2 - Predictive Modeling for Health Systems

Jonathan Silverstein, Professor, University of Chicago, Pritzker School of Medicine, Chicago, IL, United States of America, jcs@uchicago.edu

At NorthShore, we have led Epic Systems’ EMR implementation across inpatient and outpatient environments for 10 years. In addition, an industrial enterprise data warehouse is used daily for business intelligence. This talk will highlight predictive modeling in production use. Specific examples shown will include management of antibiotic resistant microbial disease, eliminating undiagnosed hypertension, reducing readmissions, and enhanced data collection for finer grained clinical modeling.

3 - Outlier-Based Alerting to Decrease Medical Errors in the ICU: An Evaluation Study

Milos Hauskrecht, University of Pittsburgh, Pittsburgh, PA, United States of America, milos@pitt.edu, Gilles Clermont, Shyam Visweswaran, Gregory Cooper

Outlier-based alerting is a data-driven approach that can, based on past data, identify unusual patient-management decisions in the electronic medical record of the current patient. Such outliers may indicate potential medical errors. We have selected 400 alerts from >33K alerts generated for >24K patient admissions. The alerts were evaluated by 18 ICU physicians. The true positive alert rate of 0.52 compares favorably to the alert rates of the existing clinical alerting systems.

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**Wednesday, 8:30am - 10:00am**

**WA01**

**Joint Session HAS/ISIM: HIV and Networks**

**Sponsor:** Healthcare Applications Society & Simulation Society

**Sponsored Session**

**Chair:** Benjamin Arbourner, Northwestern University, Evanston, IL, United States of America, arbourner@northwestern.edu

1 - Hybrid Network Data Collection in Emerging HIV Epidemics

John Schneider, University of Chicago, 5841 South Maryland Avenue, Chicago, IL, United States of America, jscncl@medicinebsd.uchicago.edu

We will discuss considerations for hybrid network data collection and analysis. Hybrid network data includes network data collected through archival or digital data such as cell phones or Facebook coupled with traditional survey data.

2 - P2P Text Messaging for HIV High Risk Groups: A Model of Information Spread on a Network

Ekkehard Beck, Northwestern University, 2145 Sheridan Road, Room C220, Evanston, IL, 60208, United States of America, ekkehardbeck1951@u.northwestern.edu, Benjamin Arbourner

Text message based HIV prevention interventions are on the rise. We propose peer-to-peer (P2P) text messaging as a new HIV prevention intervention and develop an agent-based simulation model to study its impact on the spread of information in a network of men who have sex with men.

3 - Speeding Up Network Simulations using Discrete Time

Benjamin Arbourner, Northwestern University, Evanston, IL, United States of America, arbourner@northwestern.edu

Network simulation models are becoming common for modeling the spread of infections. However, speed is often an issue for large populations. Choosing a discrete time simulation (DTS) over a discrete event simulation (DES) helps to remedy this problem at the cost some accuracy. We analyze and quantify the loss in accuracy for the common SI and SIS processes. Specifically we prove the DTS method for both processes converges with strong order 1, similar to Milstein’s method for SDEs.

4 - How Risky is Risky Sex?

Arielle Lasry, US Centers for Disease Control and Prevention, Atlanta, GA, United States of America, ftn9@cdc.gov

In estimating the risk for contracting HIV, parameters associated with the type and frequency of sex act and the preventive measures used are uncertain. Therefore, we developed a decision support tool intended for HIV-discordant couples to assess the risk of HIV transmission to the negative partner based on the couple’s choices and preferences with respect to risk behaviors and preventive measures.

**WA02**

**Data Driven Approaches to Identify and Treat Critical Illness: Applications**

**Sponsor:** Data Mining

**Sponsored Session**

**Chair:** Gilles Clermont, University of Pittsburgh Medical Center, 3550 Terrace, Scale 602A, Pittsburgh, PA, 15261, United States of America, clermont@gcm.upmc.edu

Co-Chair: Marilyn Hravnak, Professor, School of Nursing, University of Pittsburgh, 336 Victoria Blvd, 3500 Victoria Street, Pittsburgh, PA, 15261, United States of America, mhra@pitt.edu

1 - using Data Driven Approaches to Improve Care: Examples Through the Eyes of the Clinician

Marilyn Hravnak, University of Pittsburgh, 200 Lothrop, Pittsburgh, PA, United States of America, hravnakmt@upmc.edu, Karen Chen, Melissa Saul, Gilles Clermont, Artur Dubrawski, Michael Pinsky

Data from medical records and bedside monitors can be mined to inform future clinical decisions. We provide 3 examples: a) extraction of static data from a clinical and administrative database repository to assess likelihood and impact of atrial fibrillation, b) use of real-time continuous physiologic monitoring data input through an Integrated Monitoring System to enable nurses to respond to clinical instability, c) use of feature extraction from monitoring data waveforms to detect artifact.

2 - Predictive Modeling for Health Systems

Jonathan Silverstein, Professor, University of Chicago, Pritzker School of Medicine, Chicago, IL, United States of America, jcs@uchicago.edu

At NorthShore, we have led Epic Systems’ EMR implementation across inpatient and outpatient environments for 10 years. In addition, an industrial enterprise data warehouse is used daily for business intelligence. This talk will highlight predictive modeling in production use. Specific examples shown will include management of antibiotic resistant microbial disease, eliminating undiagnosed hypertension, reducing readmissions, and enhanced data collection for finer grained clinical modeling.

3 - Outlier-Based Alerting to Decrease Medical Errors in the ICU: An Evaluation Study

Milos Hauskrecht, University of Pittsburgh, Pittsburgh, PA, United States of America, milos@pitt.edu, Gilles Clermont, Shyam Visweswaran, Gregory Cooper

Outlier-based alerting is a data-driven approach that can, based on past data, identify unusual patient-management decisions in the electronic medical record of the current patient. Such outliers may indicate potential medical errors. We have selected 400 alerts from >33K alerts generated for >24K patient admissions. The alerts were evaluated by 18 ICU physicians. The true positive alert rate of 0.52 compares favorably to the alert rates of the existing clinical alerting systems.

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**WA03**

**Dynamic Optimization of Clinical Treatments**

**Sponsor:** INFORMS Optimization Society

**Sponsored Session**

**Chair:** Alexander Gutfraind, University of Illinois at Chicago, FDA/CBER, School of Public Health, Chicago, IL, 60612, United States of America, agutfraind.research@gmail.com

1 - Administering Antibiotics for Seasonal Infections – A Dynamic Programming Approach

Alexander Gutfraind, University of Illinois at Chicago, FDA/CBER, School of Public Health, Chicago, IL, 60612, United States of America, agutfraind.research@gmail.com, Alison P. Galvani, Lauren Ancel Meyers

Palivizumab, an antibody for RSV infections, costs the healthcare system some $1.35 annually. The customary protocol uses injections every 30 days. Based on data from 18 sites around the country, we show that an optimized protocol can save up to 20% cost or improve the effectiveness of the treatment.

2 - Quantile Interactive Q-Learning

Kristin Linn, North Carolina State University, 5109 SAS Hall, 2311 Stinson Dr., Raleigh, NC, 27695, United States of America, kallinn@ncsu.edu, Leonard Stefanski, Eric Laber

A dynamic treatment regime (DTR) consists of decision rules that operationalize clinical decision-making by recommending treatments over time. Methods for estimating optimal sequential rules such as Q- and IQ-learning aim to maximize the expected value of the response. Our proposed method, Quantile Interactive Q-Learning (QQ-learning), extends Q- and IQ-learning to handle optimization of quantiles of the distribution of the final clinical outcome. We derive the form of the QQ-learning optimal policy for the two-decision setting and propose estimators for the optimal rules at each stage.

3 - Biological-Driven Dose Escalation in Cervical Cancer Treatment

Fan Yuan, Georgia Institute of Technology, Industrial & Systems Engineering, Atlanta, GA, United States of America, fyu13@isye.gatech.edu, Eva Lee

This work is joint with Rush University Medical Center. We describe a tumor-control-probability(TCP) based treatment planning framework for PET image guided dose escalation high-dose rate brachytherapy for cervical cancer. Using real patient cases, robustness of the planning is tested, and plan quality, TCP, and potential outcome significance are evaluated.
Joint Session HAS/MDPM: Policy and Decision Making in Disasters and Public Health Emergencies

Sponsor: Healthcare Applications Society & Medical Decision and Policy Making

07 - Kansas City

Surgical Operations

Contributed Session

Chair: Thomas Sexton, Professor and Associate Dean, Stony Brook University, College of Business, 317 Harritan Hall, Stony Brook, NY, 11794-3775, United States of America, Thomas.Sexton@stonybrook.edu

1 - Solving the Operating Room Scheduling Problem using Mathematical Programming

Pablo Rey, Universidad Diego Portales, Av. Ejercito 441, Santiago, Chile, pablo.rey@udp.cl, Guillermo Durán, Patricio Wolff

Facilitating patient flow is imperative and difficult in a hospital with high patient occupancy. A decision support tool applying Monte Carlo Simulation has been developed to predict the impact of demand from surgical and medical patients four days into the future. We created a user-friendly tool for administrators to predict and mitigate potential bed shortages before they occur.

2 - An Inpatient Bed Demand Prediction Tool for Surgical Smoothing

Ronald Dravenstott, Intermediate Innovation Analyst, Operations Research, Geisinger Health System, 100 N. Academy Ave., M.C. 30-65, Danville, PA, 17822, United States of America, rwdravenstott@geisinger.edu, Priyantna Devapriya, David Franklin

We study patient admission policies in a neurological hospital ward, where there is high occupany. A decision support tool applying Monte Carlo Simulation has been developed to predict the impact of demand from surgical and medical patients four days into the future. We created a user-friendly tool for administrators to predict and mitigate potential bed shortages before they occur.

3 - Dynamic Surgery Assignment of Multiple Operating Rooms with Planned Surgeon Arrival Times

Xiaolan Xie, Professor, Shanghai Jiao Tong University, 800 DongChuan Road, Shanghai, China, xie@emse.fr, Na Geng, Zheng Zhang

This paper addresses the multi-OR dynamic surgery scheduling with random durations and planned surgeon arrival times. We propose a multi-stage stochastic programming model by allowing scheduling revision at all surgery completion events. A two-stage stochastic programming approximation is proposed and solved by two look-ahead strategies and valid inequalities. A lower bound is proposed based on perfect information. An efficient algorithm is also proposed for determining surgeon arrival times. Numerical results show the value of dynamic scheduling and the value of proactive decisions.

4 - Optimal Block Scheduling for the Operating Room Suite: from Tactical to Strategic Planning

Thomas Sexton, Professor and Associate Dean, Stony Brook University, College of Business, 317 Harriman Hall, Stony Brook, NY, 11794-3775, United States of America, Thomas.Sexton@stonybrook.edu, Melissa Dolan, Herbert Lewis, Kenneth Rosenfeld

We present a multicriteria nonlinear optimization model that allocates OR time among 15 surgical services in a major academic medical center. The model considers the probability distribution of demand and optimizes an objective that includes the medical center's financial success, its overall mission, and community needs, thereby elevating the OR scheduling process from the tactical realm, in which utilization is the objective, to the strategic realm, in which higher level objectives dominate.

Application of Operations Research in Healthcare

Sponsor: Manufacturing and Service Operations Management

09- McHenry

Invited Session

Chair: Saied Samiedaluie, McGill University, 1001 Sherbrooke West, Montreal, QC, H3A 1G5, Canada, saied.samiedaluie@mail.mcgill.ca

1 - Admission Policies in a Neurology Ward

Saied Samiedaluie, McGill University, 1001 Sherbrooke West, Montreal, QC, H3A 1G5, Canada, saied.samiedaluie@mail.mcgill.ca

We study patient admission policies in a neurological hospital ward, where there are multiple patient types. The patients need to wait until a hospital bed is assigned to them. The patients are different in terms of level of severity and average length of stay. The problem is formulated as an average cost dynamic program. An approximation scheme to solve the dynamic programming will be presented.
2 - Hypertension Management: A Value of Information Approach for Blood Pressure Measurement
Manaf Zargoush, McGill University, Montreal, QC, Canada, zargoush@gmail.com, Mehmet Gumus, Stella Daskalopoulou, Vedat Vertter

Hypertension is one of the most prominent risk factors for the development of cardiovascular disease (CVD), the leading cause of morbidity and mortality worldwide. In this context, accurate measurement of blood pressure is vital. In this research we model two blood pressure measurement methods as Markov Decision Processes (MDPs) and analyze the value of information (VOI) attributed to these two methods. We also identify the optimal policies under each measurement scheme.

3 - Surgical Sequencing with Stochastically Ordered Service Times
Yun Zhou, McGill University, 1001 Sherbrooke Street W, Montreal, QC, Canada, yzhou.zj@gmail.com, Mahmut Parlar, Vedat Vertter, Shannon Fraser

In this presentation, we consider two types of surgeries with random durations. The duration of one type is stochastically shorter than the other type. We compare two simple sequencing policies in terms of the total expected patient waiting time and the expected operating room overtime. We also study a constrained sequencing problem that aims to minimize total expected patient waiting time while the expected OR overtime does not exceed a certain predetermined threshold. Two case studies are provided based on 2012 data from Jewish General Hospital in Montreal.

WA10

10 - Cook
ORAHS 2- Modeling for Planning Decisions
Cluster: International Health OR
Invited Session
Chair: Sally Brailsford, Professor, University of Southampton, Southampton Management School, Southampton, SO17 1BJ, United Kingdom, s.c.brailsford@soton.ac.uk

1 - Age-Related Macular Degeneration: Combining Models Offers Health and Social Care Insights
Joe Viana, Research Fellow, University of Southampton, University Road, Hampshire, Southampton, SO17 1BJ, United Kingdom, j.viana@soton.ac.uk, Stuart Rossiter, Andrew Amos Channon, Sally Brailsford, Andrew Lotery

We aim to create a whole system model of health and social care in the context of age-related macular degeneration (AMD), a degenerative eye condition prevalent in the elderly and treatable via injections. A traditional discrete-event simulation of the eye clinic is extended via an agent-based model of AMD sufferers’ social care dynamics (with system dynamics models for sight level). This allows us to explore the combined effects of policy on clinic efficiency and social welfare.

2 - Dynamic Location of Ambulances Considering Time-Dependent Demand
Sebastian Rachuba, Research Assistant, PhD student, Ruhr University Bochum, Universitaetsstrasse 150, Bochum, 44801, Germany, sebastian.rachuba@rub.de, Brigitte Werners, Dirk Degel, Lara Wiesche

The efficient use of available resources such as ambulances is crucial for high quality medical services. We developed a mixed-integer linear program to locate and re-locate ambulances during the day. Demand and travel times are modeled time-dependent and thus explicitly for all time periods. The number of parallel occurring emergencies is derived from existing data records in order to determine a required degree of multiple coverage. Calculations show that the new approach leads to high quality solutions with respect to coverage and cost criteria.

3 - An Iterative Simulation-Optimization Approach for Hospital Layout Planning
Ines Arnoldo, Karlsruhe Institute of Technology, Englerstr. 11, Building 11 40, 2 OG, RM 204, Karlsruhe, D-76131, Germany, ines.arnoldo@kit.edu, Stefan Nickel

Most layout models are based on deterministic data, but usually patient and personnel flows are uncertain. We present an iterative simulation-optimization approach to find a robust hospital layout that performs well under uncertain flows. First, a deterministic MIP is solved. Second, a generic discrete-event simulation model is applied. Third, the layout is improved heuristically. With this approach, we take into account the influence of strategic layout decisions on the operational performance.

4 - Machine Learning Approaches for Early DRG Classification of Inpatient Services
Daniel Gartner, Technische Universitat Munchen, TUM School of Management, Arcisstr. 21, Munchen, 80333, Germany, daniel.gartner@tum.de, Rainer Koliisch, Daniel B. Neill, Rena Padman

This study examines the applicability of machine learning methods for classifying diagnosis-related groups (DRGs) of inpatients for upstream planning and better resource allocation. We evaluate different techniques on hospital data from the year 2011 containing more than 16,000 inpatient records. Results indicate that, depending on the available information, up to 79.5% accuracy can be achieved for elective patients (before admission). Moreover, more than 65% accuracy can be achieved for all (elective and non-elective) patients on the day of admission which outperforms current practice.

WA18

18 - Northwestern
Scheduling and Patient Flow for Healthcare OR
Cluster: Healthcare Scheduling
Invited Session
Chair: Jivan Deglise-Hawkinson, University of Michigan, Industrial and Operations Engineering, Office 2811, Ann Arbor, MI, 48105, United States of America, jivan@umich.edu

1 - Flexible Nurse Staffing Models under Patient Volume Uncertainty and Cost Implications of Flexibility
Kibaek Kim, Northwestern University, 2145 Sheridan Rd., C210, Evanston, IL, 60208, United States of America, kibaek.kim@northwestern.edu, Sanjay Mehrotra

Limited budget for full-time equivalent nursing positions compels hospital operations managers to efficiently utilize nursing staffs without loss of care quality. We present a nurse-staffing model to find the optimal staffing levels and patterns of full-time/part-time nurses for different care units and nurse float pool. We further analyze the cost implications of using part-time nurses and float pool nurses.

2 - Appointment Scheduling with Follow-Up Visits
Yichuan Ding, University of British Columbia, 4735 W. 4th Ave., Vancouver, BC, V6T1C3, Canada, daniel.ding@sauder.ubc.ca, Chinghua Chen, Mayank Sharma, Diwakar Gupta

Properly modeling outpatient arrivals helps physicians make better decisions regarding panel size and appointment scheduling. This paper models the patient follow-up phenomenon and investigates its effect on appointment scheduling. By formulating the problem as a Markov Decision Process, we concluded that the optimal scheduling policy is of a control-limit type, and the optimal daily booking-limit decreases as days move towards the future.

3 - Modeling Selective ICU Admission Based on Mortality Risk
Jeff Kritzman, PhD Pre-Candidate, University of Michigan, Industrial and Operations Engineering, Ann Arbor, MI, 48109, United States of America, jefkritz@umich.edu, Jivan Deglise-Hawkinson, Mark Van Oyen, Jonathan Helm

Intensive care units (ICUs) are highly utilized hospital wards that drastically improve the outcomes for medically needy patients. Some patients require treatments only available in an ICU, but who else should be admitted to the ICU? How do we control the admission to do the greatest good for the greatest number? Our partner hospital has pioneered a patient Mortality Risk Metric (MRM) that we use for improved ICU admission control.

4 - An Optimization-Based Approach to Capacity Planning for Clinical Research Operations
Jivan Deglise-Hawkinson, University of Michigan, Industrial and Operations Engineering, Office 2811, Ann Arbor, MI, 48105, United States of America, jivan@umich.edu, Mark Van Oyen, Blake Roessler

Clinical trial protocols demand complex coordination of physical and human resources over time for each participant. A clinical research unit site must service many trials. We develop a novel stochastic planning model that uses forecasting and optimization to select the highest scientific value from the portfolio of candidate trials while meeting participant access and overtime metrics. We also optimize the daily participant booking reservation strategy, and the daily staffing coordination plan.
The mathematical models are illustrated with a case study on cardiac patients. Queueing Network Analyzer adapted to health care. Moreover, we propose a variability in the patient care process, or clinical pathways, by applying the flows in order to avoid peaks in demand. We consider the impact of (reducing) 1 - Stabilizing Patient Flows and Inpatient Bed Usage

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Sponsor: Healthcare Applications Society

Hospital Operations

Chair: Alex Mills, Assistant Professor, Indiana University, Kelley School of Business, Bloomington, IN, United States of America, mills14@indiana.edu

1 - Nurse Staffing Ratios: A Case for Higher Quality Care

David Cho, Indiana University, Kelley School of Business, 1309 E. Tenth Street, Room 752-48, Bloomington, IN, 47405-1701, United States of America, dcho@indiana.edu, Kurt Bretthauer, Edwin Coe, Jari Schoofeldt

Despite the considerable attention given to healthcare in operations management and operations research, there has been limited effort to take advantage of results from the medical, nursing, and healthcare services literature to make the research more patient and nurse oriented. Thus, we present a nurse staffing model that incorporates patient outcomes, nurse burnout, and costs when making hospital capacity planning decisions such as patient-to-nurse ratios and usage of float and agency nurses.

2 - Analysis of Skilled Nursing Facility Admission Control using Event-Based Dynamic Programming

Xiaoying Yu, PhD, Indiana University, Kelly School of Business, 107 S. Indiana Ave., Room 736-5, Bloomington, IN, 47405-7000, United States of America, xy9@indiana.edu, Jonathan Helm

Skilled nursing facilities (SNF) are a major bottleneck to discharging patients from hospitals in a timely manner. These facilities typically have two main sources of patients: hospital and community. High utilizations at SNFs force a choice of which patients to admit and which to delay. We develop an event-based dynamic programming approach to optimize admission control at the SNF that seeks to balance the needs of hospital, SNF, and community.

3 - Improving ED Patient Flow: Multi-Class Admit Prediction Models at Triage

Shanshan Qiu, Research Assistant, Wayne State University, 4815 Fourth St., Detroit, MI, 48202, United States of America, dy514@wayne.edu, Ratna Babu Chinnam, Alper Murat

To predict inpatient bed demand from ED, we propose a multi-class classification model that predicts the target admit ward for the patient using information readily available right at triage. It overcomes the shortcomings of extant binary prediction models that lack the ability to predict the target admission ward to facilitate timely coordination and reduces patient waiting times and boarding.

2 - Adaptive and Anticipative Decisions in Operating Room Rescheduling

Sakine Batun, Assistant Professor, Middle East Technical University, Department of Industrial Engineering, Ankara, 06800, Turkey, sakine@metu.edu.tr, Brian Denton, Andrew Schaefer

We consider a stochastic multi-OR scheduling problem where the initial schedule is revised at a prespecified time during the surgical day. We formulate the problem as a SMIP that minimizes the sum of the fixed cost of opening ORs and the expected overtime cost. For our numerical study, we consider a special case where rescheduling decisions are made under perfect information. We use our model to estimate the value of adaptive and anticipative decisions in OR rescheduling.

3 - Operations Management Approaches in Perioperative Flow

Erkan Ceyhan, Lahey Clinic, Boston, MA, United States of America, Mehmet.E.Ceyhan@lahey.org, Patricia Roberts, Stephen Demers

We apply advance operations management techniques to (1) improve patient outcome, (2) reduce patient delays, (3) maximize efficiency of operating room, and (4) provide surgeons optimum access to OR. Initial results of following projects are presented: identifying key metrics and translating them to daily operations, monitoring OR metrics & same day surgery cancellations by statistical process control, and patient flow of perioperative services.

4 - Modeling the Effect of a Nurse as a Transmitter on Hospital Acquired Infections

Lerzan Ormeci, Koc University, Istanbul, 34450, Turkey, lormeci@ku.edu.tr, Evrim Didem Gunes, Onder Ergönül

We analyze the role of bed adjacency in hospital acquired infection dynamics in an intensive care unit (ICU). In the context of ICUs, this coincides with the role of the nurse as an agent. The analysis is carried on a data set which includes the patients’ age, sex, admission and discharge dates, length of stay, Apache II score, and colonization/infection test results. Then, we develop and numerically analyze a Markov chain model which represents the interactions between a nurse and patients.

1 - Making the Case for Case Management

David Anderson, University of Maryland, Robert H Smith School of Business, College Park, MD, 20742, United States of America, danderon@rhsmith.umd.edu, Margrét Bjarnadóttir

One of the key questions in case management is which patients to enroll, and most programs target current high-cost patients. However the real potential is including lower cost patients at high risk of future high healthcare costs. Identifying these patients is a hard classification task. In this study we infuse classical classification models with association rules to identify and include higher order interactions. We demonstrate the potential of association rules for classification and derive an upper bound on the predictive performance.

2 - Innovations in Big Data Analytics: Medical Decision Making

Eva Lee, Professor and Director, Georgia Institute of Technology, Atlanta, GA, United States of America, evaklee@isi.gatech.edu

This work is joint with Emory Vaccine Center. In this talk, we will describe a big data analytic approach for multi-disciplinary involving immunology, genomics and bioinformatics to predict the immunity of a vaccine without exposing individuals to infection. This approach addresses a long-standing challenge in the development of vaccines—that of only being able to determine immunity or effectiveness long after vaccination and, often, only after being exposed to infection.

3 - Predicting Colorectal Cancer Mortality

Leila Zia, Stanford University, Huang Engineering Center, 475 Via Ortega, Stanford, CA, United States of America, lelaz@stanford.edu

We build prediction models for colorectal cancer mortality over a horizon of 30 days to 5 years after hospital discharge considering comprehensive medical, socio-economical, geographical and hospital related data. We use two major California data-sets along with modern statistical methods such as classification trees and regularized logistic regression. We report the most important predictors and assess the quality of the prediction models, the key considerations for medical decision makers.
spontaneous disease regression. Factors and clinical history of breast cancer and allows the possibility of women's life expectancies. Our model incorporates individual's breast cancer risk process model to determine optimal biopsy referral policies that maximize mammograms. Biopsy is performed to verify the presence of cancer after positive rates. Mammography screening, although effective in reducing mortality, has high false-negative ones. We developed a discrete-time finite-horizon Markov decision process model to determine optimal biopsy referral policies that maximize the amount of cancer found on biopsy. This rule results in a high rate of detection and treatment of important tumors, while minimizing the treatment of insignificant ones. We develop a simulation model of the prostate biopsy procedure and use probability modeling to devise an effective decision rule for deciding whether to treat, based on the amount of cancer found on biopsy. This rule results in a high rate of detection and treatment of important tumors, while minimizing the treatment of insignificant ones.

2 - Panel Sizing and Appointment Scheduling in Outpatient Medical Care

Christos Zacharias, New York University, Stern School of Business, 44 West 4th Street, New York, NY, 10012, United States of America, cwzachar@stern.nyu.edu, Mor Armony

We study the joint problem of determining the panel size of a medical practice and the number of offered appointments per day, so that patients do not face long backlogs and the clinic is not overcrowded. By capturing many features of the healthcare system (balking, no-shows, walk-ins, random services), we model the two time scales involved in accessing care: out-of-clinic and in-clinic waits. We show that an open-access policy is optimal and provide guidelines for a clinic's desired panel size.

3 - A Two-Time-Scale Approach to Time-Varying Queues for Hospital Inpatient Flow Management

Pengyi Shi, Georgia Institute of Technology, 765 Ferst Drive, Atlanta, GA, 30332, United States of America, pengyishi@gatech.edu, Jim Dai

We model the patient flow from the emergency department to inpatient wards as a time-varying queue. One novel feature of the model is that each patient's service time is endogenous and non-iid. We develop a two-time-scale approach to analyze the model and evaluate strategies such as inpatient discharge policy.
2 - Prostate Cancer Screening Rules: A Comparison of Deterministic and Agent Based Model Approaches
Alana Reiter Guiney, University of Michigan, Health Management & Policy, M3048 SPH II, Ann Arbor, MI, 48109-2029, United States of America, aguiney@umich.edu
Prostate cancer is diagnosed using the low accuracy Prostate Specific Antigen test. This study compares a deterministic compartmental model to an agent-based model (ABM) of the same system to determine if there are more insights to be gained by allowing stochasticity into the behavior of individuals. The two approaches yield equivalent results in terms of financial and health costs. The ABM approach can easily expand to include more information rich agents to interact with screening rules.

3 - A Microsimulation Model for Lung Cancer Natural History and Screening for Early Detection
Ayca Erdogan, Stanford University, 1201 Welch Road Mc 5488, Stanford, CA, 94305, United States of America, serdogan@stanford.edu
We present a microsimulation model for the natural history of lung cancer and the effects of screening. The disease progression in the absence of screening is modeled based on survival data from SEER. A screening program is simulated using data from a single arm clinical study. The model closely predicts the results of the study and estimates the effect of screening compared to the simulated hypothetical noscreening arm. The model can be used to simulate different screening trials for further investigation.

1 - Hospital and Surgeon Report Cards and Patient Sorting
Tae Jung Yoon, Northwestern University, Kellogg School of Management, 2001 Sheridan Rd., Evanston, IL, 60208-2001, United States of America, taejung-yoon@kellogg.northwestern.edu
Demand-side informed choice behavior and supply-side gaming behavior after the report-card release have been presumed by previous studies, but they have not been identified separately. In this paper, I empirically examine both across-hospital and within-hospital patient sorting mechanisms induced by the cardiac surgery report cards in New Jersey. I find that patient severity of illness, traveling costs, admission sources, and provider capacity status affect patient sorting. Controlling for these factors, I show that patient informed choice and provider gaming behavior separately affect patient sorting across hospitals after the report-card release. For within-hospital patient sorting, I find that admitted patients via cardiology departments are sorted better based on their severity for cardiac surgery within the hospital.

2 - Hospital Safety Culture’s Role in Reducing Central Line Associated Bloodstream Infections (CLABSI)
Jason Richter, Doctoral Candidate, The Ohio State University, 2274 Collins Dr., Columbus, OH, 43085, United States of America, richter.97@osu.edu, Ann Scheck McAlearney, New York University School of Medicine, 620 First Ave, New York, NY, 10016, United States of America, amcalearney@nyumc.org
A change to safety culture may foster the attainable elimination of CLABSI. Statistical significance in baseline and change analysis offers robust evidence that improvements in organizational learning and management support for safety are associated with a reduction in CLABSI. Hospitals should primarily focus on these areas. Given that the CLABSI mortality rate is as high as 25 percent, the average hospital may avoid one unnecessary death each year through elimination of CLABSI.

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3 - Frictions, Contract Design and Time-to-Sell in Markets for Technology
Manuel Hermosilla, PhD Candidate, Northwestern University, Kellogg School of Management, 2001 Sheridan Road, Evanston, IL, 60208, United States of America, m-hermosilla@kellogg.northwestern.edu
To take advantage of productive efficiencies and reduce time-to-market, transactions in markets for technology should occur earlier on in the technology’s development. However, substantial contracting delays are commonly observed, suggesting that frictions may play a relevant role. Focusing on the market for developing biopharmaceuticals, I develop a structural model that characterizes two prominent types of imperfections, innovator-based adverse selection and moral hazard. Results crystallize the intuition that compounds with low privately observed quality are more likely to enter the technology market than their high quality counterparts, and conditional on doing so, more likely to do it sooner, highlighting the role of the adverse selection problem. While non-contractible innovator effort is estimated to significantly impact developmental success, contract design successfully aligns incentives for its provision, reducing the burden of the moral hazard problem.

4 - Modeling and Assessment of Total Financial Risk in Healthcare Facilities
Vikrant Vaze, Member Research Staff, Philips Research North America, 345 Scarborough Road, Briarcliff Manor, NY, 10510, United States of America, vikrant.vaze@philips.com, Saeed Bagheri, Hanqing Cao, Northwestern University, Kellogg School of Management, 2274 Collins Dr., Columbus, OH, 43085, United States of America, havan@northwestern.edu, ricther.97@osu.edu, Ann Scheck McAlearney, New York University School of Medicine, 620 First Ave, New York, NY, 10016, United States of America, amcalearney@nyumc.org
With the evolving regulatory and reimbursement landscape of healthcare industry, the management of total financial risk to the healthcare facilities has become more complicated. Variations in different aspects of performance of a hospital, e.g. in-hospital mortality rates, readmission rates, length of hospital stay, patient charges etc., contribute to the overall risk. We develop statistical models of hospital outcomes using public data. A number of interesting relationships are presented and results are validated against HospitalCompare results.
2 - Point-of-care Testing: Improving ED Performance through Process Redesign
Nicole DeHoriatus, University of Chicago, 15345 SW Lark Lane, Beaverton, IL, 97007, United States of America, Nicole@DeHoriatus.com, Esther Chen, Lije Song, Thomas Lee, Tava Olson
Hospital EDs typically rely on central labs to analyze patient samples for the purposes of diagnosing and treating patients. Point-of-care testing (POCT) is a process redesign that shifts analysis of samples from central lab to ED. We use a queuing model to generate hypotheses about how POCT affects operational performance (e.g., service time, waiting time, and quality of care). This research is unique in identifying the impact of POCT across test and no-test patients, and attendant system-wide benefits that can be attained through ED process redesign.

3 - Hurry Up and Wait: Differential Impact of Load on Patient Length of Stay
Jillian Berry Jaeker, Harvard Business School, Wyss Hall, Soldiers Field, Boston, MA, 02163, United States of America, jjaeker@hbs.edu, Anita Tucker
High work load, from high patient censuses, impacts patient LOS, but prior OM studies have found conflicting results regarding direction. Thus, it is difficult to predict load's effects on productivity a priori, inhibiting effective capacity management in high load systems. We categorize load at 283 hospitals into current patient census (congestion) and incoming patients, decomposing the latter into its levels of pressure and predictability, and quantify the magnitudes and directions of change on LOS.

Nadine Levick, EMS Safety Foundation, New York, NY, United States of America, nlevickek@attglobal.net
There are 1,000 U.S. deaths daily from out of hospital cardiac arrest. Existing strategies have had little impact on bystander effectiveness in 30 years. iRescU bridges social good, new tech, cloud based data, community engagement, crowd sourcing, proliferation, gamification, public health and safety to address these gaps in the chain of survival. Designed as a global platform that is sustainable, scalable and translatable, iRescU has 3 basic modes: Emergency response, Train and AED management.

4 - Predicting Lifetime Risk of Sudden Cardiac Death
Brittany Bogle, PhD Candidate, Industrial Engineering, Northwestern University, 2154 Sheridan Rd., Room C210, Evanston, IL, 60201, United States of America, brittanybogle@u.northwestern.edu, Donald Lloyd-Jones
Competing lifetime risk is the total cumulative risk of developing a disease of interest which adjusts for the competing risk of other competing diseases and causes of death. In our study, we examine the competing lifetime risk of sudden cardiac death from large cohort study through an adjustment of Kaplan-Meier for competing risk. We explore important risk factors through penalty norm techniques, including Lasso Regularization, and compare these to traditionally used clinical risk factors.

Wednesday, 1:30pm - 3:00pm

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3 - Modeling the Connectedness and Spread of Improvements across Healthcare Networks
Daya Martinez, Northeastern University, Boston, MA, United States of America, d.martinez@neu.edu, Corey Balint, Amanda Bell, Nicholas Adrians, James Benneyan
The slow spread of proven improvements across healthcare systems is a ubiquitous problem in many contexts. We describe ongoing work to better understand the spread of improvement across healthcare systems. As one approach, several efforts exist to develop formal and informal healthcare quality improvement networks through which improvement and innovation information can flow. We use a combination of social network mapping tools and agent-based simulation models to study the structure of several healthcare improvement networks and understand how improvements flow across these systems, similar to epidemiologic models, and what interventions can maximize spread and network quality. Several national and regional examples and ongoing work will be described.

4 - The CMS Innovation Center Healthcare Systems Engineering Summer Fellowship Program
Laura Hyde, Northeastern University, Boston, MA, United States of America, hyde@neu.edu, James Benneyan
For industrial and systems engineers to have greater impact on health care, familiarity and experience working within health systems may be required. To facilitate this, we describe a summer healthcare systems engineering fellowship program funded as part of a CMS Innovation Center grant to Northeastern University’s Healthcare Systems Engineering Institute. Partnering with dozens of Boston-area health systems affiliated with our institute and 2 federally-funded centers, this program allows undergraduate and graduate students across the U.S. to join ongoing projects in order to gain hands-on experience applying systems engineering methods to a variety of problems. Summer fellows work for 8 to 12 weeks on applied or research projects aligned with their interests, mentored by a senior doctoral student, healthcare practitioner, and faculty coach. Several students have gone on to pursue research topics in their home universities related to their summer projects. Examples of past projects, program logistics, and impact-to-date will be described.

■ WC02
02- Chicago G
Patient Flow Models for Resource Allocation
Cluster: Healthcare Operations Management
Invited Session
Chair: Jackie Griffin, Northeastern University, 360 Huntington Ave., Boston, MA, 02115, United States of America, ja.griffin@neu.edu
1 - A Queuing-Based Measure to Evaluate Responsiveness to Multi-Class Customers in Healthcare Delivery
Elham Torabi, University of Cincinnati, Lindner College of Business, 2925 Campus Green Dr., Cincinnati, OH, 45221-0130, United States of America, torabiel@mail.uc.edu, Michael Magazine, Peng Mai, Uday Rao, Yann Ferrand, Craig Froehle
In health centers with multi-priority patients, dedicating resources to different priority groups can increase responsiveness to some while increasing delays for others. Using queueing theory, we develop a surrogate performance measure to compare different resource flexibility strategies. We apply the model to allocate ORs among elective and emergency surgeries.

2 - Resource Planning for Mental Health Services Delivery
Ayten Turkan, Assistant Professor, Northeastern University, 360 Huntington Avenue, Boston, MA, 02115, United States of America, A.Turkan@neu.edu, Laura Myers, Brad Doebbeling, Stephanie Adams
Mental health services are frequently resource limited. We modeled the inpatient and outpatient mental health care system at a VAMC. Our simulation model incorporated patient population characteristics, comorbidity, treatment patterns, patient flow, and care needs based on diagnosis and severity. Experts validated the simulation model, and provided usability feedback. Our model is a resource allocation tool for capacity planning decisions and to improve quality measures and timely access.

3 - Patient-Bed Assignment Policies in Hospital Systems
Jackie Griffin, Northeastern University, 360 Huntington Avenue, Boston, MA, 02115, United States of America, ja.griffin@neu.edu, Pinar Keskinocak
To alleviate overcrowing in hospitals, hospitals may implement policies that address the management of patient arrivals through the redirection of patients to other hospitals. We model the hospital unit as a Markov chain and develop type-specific threshold policies for patient assignment while simultaneously addressing three distinct objectives.

4 - Sizing and Scheduling Health Claims Coders under a Flexible Demand
Monica Villareal, PhD student, Georgia Institute of Technology, 755 Ferst Drive, NW, Atlanta, GA, 30332, United States of America, monica.v@gatech.edu, Pinar Keskinocak
We implemented a model that schedules about 700 coders for a company in Georgia. There is a time window for the demand completion, so solving this problem requires not only scheduling the staff but also the workload. This problem was modeled as a mixed integer program, which balances capacity constraints, preferences and utilization of the staff, supervision requirements, and demand completion. We also developed and tested heuristics for settings where an optimal solution was not available.

■ WC04
04- Scottsdale
Industry-Academic Research Partnership: Advances and Challenges
Cluster: Medical Decision and Policy Making
Invited Session
Chair: Eva Lee, Professor and Director, Georgia Institute of Technology, Atlanta, GA, United States of America, evakylee@isye.gatech.edu
1 - Modeling and Optimizing Emergency Department Workflow
Eva Lee, Professor and Director, Georgia Institute of Technology, Atlanta, GA, United States of America, evakylee@isye.gatech.edu, Rulin Zhou
The study is joint with Grady Health Systems & Children’s Hospital of Atlanta. The work addresses overcrowding of the emergency department: excessive presence of patients with non-urgent medical conditions; long wait times; decreased quality of care and patient satisfaction; unnecessarily long length-of-stay, and return/readmission of patients. Systems models and advanced computation are developed for optimal care delivery to improve performance efficiency and cost-effectiveness.

2 - Rerouting Non-Emergency Patients from the Emergency Department (ED) to an Appropriate Care Setting
Kristin Schuller, schuller@tamhsc.edu, Tiffany Radcliff, Terri Menser, Jungyeon Kim
A new medical screening program that re-routes non-emergent patients age 6 to 64 from the emergency departments to an affiliated health clinic to receive care is has been implemented at a Texas hospital. All patients arriving at the ED are screened by a registered nurse in accordance with an approved protocol for triage. This study explores the impact on volume, case-mix, and revenues for both the health clinic and the ED using claims and payment information. A pre-post analysis, controlling for facility and patient characteristics, is used to analyze changes in revenues, volume, payer, and patient mix.

3 - Engineering Better Emergency Department Observation Units
Kendall Sanderson, sanderson.k@husky.neu.edu, James Benneyan, Laura Hyde
Emergency department observation units (OUs) are gaining increased interest as changes in revenues, volume, payer, and patient mix.

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4 - Leveraging the Admission Process Policy to Improve Patient Flow and Quality of Care in the ED
Hyojung Kang, Pennsylvania State University, 310 Leonhard Building, University Park, PA, 16802, United States of America, HQK3116@psu.edu, Harriet Nembhard, Chris DeFlitch
The rapid transition of admitted patients from the Emergency Department (ED) to inpatient units is essential for high quality of care and efficient use of hospital resources. This research focuses on improving the patient flow and quality of care in the ED by leveraging the admission process policy. We categorize different admission processes into five major policy types. The potential impact of the admission process policy types on patient length of stay and ED throughput were analyzed using simulation. Our work also addresses the impact of the admission process on boarding patients in the ED.
**WC10**

10- Cook

**Healthcare Policy and Finance - III**

Contributed Session

Chair: Lijian Lu, PhD Candidate, Columbia University, Columbia Business School, 3022 Broadway, New York, NY, 10027, United States of America, l2753@columbia.edu

1 - Price Competition under Subsidization: Application to Medicare Reform

Lijian Lu, PhD Candidate, Columbia University, Columbia Business School, 3022 Broadway, New York, NY, 10027, United States of America, l2753@columbia.edu, Awil Federman

We consider price competition models, in which a significant part of the price is subsidized by a third party. We characterize the equilibrium behavior and derive comparison results for the price equilibrium under alternative subsidy schemes. Applying our results to the Medicare insurance market, we estimate that implementation of various proposals, in particular the Wyden-Ryan plan, in 2010 would have enabled savings of 16.2% in the governments’ costs. For beneficiaries continuing to opt for the traditional Medicare plan, the average monthly cost is roughly $64.

**WC11**

11- Dupage

**Advances in Healthcare Delivery**

Cluster: Healthcare Operations Management

Invited Session

Chair: Eva Lee, Professor and Director, Georgia Institute of Technology, 755 Ferst Drive, NW, Atlanta, GA, 30332, United States of America, eva.lee@gatech.edu

1 - On the Development of the Scheduling System of Operating Rooms of Aichi Medical University Hospital

Atsuo Suzuki, Professor, Nanzan University, 27 Setei, Seto, 4890863, Japan, atsuo@nanzan-u.ac.jp, Yoshihiro Fujiwara, Kana Yamamoto, Mina To, Chihiro Kobayashi, Takamori Imazumi

We develop a system supporting operating rooms’ scheduling. The system provides an interface to support the process to finish up scheduling. We obtain scheduling by solving the scheduling problem, formulated as integer programming. After that we modify it by hand and solve it again under the modified constraints. We iterate this until we obtain the final scheduling. A prototype is tested in Aichi Medical University Hospital and we find that the system reduces the time for scheduling.

2 - OR/MS Offers Solutions to the Emergency Department Crisis

Doug Samuelson, President / Chief Scientist, Infologix, Inc., 8711 Chippendale Ct, Annandale, VA, 22003, United States of America, infologix1@aol.com

While emergency departments (EDs) in the U.S. are increasingly overwhelmed, often compromising treatment quality, a few analyses have produced dramatic improvements. “Door-to-Doc,” having a doctor assess patients before performing triage to assign beds, is one good example, and simulations of patient and resource flows suggest other opportunities. But to help, OR/MS analysts need to learn medical terms and practices. (Dedicated to the Memory of David Eisel, M.D.)

**WC09**

09- McHenry

**Perspectives on Integrated Analytics in Healthcare**

Contributed Session

Chair: Bradley Vincent Watts, Psychiatrist, Veterans Affairs, 215 North Main Street, White River Jct, VT, 05009, United States of America, bradley.watts@va.gov

1 - Unstructured Health Care Big Data Analytics with Semantics

Deva Reddy, Founder & CTO, Evam Technologies, Bangalore, India, deva@evamtec.com

Majority around 80% of the hospital unstructured data remains obsolete. Unstructured data consists of the physician prescription data, physician voice transcribed file and machine printed discharge summary along with the social media data. Current systems are unable to take value out of this ocean of unstructured big data. We provide great value in the following ways: to gain the leads to treat the patient, by integrating the patient records with the physician prescriptions and semantic social media; make unstructured data become value oriented asset; discover the data; understand the patterns and insights for clinical decisions and perform predictions; semantic inter-operability for integration; intelligent decision systems; personalization (alerts and updates, email, SMS, Tweets; follow-ups, updates, medicine consumption, research.

2 - Integrated Healthcare Design Optimization through Predictive Analytics and Advanced Post Occupancy Evaluation Techniques

David Morgareidge, RTKL Associates Inc., 1717 Pacific Avenue, Dallas, TX, United States of America, dmorgareidge@RTKL.com, Hui Cai

Predictive analysis tools such as Discrete Event Simulation and Space Syntax Analysis support an optimal, integrated healthcare design approach. These rigorous and quantitative analysis techniques lead to the ideal blend of architectural space, technology, staffing, and clinical processes that achieve each client’s unique clinical and financial performance objectives.

3 - Differing Focus of Biomedical Research and Operations Research and Management Science

Bradley Watts, Assistant Professor of Psychiatry, Geisel School of Medicine at Dartmouth, 215 N. Main Street, White River Junction, VT, 05009, United States of America, bradley.v.watts@dartmouth.edu, Julia McDougall Ronconi, James Benneyan, Erkan Ceyhan, TeChieh Chen, Brian Shiner

We hypothesized that operations research and management science (OR/MS) and traditional biomedical research (BMR) generally focus on different problems, decreasing synergy and slowing incorporation of systems engineering into healthcare. We reviewed abstracts from the INFORMS Healthcare conference (2011), and compared them to abstracts published and indexed by the National Library of Medicine, representing the biomedical literature. While complimentary in many areas, OR/MS and BMR differ importantly in areas of disciplinary focus. While BMR is relatively well-spread across most medical disciplines, OR/MS focuses on relatively few medical disciplines, potentially limiting the impact of OR/MS on the improvement in healthcare.
3 - The Surgical Patient Routing Problem
Sepehr Nemati, University of Pittsburgh, Department of Industrial Engineering, 1048 Benedum Hall, Pittsburgh, PA, 15261, United States of America, sen12@pitt.edu, Oleg Shylo, Oleg Prokopyev, Andrew Schaefer

Many patients face difficulties to access medical facilities in the U.S. In this study, we propose an integrated routing and outpatient surgery scheduling model for those medical centers providing transportation assistance for the patients. The objective is to minimize the total service time cost of all the patients. Our numerical study using actual medical data shows the efficacy of a unified framework to improve the quality of services to the patients.

4 - Priority Queuing Models for Hospital Intensive Care Units and the Impacts to Severe Case Patients
Matthew Hagen, Georgia Institute of Technology, College of Computing, Atlanta, GA, United States of America, matthew.hagen@gatech.edu, Eva Lee

This is a joint with with Emory University. This talk reports priority strategies for intensive care units (ICU) and the effects on wait times, utilization, return rates, mortalities, and number of patients served. Five separate ICUs are analyzed. A system-based simulation-optimization model is built to capture all possible cases of patient flow. Patients are grouped into 9 different classes that are categorized by severity and length of stay.