussion and learning are included in a debriefing session.

The elective clerkship in year 3 to 4 offers active participation in our busy transfusion service. It offers emersion in many
aspects of transfusion medicine, covering transfusion reactions, observe antibody workups, and participate in the care of apheresis patients.

Conclusion: Transfusion medicine knowledge is an important skill for a variety of physicians in training. Many different techniques or teaching styles can be utilized to deliver this information. The transfusion medicine faculty at our institution are involved in multiple ways to help provide medical student training over the course of their education.

Practice

**P001. Quality Improvement Intervention for Reduction of Redundant Testing**

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In the setting of residual use of creatine kinase M and B isoenzyme (CKMB) testing for myocardial infarction (MI), we assessed disease outcomes of discordant CKMB (+)/troponin I (cTnI)(−) test pairs in order to address anticipated clinician concerns about potential loss of case-finding sensitivity following proposed discontinuation of routine CK and CK MB testing. Time-sequenced interventions were introduced at West Virginia University Hospitals (WVUH). The main outcome was the percentage of cardiac marker studies performed within guidelines. Nonguideline orders dominated at baseline. Creatine kinase M and B isoenzyme testing in 7496 order sets failed to detect additional MIs but was associated with 42 potentially preventable admissions/quarter. Interruptive computerized soft stops improved guideline compliance from 32.3% to 58% (P < .001) in cardiology and nonacademic hospitalists not receiving peer-leader intervention and to >80% (P < .001) in emergency medicine with peer leadership that featured dashboard feedback about test order performance. This successful experience was recapitulated in interrupted time series within the other 2 services and then in 2-system hospitals, Jefferson Medical Center, a critical access facility, and Berkeley Medical Center. Improvements have been sustained postintervention. Laboratory cost savings at WVUH were estimated to be US$635 000/year. not including the incalculable additional value of preventing unneeded admissions. National collaborative data demonstrated improvement in cardiac marker utilization from fourth to first quartile compared to peer norms. This example illustrates how pathologists can provide leadership in assisting clinicians in changing laboratory ordering practices. We found that clinicians respond to local laboratory data about their own test performance and evidence suggesting harm is more compelling to clinicians than evidence of cost savings. Our experience indicates that interventions done at an academic facility can be readily instituted by private practitioners at external facilities. The intervention data also supplement the existing literature that electronic order interruptions are more successful when combined with modalities that rely on peer education combined with dashboard feedback about laboratory order performance. The findings may have implications for the role of the pathology laboratory in the ongoing pivot from quantity-based to value-based health care.

**P002. Laboratory Utilization Management at Vanderbilt University Medical Center**

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The ever-increasing rate of scientific discoveries and technological advances have propelled health care to an era of unprecedented growth. This growth comes with the promise of personalized care tailored to each individual’s health history and genetic makeup. A large part of this individualized approach to care can be attributed to the advancement in laboratory testing, which has led to a plethora of options for diagnostic tests, which necessitates tools to ensure only the most optimal tests are utilized. At Vanderbilt University Medical Center (VUMC), our goal is to provide the highest quality evidence-based, personalized, and cost-effective health care. To support this goal, a Medical Center Laboratory Formulary was developed as a multidisciplinary approach to the evaluation and use of laboratory testing.

The VUMC Laboratory Formulary initiative was chartered by the Medical Center Medical Board. The formulary committee is composed of physicians from multiple clinical disciplines. This core group of voting members is invested with the authority to approve, eliminate, and/or restrict testing. The committee collaborates with other clinical teams, laboratory operations and administration and information technology to identify opportunities for improvement and to implement committee decisions. The initiative aimed to develop a formulary composed of approved laboratory tests that are categorized based on restrictions that ensure appropriate utilization of tests. To meet this goal, we started with a list of all tests offered at the time at VUMC and began a 2-pronged approach that (1) identified tests that were overutilized or had minimal value in patient care and (2) implemented a system of vetting new tests based on evidence of positive impact on clinical care before adding to the formulary.

The laboratory formulary was approved in June 2015; in January 2016, the laboratory formulary implemented restrictions on reference laboratory ordering for inpatients with long-turn-around times. At the same time, we began genetic counselor and pathologist review of all send out genetic tests. To date, the initiative has eliminated 8 tests and restricted more than 8 tests. Six new tests have also been added after careful evaluation by the Laboratory Formulary Committee. Although
the positive impact on patient care can be difficult to capture, the financial impact of the laboratory formulary efforts from January 2015 through October 2016 has been at least US$790 000 in reduction of ordering of tests without any negative feedback or negative impact on patient care.

P003. Improving American Health Care Through Laboratory Leadership: A Project Santa Fe Report

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In vitro diagnostics, the industry term for clinical laboratory services represents US$73B of the US$3T spent on US health care—about 2.5%. And yet, this sector of health care informs the majority of health-care management decisions. Only recently have laboratories become actively engaged in developing their value propositions beyond laboratory transactions as a commodity service.

Project Santa Fe was founded in March 2016, as a coalition of like-minded national leaders and reputable institutions in laboratory diagnostics. Our goal is to create and help drive the new frontiers that will define the future economic valuation and placement of laboratory diagnostic services in American health care. Serving first as a think tank for innovation and reassessment of the role of laboratories in health care, the participants in Project Santa Fe represent major regional health systems that can operationalize laboratory-driven innovations and test their valuation in diverse marketplaces in the United States. These value statements are relevant to patients and the consumer populations that they represent, health-care providers, and payers, including both the insurer sector of health care and the employers that bear a major portion of the health care spent. Besides testing programming pilots, our goal is to develop scalable opportunities for clinical laboratories across the breadth of the industry.

Core activities of Project Santa Fe membership will include:

- Analytics on data streams so as to achieve real-time risk stratification of populations, identification, and correction of care gaps, tracking of populations of patients with chronic diseases and interventions as indicated, and implementation of novel technologies and analytics into laboratory diagnostics.
- Working with clinical and administrative leadership in our respective health systems and implementation of clinical programs based on laboratory-generated information streams.
- Advocacy efforts to align new clinical protocols/guidelines with these innovative practice models.
- Optimizing laboratory payment using these new models.

Project Santa Fe participants will track progress through the following mechanisms:

- Thought leadership, as through the publication of white papers.
- Identification of opportunities for health-care innovation through laboratory-driven analytics.
- Success in implementing scalable protocols that utilize evidence-based diagnostics and pathology consultation as a means of driving improved clinical outcomes and decreased total cost-of-care.
- Demonstration projects, leveraging the substantial geographies of the member health systems.
- Business leadership of this future lab model.

Our goal is to serve as exemplars for the value proposition of in-system laboratory services. In so doing, we hope to emerge as a nationally recognized expert coalition in providing high-value diagnostic consultation and clinical programming beyond the ability to perform tests. In this fashion, Project Santa Fe is a mechanism for its members to design a new health-care approach that leverages clinical laboratories to directly improve the patient experience, lower the costs of health-care delivery, and improve population health (the Triple Aim). Project Santa Fe aims to drive innovation through the assembled efforts of the membership and to build the evidence base for laboratory valuation in the next era of US health care.

P004. Improving Test Utilization: The Yale-New Haven Health System Experience

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Laboratory testing is a cornerstone of modern medicine, yet it is estimated that 20% to 45% of all laboratory testing is unnecessary or inappropriate. In addition to wasting resources, inappropriate testing can cause patient harm, start the testing cascade, increase hospital length of stay and add to legal liability. To address this problem at Yale New Haven Hospital, a Laboratory Formulary Committee (LFC) cochaired by a laboratory medical director and a hospitalist and comprised of representatives from varied clinical services from 3 system hospitals, pharmacy, and hospital IT was convened in November 2015. The goals of the LFC are to (1) establish the process for reviews, approvals, and communication; (2) increase awareness of LFC as the filter and governing body for these decisions; (3) work on focused utilization areas of opportunity; (4) develop best practice guidelines; and (5) implement specific clinical decision support strategies. With full institutional support, the committee secured project management, EPIC (HIS) and Beaker (LIS) resources to develop tools to both guide and monitor test utilization.

Members of the committee and others are encouraged to submit proposals to improve test utilization. Content experts and stakeholders are consulted. The hospital community is
informed via email and feedback obtained. Agreement is negotiated among 3 system hospitals and voted on in the committee. The appropriate EPIC tool is selected and implemented. A bypass mechanism for special cases is provided. Results are monitored, problems addressed, and EPIC controls adjusted as needed. Initiatives have included (1) enforcing minimum ordering intervals (range 24 hours to once in a lifetime) for an increasing list of tests, (2) eliminating creatine kinase M and B isoenzyme for clinical use, (3) eliminating redundant/outdated thyroid function tests, (4) reducing inappropriate Mg orders, (5) restricting factor V Leiden and prothrombin gene testing to outpatients, (6) restricting genetic tests to outpatients when feasible, (7) reducing urine cultures in asymptomatic patients first in the emergency department then on the inpatient wards, (8) creating a CSF order set to guide appropriate ordering, (9) restricting folate and eliminating RBC folate, (10) optimizing ionized calcium, and (11) streamlining monoclonal gammopathy orders. Results of selected initiatives in our first year and a list of EPIC tools are provided below. The impact of this committee is measured in terms of both blood and financial savings. In summary, the LFC, with the support of EPIC tools, has made a significant impact in our first year to optimize test utilization, promote efficiency, and improve outcomes.

P005. Shared Decision-Making Between Payers, Pathologists, and Providers in Areas of Complex Genetic Testing

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Value-based reimbursement has the potential to deliver high-quality care at lower cost but is often impeded by a lack of commitment and failure of communication at different levels of care. One of the least recognized meaningful collaborations may be between payers and providers, particularly with regard to diagnostic medicine including complex diagnostic laboratory tests. An interprofessional approach to shared decision-making linking multiple professionals and health-care levels with patients and their families has been extensively discussed and adopted as best practice, but reimbursement decisions still occur in a siloed fashion.

As part of an integrated health network system, the Scott and White Health plan covers a sizeable component of the patient population in the Central Texas area. With the explosion of complex, high-cost, multianalyte genetic tests in the areas of prenatal screening, reimbursement issues with inherited diseases including cardiovascular syndromes, oncology predisposition, and predictive tests were becoming significant. A multidisciplinary team including health plan medical directors, clinicians from relevant disciplines, and pathology representatives outlined guidelines from best practice documents including the National Comprehensive Cancer Care Network, American College of Obstetrics, American College of Medical Genetics among others, and implemented preauthorization requirements for submission. Routine reviews of subsequent requisitions were performed by pathology representatives as part of the evaluation team. Approval rates of over 250 requests in a 6-month period were 56% with turn-around time of consistently less than 24 hours.

Denials were broken down into categories: (1) lack of pertinent clinical information, (2) wrong or misleading clinical information, (3) lack of or insufficient evidence of clinical guidelines, and (4) wrong test ordered particularly with regard to targeted mutations versus panel tests. Requisition forms were revised to incorporate missing information responsible for denials, particularly in cases with requests for BRCA testing in individuals with no personal history of cancer but with a close relative with a history of ovarian cancer. Request denials included lack of pedigrees, cases with identification of fourth-degree relatives with ovarian cancer and cases of undocumented ovarian cancer with no history of pathological subtype or survival data. Educational material outlining appropriate guidelines are being developed, particularly for nongenetic practitioners, to improve appropriate utilization targeting an increase in approval rates and patient satisfaction.

P006. From Internal Operations to HEDIS to Payors, a Laboratory Data Lake That Maximizes Value From Pathology Results

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Overview: Pathology data have the distinct advantages of being diagnostic for many diseases, digital, discrete, real time, and objective. Their major disadvantages include being spread across data silos, held in mission critical transactional systems and require database, domain, and system knowledge to extract and interpret without risking laboratory or hospital operations. To circumvent these challenges, a laboratory data lake was created that consumes laboratory, pathology, clinical, and billing data. This tool has been used to optimize laboratory operations, fulfill Healthcare Effectiveness Data and Information Set (HEDIS) requirements to payors and explore and derive value in risk adjustment processes under insurance contracts and care management processes.

Initial Implementation: Recognizing the need to liberate data from laboratory information systems in order to optimize internal laboratory processes, we developed tools to automate data extraction from LIS’s and make these data accessible to laboratory professionals in a simple web-based interface. These “self-service” tools provide simple reporting such as volume and turn-around time as well as complex reporting correlating results across time and different domains. Users can run their own reports through a user-friendly interface, interact in real-time with the data, or download these results into Excel for further manipulations.
The Provider Value Stream: As providers and clinical practices need to demonstrate value, their data requirements have increased beyond simple reporting models and the capabilities of their own EMRs. We have used our tools to develop practice management tools and tailored reports that focus on the practices’ unique patient needs.

Realizing Value With Payors and HEDIS: The Healthcare Effectiveness Data and Information Set comprises health-care measures used by the government and over 90% of payors. Many of these measures arise from laboratory data. Using the data lake, we were able to rapidly merge data from 3 laboratory information sources and 2 billing data sources to provide complete data across the domain set. Payors, recognizing the challenges of data extraction processes, have funded these efforts to get these data.

Risk Adjustment and the Value of Data in the Insurance Market: The health insurance market in the United States is highly regulated in order to prevent “cherry-picking” and “lemon-dropping.” To accomplish this, the Medicare advantage market, comprising 32% of Medicare enrollees, implemented a risk adjustment process that was adopted by the Affordable Care Act (ACA) insurance market. Risk adjustment depends upon insurers’ ability to accurately identify enrollees with chronic conditions such as diabetes, hepatitis, and cancer. Documenting a condition can be worth between US$6000 and US$196 000. Claims data available to insurers are lossy, are missing results, and have a 4- to 5-month lag. We used our infrastructure to rapidly identify underdocumented patients so that our insurance company could claim a more accurate adjustment factor.

Care Management and the Future of Data: As price compression lowers the value of volume, we have partnered with care management to manage risk pools of patients for the health system. These efforts include risk stratification and the development of care management “critical values” to assist in identifying and preventing avoidable emergency department and hospital admissions, thus improving both health and financial outcomes.

P007. From “Curbside Consults” to an Integrated Diagnostic Consulting Service: A New Role for Clinical Pathologists

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Evaluation for rheumatologic conditions, especially the laboratory testing, may be challenging for primary care physicians (PCPs) and more so for nurse practitioners. It is error prone, often involves ordering unnecessary tests, multiple blood draws, and patient’s visits to PCPs, which cause delays in the referrals to rheumatologists and in initiation of appropriate treatment. To address these issues at the Harris Health Hospital System, which is one of the major safe-net health-care organization in the United States, we had initiated with an input from rheumatologists a project which started as a pilot study in 2012 and was fully implemented system-wide in July of 2014 when federal funding for this initiative was secured through Delivery System Reform Incentive Payment program. The project was conducted in close collaboration with the Ambulatory Service Administration, Medical Directors of the Clinics, and PCPs. The objectives were to simplify the test ordering process by implementing a disease-specific algorithmic approach to facilitate further the diagnostic process by pathologists reviewing clinical, laboratory, and all other diagnostic data and issuing a comprehensive diagnostic consult report with recommendations on referring patients to rheumatologists as needed. We called this a “one-click process” for providers and a “one-step process” for patients emphasizing the intent to eliminate unnecessary multiple steps, making the process more efficient and error-proof.

Between 2014 and 2016, we have issued about 3800 comprehensive diagnostic consulting reports. As a result of system-wide implementation of this project, we were able to essentially avoid unnecessary and duplicate tests, eliminate about 90% of unneeded referrals, decrease the average waiting time for obtaining a referral appointment more than in half (from 6 months to 1-3 months), decrease the rate of rejected referrals due to incomplete testing from 40% to less than 3%, and decrease the average number of patients visits to phlebotomists before establishing the diagnosis from 2.7 to 1.0. Most importantly, we have created a prototype of a functional billable integrative CP Consulting Service and established a new consulting role for clinical pathologists that we can expand to other areas of clinical pathology and to other health-care organizations.

P008. Harnessing Laboratory Data to Identify Undocumented Sepsis Cases Eligible for Risk Stratification

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Background: The health insurance market in the United States is regulated to prevent insurers from insuring only the healthy and leaving the unhealthy without coverage. Adjustments to account for the varying levels of illness among insured populations are done after the fact in order to account for the increased medical costs associated with less healthy members. One such risk adjustment framework originated with Medicare Advantage plans and was extended to others through the Affordable Care Act. Affected insurers document the medical conditions of their members using a Hierarchical Condition Coding (HCC) system, and the health of each insured population is
compared across the health insurance market. Supplements are then paid to insurers with particularly sick patients, whereas insurers with healthier populations are required to pay into the system.

Opportunity: Northwell Health Laboratories was engaged by an insurance company whose challenges included limited historical data on their members’ chronic conditions and inadequate clinical documentation of acute conditions. Our help was sought in identifying which of their members had conditions relevant for a risk adjustment. Sepsis is one of the more valuable conditions to document in the risk adjustment framework.

Methods: Two databases, 1 including insurance plan members (based on billing data) and the other including laboratory results, were cross-referenced to find laboratory results on the relevant patient population. Potential sepsis cases were identified by examining positive blood culture results. Clear cases of blood culture contamination were excluded based on established clinical microbiology practices. Feedback on identified potential sepsis cases was sought from the insurer, and the financial impact of identifying sepsis cases using laboratory data was then estimated using HCC coefficients.

Results: In a covered population of 110,000 insured individuals, 29 patients had positive blood culture results performed at our laboratory between January 1 and September 28, 2016. Seven patients were excluded for suspected blood culture contamination. The remaining 22 patients with positive blood cultures suggestive of sepsis were shared with the insurance company. Fourteen of the 22 identified patients were eligible for risk adjustment. Of these 14 patients, only 7 had been identified as sepsis cases, whereas the additional 7 had not been documented. Sepsis falls under the HCC category “septicemia, sepsis, systemic inflammatory response syndrome/shock.” Documenting 1 patient with sepsis is worth approximately US$3,000 per year. Based on this calculation, the additional 7 suspected sepsis cases identified represent an additional US$371,000 in potentially realized revenue to the insurer.

Conclusion: In conclusion, we used laboratory databases to identify 7 suspected sepsis cases that were likely eligible for risk adjustment but were missed due to inadequate clinical documentation. This represents 50% of eligible cases and a revenue opportunity of over US$371,000.

P009. Heparin-Induced Thrombocytopenia, It’s Time for Intervention: Uncovering Inappropriate Testing and Management Practices

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Heparin-induced thrombocytopenia (HIT) is a potentially catastrophic complication of heparin therapy and a condition troubled by challenging testing and clinical management algorithms. Although the “4T” score is a useful tool for evaluating the likelihood of thrombocytopenia being related to heparin exposure, its use in practice appears to be limited. Furthermore, appropriate testing strategies and interpretation continue to be a source of confusion among physicians. We set out to determine the scope of test utilization and patient management problems related to HIT as well as possible interventions for improvement.

As an initial step, we evaluated test ordering practices for HIT and determined a need for laboratory oversight related to interpretation of the screening enzyme-linked immunosorbent assay (ELISA) as well as appropriate confirmatory testing by serotonin release assay (SRA). We instituted a protocol whereby ELISA interpretation by the pathologist was followed by chart review and discussion with the ordering clinician for all positive results to correlate the clinical findings and determine the appropriateness of confirmatory SRA testing. Prior to this protocol, the majority of patients with suspected HIT received concomitant screening and confirmatory testing (74%). After our intervention, confirmatory SRA testing significantly decreased (23.6%).

Next, we retrospectively reviewed all ELISA and SRA tests ordered at our institution from July to November 2016 to evaluate testing and patient management practices. During this period, 143 ELISA and 19 SRA tests were ordered. Despite ongoing pathologist intervention, our review found examples of inappropriate test utilization to include testing without heparin exposure (35 of 125, 28%), duplicate tests within a single encounter (18 of 143, 12.6%), and lack of needed confirmatory testing (8 of 19, 42.1%). Furthermore, patient safety and management-related issues were analyzed by reviewing the electronic medical records of patients who underwent HIT testing. We identified inappropriate management practices to include patients receiving heparin while testing was pending (33 of 0125, 26.4%), patients receiving heparin after a positive test result (3 of 23, 13.0%), and patients not receiving appropriate alternative anticoagulation (98 of 125, 78.4%). Within the subset of patients receiving appropriate alternative anticoagulation therapy, some were delayed in receiving therapy (8 of 27, 29.6%), whereas 1 patient received extended therapy. Expert consultation by the hematology service was utilized in less than half of encounters (51 of 125, 40.8%). However, fewer patients were exposed to heparin during the testing process and more patients received appropriate anticoagulation therapy when hematologist consultation was sought, although these trends did not reach statistical significance.

Clinician education, close medication monitoring, and laboratory oversight of testing will improve diagnosing HIT, reduce unnecessary testing, and improve patient safety and management practices. In particular, pathologist involvement in test interpretation as well as early hematology consultation appears to improve testing and clinical management practices.
**PO10. Improving Time-In-Therapeutic Range for Warfarin Anticoagulation: Role of Pathology in an Enterprise-Wide Standardization Effort**

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**Brief Explanation of Example:** In 2014, a multidisciplinary group of clinical leaders in anticoagulation management called the coalition of leaders on thrombosis (CLOT) was established to lead an enterprise-wide effort to standardize anticoagulation management at Northwell Health, a large integrated health system comprising 21 hospitals and > 400 outpatient practices. We report on the role pathology can play in such a population-based activity, specifically in measuring and reporting on variability in standards of care and tracking and improving patient outcomes for patients on anticoagulants.

**Text:** Standardizing anticoagulation care for patients on warfarin represents a major clinical and operational challenge across all care settings (outpatient, inpatient, and especially transitions of care). Anticoagulation safety is an important quality metric for Joint Commission Accreditation and various pay-for-performance programs. In 2013, the health system recruited an internationally known expert (A.S.) who was tasked with standardizing anticoagulation management across the health system. Pathology was one of the earliest contributors to this effort, and a multidisciplinary clinical transformation team called CLOT was assembled in early 2014 to spearhead this effort. In addition to the anticoagulation expert (A.C.), this group comprised of a pathologist (T.K.), senior hospitalist (D.R.), a nurse (C.P.), nurse practitioner (M.V.), clinical pharmacist (E.D.) and a project management specialist (D.K.). In 2013, based on claims and laboratory data, we estimated that more than 5000 patients in our outpatient practices were on long-term warfarin. There was lack of standardized anticoagulation management and we needed measures to track optimal care processes and outcomes. Time-in-therapeutic range (TTR) is the most valid measure for warfarin monitoring. We aggregated outpatient laboratory prothrombin time/international normalized ratio (PT/INR) results from our Cerner Millennium laboratory information system to calculate the percentage of patients in therapeutic range. We targeted 25 high-volume internal medicine and cardiology outpatient practices for this standardization effort. Using aggregated PT/INR results, we calculated the mean TTR for each practice using the Roosendaal equation. After extensive validation, we created a dashboard that automates the TTR calculation. The mean TTR for the 25 practices was about 58% (range 45%-67%), the optimal being 65%. Based on these baseline data, a systematic education and quality improvement program was initiated by our CLOT team with a goal to improve mean TTR above 65% over 12 months. Interventions included the installation of clinical decision support software for using the Hamilton dosing nomogram and provider education. We tracked monthly mean TTR metric for each practice. Since the initiation of this standardization effort, the mean TTR has improved to greater than 65% for all practices in 2015 (range 62%-70%) and demonstrated sustainability in 2016. Based on the success of this effort, the CLOT group is now spearheading other anticoagulation standardization initiatives such as (1) increasing warfarin safety in inpatient settings and (2) adherence to venous thromboembolism prophylaxis guidelines. In summary, pathologists can play a crucial role in the successful execution and prioritization of enterprise-wide efforts related to population health by leveraging their knowledge of evidence-based medicine and informatics.

**PO11. Creation of a Pathology Informatics Group in an Academic Department of Pathology: Prioritization of Work Effort**

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Over the last 20 years, the importance of informatics in the practice of pathology and laboratory medicine has steadily increased. We report on de novo establishment of a pathology informatics group. The 2013 recruitment of a pathologist specializing in public health (T.K.) and the 2014 recruitment of a senior pathologist informaticist (T.C.) enabled further recruitment of informatics project specialists and engagement of existing pathology department faculty, trainees, and management. This 3-year effort has supported system quality initiatives, business intelligence, and management of a managed care risk-based population of patients. The prioritization of pathology informatics work effort was based on enterprise-wide high-priority clinical programs and financial initiatives. In addition to informatics efforts internal to the pathology department, system-level initiatives have included (1) support of a nephrology-led program in identification and treatment of patients with chronic kidney disease, (2) support of enterprise growth in health services research through the provision of laboratory data to these programs, (3) support of an enterprise-wide effort to standardize adherence to anticoagulation medication management algorithms, (4) establishment of a program for early identification of acute kidney injury (AKI) during hospitalization, (5) validation and reporting of laboratory-derived data in fulfillment of contractually required HEDIS reporting measures, (6) reporting on enterprise-wide blood culture fill volumes in support of interprofessional and multidisciplinary efforts to improve adherence to quality guidelines, (7) using primary laboratory data to identify of gaps-in-care and reporting of hierarchical conditions coding for the health system full-risk insurance products, (8) improving revenue cycle for diagnostic testing, and (9) evaluating and managing laboratory test utilization in the
inpatient and ambulatory setting. At the enterprise level, the documented annualized favorable financial impact of the pathology informatics effort exceeds US$5M (US$2.6M AKI, US$0.4M HEDIS; US$2.3M revenue cycle, US$0.5M coding) reflecting greater than a 5:1 return on investment. These data are evidence supporting further institutional investment in growth of the pathology informatics group. The work accomplished also provides a rich source for planned academic productivity. This approach to prioritization of pathology informatics work effort may serve as a template for other pathology departments that wish to develop pathology informatics programming.

**P012. The Financial Costs of Emergency Room Admissions by Pathophysiological Categories in a Large Urban/Suburban Integrated Health-Care System**

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Although extraordinary medical value can be realized in avoiding hospitalizations and preventing hospital acquired conditions, the financial value of prevention has been harder to quantify. The Center for Medicare and Medicaid Services (CMS) recently published cost and utilization data for 2014 Medicare hospitalizations, traceable to medical severity-diagnosis related groups (MS-DRGs). These data suggest a methodical evaluation of the medical as well as financial prioritization of resources to support emergency room admission patients.

**Methods:** Center for Medicare and Medicaid Services data which reflect the Medicare population and combine both emergency room and scheduled hospitalizations were downloaded from the CMS website. Average 2014 reimbursements by DRG were used as a proxy for cost per admission and correlated against 2015 discharges at 13 hospital facilities comprising urban and suburban hospitals. Hospitalization data, including facility, admission source, patient age and gender, length of stay, disposition, MS-DRG, major diagnostic categories (MDCs), and admit and discharge ICD-9/10 codes were acquired from the finance department of a large health system. Using the CMS-developed MDCs as a guide, MS-DRGs were evaluated and classified into pathophysiological categories by a pathologist.

**Results:** Within 13 hospitals of the health system, 157 555 (59%) of the 267 745 discharges originated in an emergency room. These admissions comprise approximately 0.9% of all emergency room admissions in the United States. Of these patients, 75.0% were discharged to home and 2.5% expired. Septicemia or severe sepsis without mechanical ventilation at >96 hours with major complications or comorbidities was the costliest DRG (#871), comprising 6.1% of costs and 4.6% of patients. The top 10 DRGs comprise 22% of total costs (Table 1).

When analyzed using broadly inclusive CMS MDCs, circulatory system disease patients were the most numerous and costly. After remapping DRGs into underlying pathophysiological categories, the costliest categories according to CMS average reimbursement rates were infectious (19.5% of costs), circulatory (18.7% of costs), and digestive disease (11.1% of costs, Table 2). The relatively high cost of patients with sepsis (US$13 214 per hospitalization) and infectious disease with operating room procedures (US$34 282) versus chest pain (US$1569) and syncope (US$5947) contributed to the greater financial significance of infectious diseases over circulatory diseases despite the plurality of the latter.

**Conclusion:** To best utilize limited resources and improve population health, it is necessary to optimize the cost-benefit ratio when considering different investments in diagnostic or therapeutic technologies. The ICD 9/10 and MS-DRG categorizations prioritize organ system over underlying pathophysiology. This can be misleading because diseases with similar underlying pathophysiology can fail to group together. For example, pneumonia and urinary tract infections (2.3% and 1.4% of hospitalizations, respectively) are classified as respiratory and kidney/urinary tract diseases rather than infectious diseases. A pathophysiological approach to disease categorization better reflects diagnostic and therapeutic modalities. Surprisingly, with this approach, infectious diseases have the greatest opportunity to find financial value among emergency room admissions. These epidemiological data on local patient populations and a detailed quantitative understanding of the financial implications at the health-care system level assist in prioritizing allocation of effort and resources for improvement in patient and population outcomes.

**Research**

**R001. Ubiquitous and Continuous Diagnostics and Wellness Monitoring**

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The future of an affordable and safe health-care system will require a focus on preventative medicine and home-based health-care delivery. Novel wearable, implantable, insertable, and near patient sensing technologies are enabling continuous monitoring of body chemistry and physiology as well as activities such as sleep, nutrition, bathing, and socialization. Pathologists will be instrumental in the creation of appropriate technologies for continuous diagnostic assessment and wellness monitoring. For example, we are developing a submillimeter-sized glucose analyzer that will be inserted into a tear duct in order to report tear glucose to a nearby cell phone for interpretation and logging. A smartphone app can alert the wearer to changes in body glucose and anticipate and then direct therapeutic interventions. The app can also provide motivational information that can guide exercise and nutrition choices. Another example is a semiautonomous remote
monitoring system we developed that is currently operational in over 1000 homes of independently living senior citizens and providing continuous sleep, bathing, and nutritional information to the care providers and loved ones. Our case-controlled studies have demonstrated not only improved quality of life through continuous monitoring but also a 75% reduction in the cost of care for our study participants.

**R002. Evolution and Revolution in Anatomic Pathology: Report of a Banbury Conference**

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Anatomic pathology is on the cusp of disruptive change, with the expectation that this field will change fundamentally over the next 5 years. However, this transformation will not be easy. In December 2016, a 2.5-day Cold Spring Harbor Laboratory-hosted Banbury Conference was convened to examine the barriers and opportunities to implement new technologies and the enhancements (and potential disruptions), and they may offer clinical practice. Participants included experts in pathology, oncology, genomic sciences, computer sciences, information technology, safety, quality, and regulation. The discussions examined anatomic pathology as quantitative evidence for medicine, tissue-based molecular diagnostics, data integrity and interoperability, the pre-analytical environment, image analytics, machine learning and automation, regulatory and payer environment, clinical workflow, and pathology education.

**Key Conclusions of the Conference Include:**

- This expected transformation should be managed as a “project” by stakeholders in our profession.
- Deep engagement with industry and federal regulatory agencies will be necessary to support the critical path for implementation of novel technologies.
- Specific technical hurdles need to be addressed, including implementing standards for pre-analytic handling of specimens, creation of quantified structured data in specimen collection, grossing, sampling, slide creation and staining, automation of specimen processing and histology, quantitative validation of image quality, continued integration of biomarkers translated from genomic sciences into image diagnostics, image annotation and diagnostic image analysis, integration of machine learning and automated image processing into interpretive algorithms, development of systems that allow for pathologist evaluation of new technologies alongside traditional slide imaging at the time of case interpretation, and active pursuit of clinical follow-up as part of the pathology workflow.
- Education of pathologists in informatics, industrial engineering, and data sciences relevant to anatomic pathology should be a high priority.
- Value statements for advances in anatomic pathology should be articulated for payers, senior health system stakeholders, and the public.
- A foundation as a mechanism for funding and managing industry and government relationships should be considered.

The follow-through for Banbury Conference participants will include the following:

- Formation of an Executive Group, with the initial tasks of writing a white paper summarizing the conference, mapping out a critical path for integration of these technologies into diagnostic and treatment pathways, and seeking the value propositions for implementation of these technologies.
- Doing a cross-walk of the conclusions and action items of this conference to existing assets, including existing national initiatives, existing organizations and their governance structures, the efforts arising from prior convenings of thought leaders, and the ongoing activities of institutions and other industry stakeholders pursuing innovation in this space.
- Working with leading stakeholders in the field, to establish and/or strengthen a “project management” approach for advancing the field of anatomic pathology.

The activities of participants during the calendar year 2017, including participation in relevant national society meetings during 2017, should give opportunity to integrate these objectives into the overall trajectory of this field.

**R003. How Inkjet Printing Technology Can Defeat Multidrug-Resistant Superbugs**

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When there is a mismatch between empiric therapy and organism susceptibility—a much more likely occurrence for emerging multidrug-resistant bacterial pathogens—patients do poorly. Furthermore, antimicrobial susceptibility testing (AST) for new antibiotics or agents of last resort such as colistin must be sent to reference laboratories for broth or agar dilution testing, manual methods too complex for hospital-based clinical laboratories to perform, thus leading to further unacceptable delay.

Therefore, we conceived and developed 2-related, novel AST platforms called digital dispensing method (DDM) and microscopy-based AST (for MAST) to close the antimicrobial testing gap. Both make use of inkjet printer, digital dispensing technology that enables us perform AST on any antimicrobial at will. Specifically, the million-fold range of possible inkjet droplet sizes allows the exact amount of any antimicrobial desired to be dispensed automatically in 384-well plate format from a
single antibacterial stock solution. Notably, we previously validated that DDM testing of antimicrobials including colistin in broth microdilution format was as accurate and more precise than the gold standard used for FDA clearance studies. However, in contrast to this manual reference method, which requires 40 human steps, DDM only requires a single pipetting step, making it simple enough to be used in a clinical laboratory setting. Lastly, DDM allowed us to facilely perform, large-scale, combinatorial checkerboard antibiotic testing. Notably, we obtained susceptibility data for approximately 3-fold more antimicrobial combinations than described thus far in the world’s literature against carbapenem-resistant Enterobacteriaceae (CRE), a CDC-designated most urgent drug resistance threat. Importantly, we identified at least 1 combination with clinically achievable synergy in 90% of CRE strains, making the case for clinical synergy testing to guide rescue therapy for CRE infections that might otherwise not be treatable. Importantly, combinatorial testing, heretofore, only available in a research setting, requires only 2 pipetting steps when performed by DDM, thereby for the first time placing combinatorial testing within the capabilities of a hospital-based clinical laboratory.

We then examined whether we could accelerate AST further. We initially demonstrated that the same inkjet technology could be used to quantitatively ($R^2 = 0.99$ for Escherichia coli) deliver bacteria to a precise location in a microwell and further established spatially precise dispensing of bacteria onto a solidified Mueller-Hinton growth medium. We also confirmed reliable printing of major human pathogen groups. Notably, the use of a long focal length objective and automated image acquisition allowed real-time visualization of bacteria replication on these microwell surfaces using standard light microscopy optics. Effects of antimicrobials were detected reliably within 4 hours. Furthermore, a machine-learning algorithm automatically detected and quantified bacterial numbers over time, laying the foundation for completely automated susceptibility calls. Supplies were all off-the-shelf, commercially available, and inexpensive.

We envision the MAST platform as a way to perform MIC-based AST for any antimicrobial at will in only a few hours and also avoid need for reference laboratory testing. Taken together, these attributes should help address the antimicrobial testing gap and save lives.

R006. Pathology Plays a Key Role in Supporting Hepatitis C Virus Screening at a Safety Net Hospital

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**Background:** In addition to the existing national concern for hepatitis C virus (HCV) infection in the “baby boomer” 1945 to 1965 birth cohort, an alarming increase in the incidence of HCV infection has recently emerged in the Massachusetts population born after 1965, due in part to the opioid use epidemic. Hepatitis C virus screening and navigation to treatment is an important public health initiative. Pathologists and administrators co-led the hospital screening initiative, by guiding hospital policy and establishing reflex testing and result reporting. Boston Medical Center (BMC) partnered with Gilead’s FOCUS group and the Massachusetts Department of Public Health to fund the screening program, research collection, and data analysis.

**Methods:** Pathology leaders guided institutional approval for the program ensuring that integrated reflex testing and hospital policies were written and approved by the Medical Executive during programmatic ramp-up in calendar year 2016. The laboratory and the information systems team designed specimen collection, testing and reporting algorithms that enabled a 1-step laboratory draw (2 tubes) to provide screening, RNA viral load and diagnostic confirmation, and genotype testing for antibody-positive patients. The reflex testing program is now hospital wide.

**Situation Assessment:** Multiple laboratory draws and length of time between visits reduced the success of procuring RNA confirmation for antibody-positive patients and navigating them to treatment and care. In an 11-month period of prereflex testing internal medicine RNA confirmation follow-up rates were at 87.1%. After 4 months of postreflex implementation, testing was at 99.1%. Initially emergency department screening volume grew exponentially (from 18 to 1236 tests per month) with RNA follow-up increasing from 29.4% to 97.4% in a 4.5-month period. Overall, of 11,072 patients screened since reflex “go live” (August 2016-May 2017), 10.7% are HCV antibody-positive with an active infection rate of 6.2% among all those screened. Average turnaround time for antibody-positive patients reflexing to RNA confirmation over a 4-week period is at 4.4 days.

**Conclusion:** Pathology engagement in reflex testing and reporting algorithms have contributed significantly to the initial success of the HCV screening program by increased RNA confirmation follow-up and genotype determination.

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R007. Use of Metabolomics and Gut Microbial Profiling in Precision Diagnostics of Type 2 Diabetes in Caribbean Populations

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Type 2 diabetes mellitus (DM) is a globally prevalent disease with substantial morbidity and mortality. Early prediction of
the pathological processes that lead to type 2 DM is important because it will facilitate novel interventions aimed at delaying or preventing the disease. Several risk prediction models that combine clinical information with conventional biomarkers exist, but most do not account for the large variability in biological and environmental factors and tend to overestimate risk.

Our long-term goal is to use a precision medicine approach to discover novel diagnostic biomarkers for early detection of type 2 DM. The biomarkers will be tailored to specific subject populations, thereby achieving the precision medicine goal. Our first objective toward this goal will be to carry out comprehensive analyses of the blood metabolome and gut microbiome in samples collected from the National Institute on Minority Health and Health Disparities (NIMHD)-funded Eastern Caribbean Health Outcomes Research Network (ECHORN) patient cohort. We will use the approach of targeted mass spectrometry metabolomics of plasma and stool samples and 16S RNA sequencing of the stool microbiome. Samples from healthy participants, patients with prediabetes, and patients with established type 2 DM will be first analyzed in a screening study to identify sets of candidate biomarkers for prediabetes and type 2 DM. The identified metabolites and microbial profiles will also be correlated with subject-specific characteristics such as gender, ethnicity, dietary history, use of nicotine, current medications, body mass index, and blood pressure. We will next establish the sensitivity and specificity of the candidate biomarkers in a second, prospective study of healthy participants who will be followed with annual collections of blood and stool samples for at least 5 years. Our working hypothesis is that a unique signature of blood metabolites will predict the development of type 2 DM earlier and more accurately than traditional biomarkers.

The Yale Laboratory Medicine Department initiated this project in collaboration with the Equity Research and Innovation Center (ERIC) at Yale University, combining the department’s strengths in “-omics” with the population health expertise of ERIC. As a proof of concept, we have carried out preliminary studies in a group of 23 participants selected from the “Pediatric NAFLD/NASH Cohort,” consisting of 400 obese youth. Our study has revealed for the first time in a pediatric cohort that plasma concentrations of the branched amino acids isoleucine, leucine, and valine were significantly higher in obese adolescents with fatty liver compared to the group with low hepatic fat accumulation. Moreover, several other amino acid species particularly tryptophan, lysine, glutamate, ornithine, and alanine were significantly different or showed a significant trend toward significance between the 2 groups. We envision that applying this powerful methodology to a well-characterized cohort with a unique ethnic composition as present in the ECHORN cohort will reveal similarly predictive markers that may prove valuable diagnostic and prognostic targets in the future.

**R008. Electronic Medical Record and Clinical Laboratory Data Integration for Real-Time Quality Management**

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Recent technology advances have enabled real-time access to data from the entirety of clinical laboratory results. With adequate monitoring tools, these data can be used to anticipate and identify problems within the clinical laboratory, potentially improving turnaround time and quality of testing. The value of this information can be augmented by linkage with relevant nonlaboratory information from the electronic health record (EHR), but the management, organization, and visualization of data from the laboratory information system (LIS) and EHR often face barriers related to interoperability, storage, and security. With the deployment of the Beaker LIS at our institution, we aimed to develop an internal application that could capture, store, and display a real-time feed of clinical laboratory and associated patient data. The goal of this system was to provide a more powerful quality management platform based on moving averages and other statistical analyses. In addition, we hoped to provide real-time business intelligence related to test order volumes, turnaround time, and other customized metrics for our laboratory managers. The software solution was developed locally on our data science cluster built on the Hadoop and ElasticSearch platforms. Data from the EHR and LIS were streamed to these systems and integrated with the specialized distributed storage system that allows quick access to large data sets. By working closely with information security and data integration teams within the health system, we were able to develop and deploy this platform quickly within a production environment. Ongoing work with laboratory managers and technicians will enable us to improve the visualizations and dashboards used for business intelligence with the ultimate goal of increasing laboratory quality. Since deployment, similar frameworks have been used within the health-care system to acquire, data for patient monitoring and to integrate results from clinical next generation sequencing laboratories. These repeatable use cases and system architectures offer significant potential for efficient integration and deployment within other health-care systems.

**R009. Process Improvements in Biobanking in Partnership With the National Cancer Institute**

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**Statement of the Problem:** High-quality cancer biospecimens from a racially and ethnically diverse patient population is
crucial to successful cancer research. Implementation of a centralized biospecimen archive research core (BARC) at our institution was set as a strategic goal in 2007. Evidence of the ability to consent a traditionally underrepresented population, the ability to obtain high-quality specimens, and funding was needed in order to make this a successful goal.

**Proposed Solution:** The BARC is integrated into the diagnostic pathology service and therefore leverages many of the necessary requirements for a successful program, namely: available board-certified pathologists, rapid tissue processing, strong relationships with surgical and medical oncologists, the surgical preprocedure service, a partnership with radiology to share images linked to specimens, and committed information technology support. A central tenet was that diagnostic material would be the first priority, followed by biospecimen collection. Since inception, the BARC has a consent rate of 97% with an ethnic breakdown of 52% Caucasian, 28% African-American, 7% Hispanic, 6% listed as other, 5% Asian, and 3% American Indian and >1000 specimens. The BARC has adopted the National Cancer Institute Best Practices for biospecimen procurement and storage. Contractual partnerships with The Cancer Genome Atlas and Biospecimen Pre-analytic Variables program allowed the BARC to develop a strong Quality Management System and procure high-quality samples rapidly (average time from cold ischemia to fixation was 48 minutes). With further contract relationships with the Clinical Proteomics Tumor Analysis Consortium and most recently the Thrombosis in Cancer Patients study, we have decreased the average time to fixation to 33 minutes, while still procuring samples suitable for all future cutting edge research.

**Conclusion:** By utilizing the skill sets of the diagnostic pathology service, the biorepository has achieved a high consent rate from a diverse patient population. Consequently, the BARC became a valuable core repository for the institution, was able to secure extramural funding, and increased the quality and the number of specimens collected and utilized.

**Methods:** A total of 101 303 admissions/discharges during 2016 in 13 acute care hospitals of Northwell Health, a large, integrated urban healthcare network, were selected out of a total 274 730 by choosing patients whose LOS was less than 11 days, were admitted through the Emergency Service, and were discharged home (82% of all discharged patients were sent home).

**Results:** The number of registered beds (103-1025) and yearly discharges (3942-54 391) ranged widely among the 13 hospitals. But in most, the number of daily inpatient discharges reflects a regular pattern with a nadir of about 9000 out of the 101 303 discharges taking place on Sundays and a peak of almost 20 000 on Fridays. Admissions were also lower on weekends, but to a lesser extent: about 12 400 admissions took place on Sundays, and roughly 15 800 on Mondays, the weekend with the highest number of admissions.

The average LOS (ALOS) of patients discharged on different days varied: from 3.56 days on patients discharged Monday and Tuesday to 3.00 days on Sunday. To account for differences in disease severity, we calculated the difference between the LOS and the Center for Medicare and Medicaid Services (CMS) medical severity-diagnosis related group Arithmetic Mean LOS for each patient. The ALOS were all lower than the CMS means, but the negative difference was smallest for patients discharged on Mondays and Tuesdays (−0.65 days) and increased to a maximum (−0.97 days) on those discharged on Sundays. Assuming a uniform mean LOS difference versus CMS every day of the week similar to that of patients discharged on Fridays (−0.95 days), we estimated a potential overall decrease of ALOS of more than 20% for the population of patients studied.

**Discussion:** The qualitative impact and cost of weekend admission and discharge patterns have been widely discussed. The information presented herein assesses their magnitude and regularity, as well as recognizes (1) the sizable upstream pattern of Friday increase in discharges and the downstream effect of sluggish Monday discharge rates, (2) the longer LOS in patients discharged early in the work week, and (3) the long LOS of patients admitted on Fridays. These patterns reflect the magnitude and impact of the overall slower pace of hospital activity on weekends.

**Conclusion:** By assessing the upstream and downstream ripple effects of the weekend drop in discharges, we estimate that a ~20% potential decrease in overall inpatient LOS could have been realized had the day-to-day hospital workload been uniform. It is possible that other indicators of hospital activity would show similar improvement.