Regenstrief Center for Healthcare Engineering

Report to the Regenstrief Foundation

June 2010
RCHE views a patient’s interaction with the healthcare system as a continuum. The Integrated Healthcare Delivery Model (above) emphasizes healthcare as a patient-centric process. Beginning on the left side of the model, the “patient” often includes the family. The patient may be a child or senior citizen, so a parent or adult child may advocate for them and accompany them to appointments.

Following along the bottom half of the model, each episode requiring care — be it regular, planned care like a physical or diabetic check up, or unplanned acute care like a sudden illness or broken arm — has care outcomes for that episode. Based on the six aims from the Institute of Medicine, patient outcomes should reflect care that is safe, effective, patient-centered, timely, efficient, and equitable. However, taken as a whole, the entire care cycle (i.e. sequence of care episodes) should also have the same six outcome measurements. The six aims should be pursued in both individual episodes as well as throughout the care cycle.

Care exists at many levels. An individual may provide their own care by bandaging a wound. They may be provided care by a care team of physicians, nurses, etc. An organization can provide care, as in the case of a hospital or pharmacy. The environment refers to a group of care resources — state healthcare agencies, healthcare technology providers, policymakers, regulators, etc.

The letters A–D indicate the four areas of RCHE research — patient/provider interaction (A), care cycle management (B), care outcomes (C), and system support (D).

Research foci

Partnerships with national organizations helped RCHE continue to specify its research focus over the past year. The spring 2009 conference brought six priority topics to the forefront, and dialogue with stakeholders helped RCHE narrow the six priorities to two focus areas — care coordination and population health. The areas were identified through an analysis of RCHE’s research strengths, key national priority areas, and areas of interest from partners and researchers. While there have been significant changes in healthcare over the past year, these partnerships have helped RCHE establish focus areas that continue to be reflected in national legislation and strategy.

Approach to focus area research

The healthcare system is often criticized for being extremely fragmented, opening the door for errors, redundancies, and confusion. Coordinating care across providers presents an opportunity not only to reduce errors and redundancies but to improve the quality of care through increased information and the development of patient-centered care. RCHE research in care coordination focuses primarily on primary care with a growing emphasis on chronic disease management.

Care coordination research often focuses on individuals or small groups of patients. Applied at a macro level, advances in care coordination can lead to improvements in population health. RCHE’s population health research projects address key populations, including Medicare and Medicaid patients, patients with chronic diseases, and under-served patients.

Advancing EHR adoption

RCHE was an active participant in the $12 million I-HITEC grant awarded to Purdue in February. Partnering with Purdue’s Office of Engagement and led by Healthcare TAP (HTAP), an RCHE affiliate, I-HITEC will assist more than 2,000 Indiana providers in adopting EHRs and meeting federal meaningful use standards with them. The program draws on Indiana’s existing health information exchanges and Purdue’s extension network. The exchange of information made possible by electronic health records is an essential step in pursuing more coordinated care across providers and health organizations. RCHE will participate in this project with HTAP through 2012.

The impact of health reform legislation

The recently passed health reform bill may be one of the most significant changes in American healthcare since the creation of Medicaid almost 50 years ago. RCHE’s research foci were established in consultation with various stakeholders, including leading national organizations like the American College of Physicians, and the American Hospital Association. These foci continue to be reflected as national priorities in this legislation, reinforcing the value of RCHE’s national partnerships.
Core competencies

RCHE’s competencies come from leveraging the strengths of faculty and researchers across Purdue’s academic colleges as well as its service units like information technology.

Healthcare Engineering

Data mining  
Data repository management  
Data streaming and sensors  
Decision analysis  
Decisions under uncertainty  
Dynamic programming  
Engineering economics  
Facility planning  
Functional data analysis  
Game theory  
Geographic information systems  
Goal programming  
Graphical user interfaces  
High dimensional inference  
High performance cluster computing  
Human performance modeling  
Human systems integration  
Integer programming  
Lean  
Linear programming  
Meta-analysis  
Multiple objective optimization  
Multiscale methods  
Network optimization and analysis  
Non-linear programming  
Pandemic planning and gap analyses  
Patient flow and scheduling  
Patient safety  
Prediction and forecasting  
Quality control  
Quality improvement  
Queueing methods  
Remote sensing analysis  
Rendering  
Simulation  
Six Sigma  
Spatial analysis  
Spatial econometrics  
Statistical analysis  
Supply chain management  
Systems dynamics  
Systems modeling  
Visualization

Health Informatics and Learning Technologies (HILT)

Communication technologies  
Community building  
Design of interdisciplinary learning environments  
E-learning  
Health communication  
Identification, authentication, and privacy  
Immersive environments  
Knowledge acquisition and concentration frameworks  
Knowledge management  
Multimedia databases  
Organizational learning  
Social networking/collaboration  
Telemedicine

Center for Health Outcomes Research and Policy (CHORP)

Analysis of categorical data  
Biostatistical inference  
Design and analysis of experiments  
Epidemiology  
Gerontology  
Health promotion  
Pharmacy
Operations

Selected projects

**Communication and learning in treating diabetes**

**PI:** Bart Collins, Communications

**Healthcare partners:**
- Center for Innovation, Mayo Clinic, Rochester, MN
- Austin Medical Center, Austin, MN

**Core competencies:**
- E-learning
- Telehealth
- Modeling
- Statistical analysis

**Project summary:**
Based on concepts from Wagner’s Chronic Care model, RCHE and Mayo Clinic are collaborating on a project to assess delivery system design and support of patients with diabetes, to support providers in delivering better care, and patients in supporting their own care. The first phase of the project addresses the following questions:

1. How effective are Mayo primary care physicians at providing support for diabetes patients consistent with key factors identified in the Chronic Care Model?

2. How well are Mayo diabetes patients adhering to clinical guidelines associated with the care of diabetes?

3. How are variation in patient assessment of physician support of the Chronic Care Model and variation in patient activation related to patient adherence to clinical recommendations for the management of diabetes based on data in the patient’s medical record and other health outcomes?

A second phase of the project will examine use of e-health systems on patient activation and the healthcare team. E-health systems present the potential for monitoring patients remotely, providing primary care teams with more information with which to work with the patient.
A financial model for sustaining the medical home

**PI:** Ping Huang, research scientist, RCHE

**Faculty:**
- Mark Lawley, Biomedical Engineering
- Ken Musselman, RCHE
- Fei Pan, Krannert School of Management
- Steve Witz, RCHE

**Healthcare partners:**
American College of Physicians

**Core competencies:**
- Statistical analysis
- Modeling

**Project summary:**
Because primary care is perceived to be under-valued, many see the need for new modes of delivery to improve both its effectiveness and appeal. This project goal was to determine the conditions under which the medical home could be financially sustainable. The team created a model to help identify the appropriate levels of capitation, incentive, and resource investment for medical home services. Because these decisions are distributed between payers and providers, the objective was to characterize an equilibrium representing the set of strategies that neither party has reason to modify.

The modeling resulted in a unique Nash equilibrium point, which specifies a payment point that can be mutually beneficial to both provider and payer. The model was also applied to data from AHRQ and MGMA, allowing for observations on the practical behavior of the model. The results suggest that there is a practical foundation for developing new reimbursement models that can be mutually beneficial to payers and providers.

Post-operative surgical outcomes in older adults

**PI:** Laura Sands, Nursing

**Faculty:**
- Joseph Thomas, Pharmacy
- Diane DeBerry, Nursing
- Zhiyi Tian, RCHE
- Jacqueline Leung, University of California, San Francisco

**Healthcare partners:**
- St. Vincent Institute on Aging
- Pat Healy, St. Vincent Health
- Shirley Delaney, St. Vincent Health
- Beth Johnson, St. Vincent Health
- Mary Ziemba-Davis, St. Vincent Health

**Core competencies:**
- Statistical analysis

**Project summary:**
Many primary care providers are reluctant to refer older patients for surgery because of the perception that the potential risks outweigh the benefits. This study examined retrospective data from the University of California San Francisco medical center and St. Vincent Hospital to determine whether it was possible to identify which patients were at greatest risk for adverse events after hip and knee surgery. The study focused specifically on
patients 60 and older.

Patients with a preoperative diagnosis of valvular disease or dysrythmia were more likely to experience a post-operative cardiac event. Additionally, two indicators of functioning in older adults — activity of daily living and cognitive impairment — were also significant predictors of a post-operative cardiac event. Including these two measurements increased the accuracy of the model from .55 to .85. Only one of the two hospitals collected these measurements.

The results of the study suggest the need for collecting the additional measurements in older adults. Providers considering whether to recommend surgery for patients can now know that there are several measurable factors besides age that have a significant impact on the post-surgery outcome.
Recently funded initiatives

In keeping with the research foci, RCHE has launched two large-scale research projects to lay the groundwork in key areas.

Readmissions

“Rehospitalization is quite possibly the most conspicuous and powerful single example of the cost we are paying for fragmented, provider-centered care.” – Stephen Jencks

PI: Steve Witz, RCHE

Faculty:
- Lingsong Zhang, Statistics, Purdue University
- Hong Wan, Industrial Engineering, Purdue University
- Jim Benneyan, Industrial Engineering, Northeastern University
- Jose Zayas-Castro, Industrial Engineering, University of South Florida

Healthcare partners:
- St. Vincent Hospital, Indianapolis, Indiana
- BayCare Health System, Tampa, Florida
- Good Samaritan Hospital, Boston, Massachusetts

Core competencies:
- Statistical analysis
- Prediction
- Data mining

Project summary:

Reducing preventable readmissions has been a healthcare issue for decades but gained new notoriety when it became part of the federal health reform bill and included provisions for reduced federal reimbursements for hospitals with “higher than average” readmissions rates in several conditions. A review of the literature determined that there were dozens of interventions available but little research on what type of intervention worked best for a given hospital profile. In concert with three hospital from three different states, the research team will:

1. Develop descriptive and statistical profiles of the hospital readmissions situation;
2. Establish a predictive model for which patients may be most likely to be readmitted;
3. Select and implement readmissions interventions targeted to the hospital’s readmissions profile;
4. Evaluate the success of the interventions.
“In 2009, minorities were less likely to have insurance and less likely to get the treatments they need. The lack of care can lead to chronic disease and even death.”
— Howard Koh, MD, Assistant Secretary for Health

Safety Net

PI: Haslyn Hunte, Health & Kinesiology, Purdue University

Faculty:
Raymond Florax, Agricultural Economics
Chris Miller, Libraries
Brigitte Waldorf, Agriculture Economics
Lingsong Zhang, Statistics

Healthcare partners: Regenstrief Institute

Core competencies:
Geographical information systems
Spatial analysis

Project summary:
Safety Net providers serve primarily patients who are considered “under-served” by the general medical community. These patients are often on Medicaid or Medicare and not able to pay at the same rate as privately insured patients.

The results of this study will provide policymakers with a clear understanding of where uninsured (and insured populations) go to seek care and some insights of how safety net providers working with the surrounding medical care system can possibly provide more coordinated care, thereby maximizing the benefits of our current resources, reducing the use of unneeded care, and decreasing the exposure to potentially harmful procedures.

This study will:

1. Map the locations of individuals and where they go to seek care, including the characteristics of the neighborhoods of patients, and the supply and demand characteristics of the medical care system.

2. Examine the association between the choice of provider, characteristics of provider, individual characteristics (race, gender, age, and health insurance status) and health status.

3. Follow patients across time to understand the associations between where, how often, and why patients go to seek care based on the same variables as in 2.

4. Examine strategies that hospitals and emergency departments in a defined geographical area can adopt to provide coordinated, patient-centered, quality care in the appropriate medical care setting.

5. Examine the impact of the economic recession on safety net provider’s ability to deliver care.
University Engagement

RCHE is actively involved with faculty in many of Purdue’s academic colleges. Additionally, Purdue has launched a College of Health and Human Sciences, which will begin in August, and will encompass the following departments: Child Development and Family Studies; Consumer Sciences and Retailing; Foods and Nutrition; Health and Kinesiology; Health Sciences; Hospitality and Tourism Management; Nursing; Psychological Sciences; and Speech, Language, and Hearing Sciences. RCHE looks forward to playing an active role in supporting the new college.

Affiliated faculty and staff

<table>
<thead>
<tr>
<th>Unit</th>
<th>Faculty affiliates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering</td>
<td>19</td>
</tr>
<tr>
<td>Pharmacy, Nursing, &amp; Health Science</td>
<td>17</td>
</tr>
<tr>
<td>Liberal Arts</td>
<td>11</td>
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<tr>
<td>Technology</td>
<td>8</td>
</tr>
<tr>
<td>Science</td>
<td>7</td>
</tr>
<tr>
<td>Consumer and Family Sciences</td>
<td>6</td>
</tr>
<tr>
<td>Library Sciences</td>
<td>5</td>
</tr>
<tr>
<td>Krannert (Management)</td>
<td>4</td>
</tr>
<tr>
<td>Vet Med</td>
<td>2</td>
</tr>
<tr>
<td>Agriculture</td>
<td>2</td>
</tr>
<tr>
<td>Medical Education</td>
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</tr>
<tr>
<td>Education</td>
<td>1</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>83</strong></td>
</tr>
</tbody>
</table>

RCHE also attracts staff members throughout Purdue who wish to be affiliated with the center.

<table>
<thead>
<tr>
<th>Unit</th>
<th>Staff affiliates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discovery Park administration*</td>
<td>12</td>
</tr>
<tr>
<td>Technical Assistance Program</td>
<td>3</td>
</tr>
<tr>
<td>Human Resource Services</td>
<td>2</td>
</tr>
<tr>
<td>Information Technology</td>
<td>1</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>18</strong></td>
</tr>
</tbody>
</table>

*Includes six RCHE staff members.
Outreach

RCHE uses several methods to disseminate research findings and engage stakeholders around the state and the nation.

Communications

The quarterly RCHE e-newsletter currently has 334 subscribers. RCHE will begin to track and evaluate readership of specific stories in the newsletter to further target the newsletter to its audience.

The RCHE website continues to draw visitors from around the country and the world. In the past year, the RCHE website has had the following traffic:

- 15,249 visits
- 5,467 unique visitors
- Visitors were from 97 countries, of which the top five were: US, India, Canada, South Korea, and the UK.
- Visitors from all 50 states, plus D.C. Top states were: Indiana, Illinois, California, New York, and Texas.

catalyzecare.org

It has become clear that an online space for healthcare systems research and collaboration is necessary to assist with both research and dissemination. Using funds from the supplement grant, RCHE is spearheading the effort to create this space, which will be built on the robust hubzero technology. Named “CatalyzeCareHUB” and found at www.catalyzecare.org, the site is currently in development and expected to undergo beta testing during the fall with its public launch in spring 2011.

The hub includes all of the functionality of a website plus the additional capabilities of running tools and simulations. As such, users will be able to test models using the site without needing to run a given software program on their computers; the program and the model will run off of the hub. Communities will allow users to collaborate with others in the areas of greatest interest to them.
Research effectiveness

Research partners
Strategic partnerships provide RCHE researchers with living laboratories for research and opportunities for dissemination of research findings.

Research validation
During the 2009–10 academic year, RCHE affiliated faculty reported 24 papers published in peer-reviewed journals, with an additional 10 accepted but in press. The complete list of papers is available on the RCHE website. Highlights include:


Faculty were asked to present their work at more than 25 conferences or professional meetings this year. Highlights include:


Both faculty and graduate students won awards for their work this year.

Yuehwern Yih, professor of industrial engineering, was named an IIE Fellow in 2009. Yih was also invited to participate in the Care Integration Executive Session at the Lucian Leape Institute at the National Patient Safety Foundation in March.

Lisette Reyes Paulino, a graduate student working with the Health Informatics and Learning Technologies group, was awarded the Design and Development Showcase Certificate of Recognition to an Innovative Training and Educational Program, at the Association of Educational Communications and Technology: Design and Development Division, in Louisville, KY.

Joseph Thomas III, professor of pharmacy practice, received the Provost’s Award for Outstanding Faculty Mentor.

Research collaboration

*Healthcare Engineering Association*

RCHE continues to be an active participant in the HEA, an association of universities that are actively engaged in healthcare engineering and which RCHE helped found. The 2010 conference was held at the University of Arkansas on May 20–21.

*Other universities*

RCHE works with researchers at other universities as a means of strengthening collaborations, growing the field, and learning from others. Collaborations with other universities in 2009–10 include:

- Northeastern University — readmissions
- University of South Florida — readmissions
- University of Wisconsin — Infusion informatics
- Indiana University — no-show behavior, trauma care
- University of California, San Francisco — surgical outcomes in older adults

*Regenstrief Institute*

Several projects and researchers collaborated with the Regenstrief Institute this year, including:

- Haslyn Hunte on the Safety Net project. The Institute has been instrumental in helping to create and define the scope of the research.
- Laura Sands continues to work with Institute researchers on various projects.
- RCHE and the Regenstrief Institute both participated in the HITEC grant.
VERC

RCHE participated in several VERC applications, including the successful one by the Indianapolis-based Roudebush VAMC. The center and affiliates continue to be involved in the program. The Indianapolis VERC award was $1,000,000, and is renewable.
Learning and innovation

Conferences

Fall 2009

Held in conjunction with the Healthcare Engineering Alliance meeting, RCHE’s fall 2009 conference targeted its two research foci — care coordination and population health. Approximately 150 people attended, including faculty, students, and local providers.

Speakers included:

- Mark Braunstein, MD; Professor of Practice, Health Systems Institute at Georgia Tech
- Peter J. Fabri, MD; Professor of Surgery, University of South Florida
- Nan Kong, PhD; Assistant Professor of Biomedical Engineering, Purdue University
- Glen P. Mays, PhD, MPH; Associate Professor, Chair Pro Tem, and Director of Research, Department of Health Policy and Management, University of Arkansas for Medical Sciences (UAMS)
- Stephen Roberts, PhD; Professor of Industrial Engineering, North Carolina State University
- Vinod Sahney, PhD; Senior Vice President and Chief Strategy Officer, Blue Cross Blue Shield of Massachusetts
- Laura Sands, PhD; Professor of Nursing, Purdue University

Feedback was positive, with 91 percent of respondents saying the conference was “useful” or “very useful” for them.

Spring 2010

RCHE’s spring 2010 conference highlighted the importance of implementation research and strategies for creating mutually beneficial partnerships. Speakers covered issues such as implementation and ROI in funding applications, successful collaborations, and issues to consider in creating research partnerships.
Approximately 60 people attended, including faculty and students, but with a noticeable increase in attendance from small business owners.

Speakers included:

- Jim Benneyan, PhD, professor of industrial engineering, Northeastern University
- Ann Christine Catlin, researcher, Rosen Center for Advanced Computing, Purdue University
- Dan Degnan, medication safety officer, Community Health Network
- Al Rebar, executive director of Discovery Park, Purdue University
- Dave Zook, managing partner, Baker & Daniels

Feedback was positive; all speaker presentations were rated highly.
Financial management

Examples of funded projects

Key funded projects in 2009–10 included:

- I-HITEC. Vic Lechtenberg, Engagement; Steve Witz, RCHE; Dave McKinnis, TAP; Mary Anne Sloan, HTAP. Funded by the Office of the National Coordinator. $12,000,000.
- Prognostic Significance of Insufficient ADL Help on Health Outcomes/Utilization. Laura Sands, Nursing. Funded by the National Institutes of Health. $1,112,313.

Funding sources

RCHE and its faculty continue to draw funding from organizations around the country. In 2009–10, these included:

- National Institutes of Health
- Office of the National Coordinator for Health Information Technology
- Indiana State Department of Health
- The Helene Fuld Health Trust
- University of California at San Francisco
2009–10 financials

Note: Center-generated support does not include the $25,000,000 CTSI grant, of which RCHE was a part, nor the VERC awards for regions other than Indiana. I-HITEC award is counted in Center-Generated Support, although the project benefits from a significant contribution by HTAP. VERC is listed under Center-Generated Support.
Laura Sands, PhD
Professor of Nursing
Director of Research, School of Nursing, Purdue University

Education

Laura Sands received a BA in Psychology, a MA in Biostatistics and a PhD in Quantitative Psychology, all from the University of California, Berkeley.

Dr. Sands’ current research is focused on identifying care pathways that optimize health, functioning and quality of life in older adults, particularly those who are disabled. She is analyzing several large data bases, that include self-reported data, clinical data and medical claims data to understand: 1) risks for loss of functioning and need for long-term care services among older adults, 2) how the type and amount of home-based long-term care services received by disabled older adults affect the amount of time they are able to remain in the community, and 3) how unmet needs for long-term care services affect patients’ health and subsequent use of health care services. In addition, Dr. Sands is working with Purdue University biomedical and industrial engineers to develop efficient systems to improve attendance rates to scheduled appointments. Dr. Sands’ prior research included determining whether individual dementia patients benefit from pharmaceutical therapy. She has also contributed psychometrically to the development of instruments to assess quality of life in persons with dementia; patient satisfaction; and patient preferences for treatment.

Interests

- Research methods
- Health Services Research and Policy
- Gerontology
- Long-term Care Policy
- Understanding predictors and outcomes of no show behavior

Service and Engagement

Dr. Sands is Director of Research of the School of Nursing at Purdue University. She serves on the graduate education committees of the School of Nursing. She is a member of the steering committee of the Center on Aging and the Life Course at Purdue University.

Teaching

Dr. Sands teaches Biostatistics, Health Care Policy, and Evidence-based practice to Doctor of Nursing Practice (DNP) students. She also helps mentor graduate students from the Departments of Statistics, Nutrition, Sociology, and Political Science in their research on older adults.

Currently Funded Grants


Title of Project: Risks for Poor Surgical Outcomes Among Older Adults

Project Personnel at Purdue University: Laura P. Sands, Joseph Thomas III, Diane DeBerry, Zhiyi Tian
St. Vincent Institute on Aging, St. Vincent Health: Patrick Healy, Shirley Delaney, Beth Johnston, Mary Ziemba-Davis

Project Personnel at University of California, San Francisco: Jacqueline Leung

Purpose of Project:
To inform clinicians which patients aged 60 and older are at highest risk for post-operative adverse events following major elective knee and hip surgery requiring general anesthesia.

Significance of Project:
The aging of the American population and the increase in prevalence of patients with advanced osteoarthritis has resulted in a precipitous increase in the number of adults aged 60 and older who meet criteria for referral for major hip and knee surgery. Historically, primary care providers are less likely to refer their oldest patients for surgery because of the perception that potential risks outweigh potential benefits. On the other hand, restriction of patients from surgical interventions may negatively impact their independence, functional ability, and quality of life. It is important to determine which patients are most likely to experience adverse events after surgery to improve patient-centered counseling about potential risks of elective hip and knee surgery and to identify which patients would benefit from interventions to reduce their risk for post-operative adverse events.

Methods:
Researchers from the Regenstrief Center for Healthcare Engineering partnered with clinicians and staff from St. Vincent Hospital to determine data resources available to determine whether there were significant differences in incidence of post-operative outcomes between adults aged 60-69, 70-79 and 80 and older who undergo major elective hip and knee surgery. In addition, the research team sought to determine whether it was possible to identify which patients were at greatest risk for adverse events after hip and knee surgery.

Data from St. Vincent hospital were collected from the billing records of patients aged 60 and older who had elective non-emergent knee or hip arthroplasty between April 2008 and June 2009 whose length of stay was at least 48 hours after surgery. Billing data included demographic information and preoperative and post-procedural ICD-9 and procedure codes that provided information about patients’ health status upon admission and post-surgery. Determination of relevant ICD-9 codes was completed by a collaborative team that included project staff from Purdue University and St. Vincent Hospital including physicians, nurses, researchers, a coding specialist and a billing specialist.

Comparison data were collected from a second site at which ongoing studies are being conducted to determine risks and interventions for post-operative adverse events. Pre-, peri- and post-operative data were available from adults aged 60 and older who underwent elective surgery at the University of California, San Francisco (UCSF) between 2001 and 2008. Trained research assistants collected data from patients’ medical records and from structured patient interviews.
Statistical Methods:

1. Assessing differences between age deciles in post-operative adverse events:

Mantel-Haenszel Chi-square tests (or Fisher’s exact test if cell counts are less than 5) were conducted to determine the association between age deciles and the following post-operative outcomes: cardiac complications, pulmonary events, renal failure, infection and central nervous system events.

The results show that of 778 patients undergoing elective hip and knee surgery at St. Vincent Hospital, eleven percent experienced a cardiac complication. Incidence of cardiac complications significantly differed across age deciles with adults aged 60-69 experiencing the lowest incidence of cardiac complications (8.7%) and was highest among adults aged 80 and older (15.3%; p=0.02; see Table 1 below). Incidence of pulmonary complications was about three times higher for adults aged 80 and older compared to adults aged 60-69. There were no detectable age differences in post-operative complications attributable to renal failure, infection or central nervous system events.

Table 1. Age Differences in Incidence of Post-Operative Complications Among Patients Undergoing Elective Hip and Knee Surgery at St. Vincent Hospital

<table>
<thead>
<tr>
<th>Postoperative complication (n (%))</th>
<th>Age</th>
<th>Total n=778</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>60-69 n=358</td>
<td>289 n=131</td>
<td>89 n=20</td>
</tr>
<tr>
<td>Cardiac Complication</td>
<td>31 (8.66)</td>
<td>38 (13.15)</td>
<td>89 (11.44)</td>
</tr>
<tr>
<td>Pulmonary</td>
<td>9 (2.51)</td>
<td>17 (5.88)</td>
<td>28 (4.88)</td>
</tr>
<tr>
<td>Renal Failure</td>
<td>12 (3.63)</td>
<td>12 (4.15)</td>
<td>29 (3.73)</td>
</tr>
<tr>
<td>Sepsis Acute Infection</td>
<td>1 (0.28)</td>
<td>4 (1.38)</td>
<td>6 (0.77)</td>
</tr>
<tr>
<td>Central Nervous System</td>
<td>18 (5.03)</td>
<td>12 (12)</td>
<td>40 (5.14)</td>
</tr>
</tbody>
</table>

2. Determining risks for post-operative cardiac events:

Post-operative cardiac events was the only class of post-operative adverse events that occurred with sufficient frequency to construct a predictive statistical model. Bivariate associations between candidate predictor variables and whether or not the patient experienced a post-operative cardiac event were computed using chi-square tests. Those candidate predictor variables with an association of p<= 0.20 with post-operative cardiac events were then entered into a multivariable logistic regression model. Candidate variables that were considered from the St. Vincent data included demographic information and diagnoses present upon admission.

A predictive model for post-operative cardiac events was also constructed from UCSF data using the same statistical methods mentioned above. However, candidate predictor variables from the UCSF data also include the patients level of cognitive functioning (as assessed by the Mini-mental state examination) and their level of dependency in five basic activities of daily activities (bathing, dressing, eating, toileting, and getting across a room).
The results shown in Table 2 below show that only two variable from the St. Vincent dataset were statistically significant risks for a post-operative cardiac event. Those with a pre-operative diagnosis of valvular disease were nearly three times as likely to experience a post-operative cardiac event (OR=2.70; p=0.03) and those with a preoperative diagnosis of dysrhythmia were one and a half times more likely to experience a post-operative cardiac event. However, the fit of the predictive model was not good. The c-statistic (c=0.556) reveals that only about half of the time were who actually experienced a cardiac event actually predicted to be at high risk for experiencing the cardiac event.

The results from Table 2 show that including additional predictors in the model increased the predictive accuracy of the prognostic model. Two commonly used clinical indicators of functioning among older patients (ADL and cognitive functioning) significantly improved the predictive accuracy of the model. Similar to the St. Vincent data, the UCSF data revealed that preoperative diagnoses of valvular disease and dysrhythmia were significant predictors of a post-operative cardiac event. In addition, dependency in one or more activities of daily living and cognitive impairment were also significant predictors of a post-operative cardiac event. The c-statistic of 0.854 reveals that the model correctly identified those who actually experienced a post-operative cardiac event as being at high risk 85% of the time.

**Table 2.** Predictive Models for both Western hospital and Midwestern hospital

<table>
<thead>
<tr>
<th>Predictor Variables</th>
<th>UCSF Odds Ratio (95% Confidence Interval)</th>
<th>p-value</th>
<th>St. Vincent Odds Ratio (95% Confidence Interval)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity of Daily Living Dependency</td>
<td>3.724 (1.369, 10.129) p=0.010</td>
<td></td>
<td>Data not available from St. Vincent dataset</td>
<td></td>
</tr>
<tr>
<td>Cognitive Impairment</td>
<td>0.25 (0.09,0.73) p=0.011</td>
<td></td>
<td>Data not available from St. Vincent dataset</td>
<td></td>
</tr>
<tr>
<td>Pre-op Valvular Disease</td>
<td>11.89 (2.13, 66.45) p=0.008</td>
<td></td>
<td>2.70 (1.10,6.62) p=0.030</td>
<td></td>
</tr>
<tr>
<td>Pre-op Dysrhythm</td>
<td>5.21 (1.89-14.48) p=.0016</td>
<td></td>
<td>1.520 (0.936, 2.468) p=0.091</td>
<td></td>
</tr>
<tr>
<td>C-statistic</td>
<td>.854</td>
<td></td>
<td>0.556</td>
<td></td>
</tr>
</tbody>
</table>

**Systems Significance of Results and Dissemination of Findings:**

The results provide evidence that age alone should not be considered when determining which patients are at greatest risk for post-operative adverse events after elective hip or knee surgery. The results also provide evidence of the importance of conducting assessments of older patients’ activities of daily living and cognitive functioning preoperatively to determine which patients would be at greatest risk for experiencing an adverse cardiac event after elective knee and hip surgery. The results reported above have been discussed with St. Vincent project staff and will be presented to St. Vincent employees on June 16, 2010 at the St. Vincent Research Conference.