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MONOGRAPH

Research Immersion at the Virginia Tech Carilion School of Medicine – An Integrated Curriculum Producing Scientist Physicians for the Future of Healthcare

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Abstract
The Virginia Tech Carilion School of Medicine (VTCSOM) is a four-year allopathic medical school in Roanoke, Virginia, that matriculated its first class of 42 students in August, 2010. The creation of a new medical school through the partnership of an established public research intensive university, Virginia Tech, and an established private health system, Carilion Clinic provided a rare opportunity to craft a high-impact research curriculum, unique in both design and delivery. As part of the new curriculum, the faculty created a comprehensive four-year, longitudinal, research program that integrates the principles and practice of active participatory research into both basic and clinical science education and ultimately into the lifelong application of evidence-based medicine to patient care.

Importance of the Science of Medicine
A recent report, Scientific Foundations for Future Physicians, from the Association of American Medical Colleges (AAMC) and the Howard Hughes Medical Institute (2009) emphasizes the importance of the science of medicine for selecting and educating tomorrow's doctors and for improving healthcare delivery.[1] A key element of the science of medicine is the discovery process itself, including scientific reasoning, understanding how data are obtained and evaluated, assessing the validity of medical and scientific claims and practicing evidence-based medicine. Putting what's best for the patient as the top priority often requires weighing competing claims from the medical literature, from colleagues, from industry, as well as from the patients themselves and their families. Also included in the recommendations was the need for increased awareness of such potential conflicts when evaluating claims and making decisions based on evidence.

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Medical schools throughout the United States and Canada accredited by the Liaison Committee on Medical Education (LCME) use a wide variety of strategies to address these educational goals. These strategies range from students performing scientific literature reviews of clinical topics in clerkships to requiring additional years spent in medical school either completing an in-depth research project or obtaining an advanced degree (MS, MPH or PhD).[2-7] Some programs have incorporated as much as a full year of research carved out of the four year traditional medical curriculum.[3] The development of MD/PhD programs to train physician scientists has been a major step in our nation's approach to bridge the science-medical practice gulf.[8] The goals of these programs include producing tomorrow's leaders in academic medicine. However, due to the costs and time involved, the percentage of physicians graduating from such programs will necessarily remain relatively small and it still remains to be determined how many graduates will follow truly dual career paths, with active clinical practices and research programs.[9-14] While such physician scientists have much to offer the nation's health care enterprise, the case can also be made for a larger cohort of practicing physicians who also

bring strong scientific training credentials and a deep understanding and appreciation of how biomedical and health research are carried out.[15] The pace of discovery in molecular, genetic, computational, behavioral and health outcomes research is increasingly rapid, however implementation of these advances can lag far behind since practicing physicians often have little time to stay current in quickly changing disciplines while in training.[16-19] Moreover, as with good clinical practice, utilization of the principles of contemporary biomedical and health science research benefits from not only studying but also doing.

Thus, to meet these challenges to contribute to the development of scientifically-based medical practice and to the incorporation of the discovery process into all aspects of medicine, the faculty developed a program for students to learn these values and competencies through participating in original medical research under the mentorship of accomplished scientists and physicians. VTCSOM has embarked on a program to train scientist physicians (vs. physician scientists) as a complementary component of the physician workforce. Graduates of this program will primarily be committed to the practice of patient-centered medicine. However, they will be differentiated from classically trained practitioners by virtue of active participation in research throughout all phases of their four-year undergraduate medical education. This level of research engagement will instill healthy skepticism and an insistence on a sound scientific basis for all medical decision-making among graduates. These attributes, coupled with the confidence to evaluate primary research data, will empower graduates to be uniquely qualified advocates for their patients' best interests.

VTCSOM Curriculum Overview

At VTCSOM four educational value domains (basic science, research, clinical science, and interprofessionalism) run in parallel throughout the four years of medical school and provide the educational framework for a unique medical school experience that equips students with the knowledge, skills, and attitudes to become scientist-physicians who can improve the quality and safety of healthcare for patients, generate new medical knowledge, and improve operational aspects of healthcare systems of the future.

The patient-centered curriculum at VTCSOM utilizes a variety of sound educational strategies to maximize self-directed student learning. Chief among the many strategies employed at VTCSOM is a problem-based learning (PBL)-hybrid educational model in which small groups of medical students devote nine hours each week to work on patient-centered learning cases designed to introduce them to fundamental basic science concepts in a clinical context. This occurs during the first phase of the students' education (Years 1 and 2), in blocks of varying duration (themes and subthemes for Year 1 are presented in Figure 1, Appendix). These weekly cases provide a framework that allow for integration across all of the VTCSOM value domains, including research, as described below. Another hallmark of the VTCSOM curriculum is the immersion of students in a longitudinal research experience beginning in the first year. Research immersion across both phases (Phase 1 = Years 1 and 2; Phase 2 = Years 3 and 4) of medical education is designed to fully develop the skills of inquiry necessary in a scientist physician devoted to the practice of evidence-based medicine. Prior to the selection of a research project, students are engaged in a classroom-based curriculum designed to immerse them in the language, culture and practice of scientific research.

Research Value Domain Curriculum

The Research Value Domain is incorporated throughout all four years of the curriculum with the goal of developing scientist physicians. Scientist physicians are medical practitioners whose main focus is patient care but who bring the perspective, knowledge and analytical skills of a scientist to all aspects of the practice of allopathic medicine.

During the Year 1 classroom sessions, original medical scientific literature is used to expose students to both seminal and contemporary research related directly to the topics that are explored in the Basic Science Domain, as well as to introduce them to real-world challenges and limitations of modern medicine that require ongoing inquiry. Fundamental research principles (the scientific method, the ethical and regulatory issues associated with human and animal research, successful scientific collaboration, inferential reasoning) and contemporary tools of medical research (biostatistics, epidemiology, analytical exposition of the logic of research studies) are introduced in the context of real medical scientific literature, allowing students to simultaneously experience how these concepts are applied in actual research and to become adept at navigating medical literature to efficiently identify the information they seek. The Research Value Domain core competencies and goals are presented in Table 1.

CORE COMPETENCY	GOAL
The Scientific Method	Graduates will be able to identify, understand and apply the scientific method in both basic and clinical science settings.
Thinking Like a Scientist Physician	Graduates will be able to frame questions using the tools nad language of the scientist physician.
Basic, Clinical, and Translational Research	Graduates will be able to describe the research continuum that translates scientific discoveries into clinical applications.
The Protection of Human Subjects in Research	Graduates will be able to identify the ethical foundations of human research and apply the associated regulatory principles and procedures.
The Use and Protection of Animals in Research	Graduates will be able to identify the ethical foundations of animal research and apply the associated regulatory principles and procedures.
Biostatistics	Graduates will be able to identify, define, and apply the basic tools of biostatistical analysis.
Epidemiology	Graduates will be able to identify, define, and apply the basic tools of epidemiologic design.
Keys to Successful Collaboration	Graduates will be able to understand and apply the components of collaborative research.
Introduction to Medical Literature	Graduates will have advanced competencies in literature search, citation, report type, and sources.
Medical Research and Scientific Misconduct	Graduates will be able to interpret and apply legal principles to medical research in clinical and basic science domains.

Table 1: *Core competencies and goals for the Research Value Domain at VTCSOM.*

Because often the most cutting-edge research is disseminated not through written but rather oral means, the Research Value Domain Year 1 curriculum is designed to provide ample opportunity for students to become skilled attendees and participants at oral scientific presentations. Students have in-class presentations from faculty members describing on-going research opportunities (a weekly series referred to as "Research Live!") as well as a formal seminar series entitled the "Timothy A. Johnson, PhD Medical Scholar Seminar" series that integrates the Research and Basic Science Domains by bringing in highly accomplished scientist physicians who are conducting research on topics that the students are currently studying. For example, during Block I, students study a case of a young girl with cystic fibrosis, meeting three times during this week in their PBL groups (n=7) with a faculty facilitator to process the case, uncover the diagnosis and to develop and present basic and clinical science learning issues to each other. The introduction to this case as well as the case objectives are presented in Figure 2 (Appendix). At the end of the week, the small groups are brought together with the patient, family, and a physician to discuss the humanistic patient-centered aspects of the case. During the 2012-2013 school year, a physician investigator nationally known for research in the development of new treatments of cystic fibrosis was invited as a Medical Scholar to coincide with the cystic fibrosis case. Prior to the Medical Scholar's visit, students studied current research papers (titles presented in Table 2, Appendix) published by the visiting Medical Scholar in a program called Methods in Logic, where not only the research results but the logical foundations of the scientific approach were explored. A subset of students worked with faculty content experts to prepare a student-led discussion of these papers during a Research Domain classroom session. The experience concluded with a research seminar given by the Medical Scholar on the latest advances in understanding of the pathogenesis and treatment of cystic fibrosis. This process fully integrates basic science foundational knowledge, clinical application and reasoning, and research to bring enhanced understanding of a particular disease and to improve patient care. This is a unique combination that affords VTCSOM students the complete experience of modern medicine and unveils the sometimes hidden connection between research discovery, evidence-based practice, and quality patient care. VTCSOM currently has eight of these Medical Scholar seminars to be delivered this academic year (Table 2, Appendix).

The Medical Scholars seminars are open to the entire VTCSOM community, offering students a continued opportunity to hear talks on ground-breaking research throughout Years 2-4 and to interact with physicians and researchers who share similar interests. This constant exposure to the language of research is in keeping with the VTCSOM goal of fostering life-long learning in its graduates. Scientist physicians who are driven by inquiry, research, and discovery will, of necessity, refer constantly to newly published research and seek out presentations by active medical researchers in whatever setting they are practicing; the Research Domain curriculum aims to help instill these habits in our students from the beginning.

The fundamental principles and application of research are taught in Phase 1 using a variety of approaches that includes lectures, problems, panel discussions, online training courses, experiential learning activities, and research-related objectives in the previously described Patient Centered Learning cases. Because 4.5 hours per week are devoted to the Research Value Domain in Year 1, this program provides an in-depth foundation of research principles from an instructional and experiential perspective to first-year medical students regardless of their prior research background prior to coming to VTCSOM.

VTCSOM Student Research

The primary VTCSOM educational strategy for creating scientist physicians is the immersion of students in actual research. Each student is required to complete a scholarly project that is hypothesis-driven, provide a written document suitable for publication, and present their work to colleagues in an appropriate venue such as a national meeting. To help ensure that these requirements are achievable, students are exposed to faculty researchers from various disciplines during the Year 1 "Research Live" series mentioned above. These brief presentations introduce students to potential research mentors. Available research areas span a wide range of topics, including lab-based basic biomedical research, computational modeling, translational research, clinical research, and community and population-based research. Students select a mentor and a project by the end of Block III (March of Year 1). Block IV, although still classroom-based, begins to help transition the students into their chosen research group. Class activities and assignments focus on the student's individual research project. A research prospectus defining the student's research question and outlining the proposed approach is prepared in cooperation with the research mentor and a small committee of faculty advisors. This proposal is presented orally by the students to their classmates, and feedback is solicited and responded to. This process prepares each student to begin his or her research immediately. At the conclusion of Year 1, students' participation in the Research Value Domain becomes predominantly self-directed, beginning with a three-week summer course at the end of Block IV (May-June).

Students have 4.5 hours per week of dedicated time in Year 2 to continue their research in concert with the rest of the on-going VTCSOM curriculum. Students are guided in their project by a research mentor and two co-mentors (basic and/or clinical scientists) who provide regular feedback to the student on their progress and to the Director of Research Education at the end of every block. In order to successfully pass the Research Value Domain in Year 2, students must submit a mentor-signed research progress report for approval by the Director of Research Education. Representative selections from the list of current research projects (total =84) in which VTCSOM students are actively engaged is presented in Table 3 (Appendix). Beginning in late February during Block IX, students have 14 weeks dedicated to their project (no course work during this period) and to preparation for the USMLE Step 1 Exam.

Phase 2 (Years 3 and 4)

Blocks of time are subsequently designated for the student to be fully engaged in their research project in each year of the curriculum. In addition to these scheduled research times, students are expected to maintain an active research effort during intervening periods. This approach will prepare the student for the practice of evidence-based medicine where they will be required to integrate patient care with the discovery process on a daily basis. Interested students may also pursue a Masters, MPH or PhD after Year 2.

Phase 2 begins in July of a typical Year 3 medical school schedule which includes: 6-week rotations in internal medicine, surgery, family medicine, pediatrics, psychiatry, and OB/GYN, 2-week rotations in radiology and neurology and a 4-week research rotation. Students can choose to take additional elective research rotations during Years 3 and 4. Goals and objectives for all four domains are woven into each of the rotations. An example of how radiology has integrated research goals and objectives into the clerkship objectives is presented in Figure 3 (Appendix).

During Year 3, students are brought together two Friday afternoons per rotation to continue to integrate the four educational value domains (Basic Science, Clinical Science, Research, Interprofessionalism). The goal of these sessions ("Domain Days") is to provide reinforcement of the four VTCSOM domains through in-depth evaluation of concepts, cases, and/or technologies that arise in the student clerkship experiences. One purpose of Domain Days is to emphasize that both current and future medical care will be dependent not only on clinical knowledge and skills but on the continuing insights of research into basic principles, translated into a clinical context, and increasingly delivered through integrated, team-based practices. The planning and implementation of the content of these "Domain Days" sessions is rotated among the various clinical rotation departments.

During Year 4, students complete a series of 2-4-week required clinical experiences in emergency medicine, one medical subspecialty (2 weeks), and one surgical subspecialty (two weeks). In addition, a 2-week rotation in ICU/Critical Care and research is required. Students have one 4-week elective that is site-specific, and 16 weeks of additional elective time.

The culmination of the Research Value Domain is a publishable quality manuscript that may either stand alone or may be integrated into a larger body of ongoing work from the mentor's research program. During Year 4, students submit their manuscript for approval to their committee and make a formal oral presentation on their work. In addition, the student's work is submitted to an appropriate medical or scientific forum for presentation. The Research Value Domain activities during Year 4 thus provide students the opportunity to demonstrate their successful mastery of both the language and practice of research as future scientist physicians. A medical student research poster session will provide a venue for the VTCSOM community to learn about the accomplishments of their colleagues.

Desired Impact

The intensive research curriculum at VTCSOM was designed with the expectation of achieving several outcomes: 1) producing a substantial cohort (50% of class) of practicing community physicians who are willing and able to collaborate successfully with academic medicine physicians on research projects that require access to patients, samples, and outcome data from community populations; 2) producing a small but significant cohort (10% of class) of practicing physicians who are actively involved as principal and/or co-principal investigators in translational medical research; 3) producing a substantial cohort (40% of class) of practicing physicians who, while not necessarily actively engaged in research or in the provision of research data or samples themselves, actively incorporate contemporary medical findings into their practice. This will inform their delivery of evidence-based medicine and allow them to serve as effective advocates for their patients. It is critical that the impact of this four-year research emphasis on VTCSOM graduates be measured over the course of the next several years.

Understanding the importance of the science of medicine is a fundamental principle for delivering quality healthcare to patients. The curriculum at VTCSOM with the four integrated value domains of basic science, clinical science, research, and interprofessionalism links the science of medicine to the practice of medicine from the very beginning of medical school. VTCSOM is providing an innovative in-depth immersion experience in research in four years of medical school that typically would require an additional year, additional tuition, and additional student debt. Medical students are given the opportunity to observe research applied to patient cases, and this experience crystallizes for them the connection between what is known about a given disease and more importantly what may be yet to be discovered. Medical students are required to participate in the generation of new medical knowledge with all of the challenges and rewards that only participation at every level of a project can produce. The Research Value Domain equips students with the knowledge, skills, and attitudes to ask important questions, generate new medical knowledge, and to find solutions to improve the quality of healthcare delivery in their practices and in healthcare systems in the future.

Key Words
Scientist physician, medical student research

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APPENDIX

Figure 1: *Curriculum themes and subthemes for the blocks in years 1 and 2 at the Virginia Tech Carilion School of Medicine*

Year One Block Schedule

Block I August - October (8weeks)	Block II October - December (8weeks)
Functional Biology of Cells and Tissues Molecules, Genes, Chromosomes, Proteins, Cells, Tissues, Metabolism, Transcription, Translation, Early Development, Musculoskeletal, Pharmacodynamics, Pharmacokinetics	**Human Body I** Immunology, Cardiovascular, Respiratory, Autonomic Nervous System
Interviewing and Physical Exam I Patient Centered Interviewing Introduction to the Physical Exam (The Musculoskeletal Exam), and Musculoskeletal Ultrasound)	**Interviewing and Physical Exam II** Patient and Doctor-Centered Interviewing Physical Exam (History of Present Medical Illness, Past, Medical, Family, Medications & Habits), Vital Signs, Heart and Lungs, BMI, Heart & Lungs, Vascular Ultrasound, LACE
Fundamentals and Foundations of Research The Scientific Method, Thinking like a Scientist Physician, Basic Clinical and Translational Research Principles, the Protection of Human Subjects in Research, the Use and Protection of Animals in Research "Research Live", and the Medical Scholars Series	**Biostatistics** "Research Live" and the Medical Scholars Series continued
Interprofessional Teamwork and Roles for Collaborative Practice Healthcare Roles and Responsibilities, Introduction to Team Building, Interprofessional Collaboration, Interprofessional Teams from an Individual Perspective	**Interpersonal and Interprofessional Communication** Team Dysfuntion, Challenges and Issues in Team Dynamics (Conflict Resolution, Accountability, Feedback, etc); Begin Planning for Service Learning Project

Figure 1 (Continued)

Block III January - March (8 weeks)	Block IV March - May (8 weeks)
Human Body II GI Tract, Liver & Biliary, Renal, Endocrine, Reproduction	**Biology of the Nervous** System Central Nervous System, Peripheral Nervous System, Special Sensory Structures
Interviewing and Physical Exam III Patient and Doctor-Centered Interviewing (Personal & Social Hx), , Abdominal Exam, Male and Female Genitourinay Exams, Breast Exam, Cultural Considerations, Abdominal Ultrasound, LACE	**Interviewing and Physcial Exam IV** Patient and Doctor- Centered Interviewing (Review of Systems), Neurological Exam, Pediatric Development, HEENT, Dental Exam, Mental Status Exam, Normal Aging Process, LACE
Epidemiology "Research Live" and the Medical Scholars Series continued. Research Mentor and project selection completed by the end of the block.	**Research Outcomes** Research Prospectus preparation and presentation, Medical Scholars Series continued
Collaborative Leadership in the Healthcare Environment Quality of Healthcare and Patient Safety, Application of Leadership Practices that Support Collaborative Team Effectiveness; Planning Community Service Learning Project	**Community Service Learning Project** Practicum for Demonstrating Teamwork skills

Figure 2: *Cystic Fibrosis Case Introduction and Objectives*

Helen "Lilly" Hull is on your schedule today as a hospital follow-up. She is a one month old who was born at 38 weeks gestation and had intestinal obstruction due to meconium ileus. She was treated with daily hypertonic enemas, which resolved her obstruction, and was sent home breastfeeding and doing well. Her appointment today was set up to make sure she continued to do well and to review some laboratory testing that was pending at the time of discharge.

Case Objectives

1. Review the normal anatomy of respiratory passageways, both conducting and respiratory, from the nose to terminal bronchioles.
2. Review the formation and composition of mucus. Discuss the molecular structure of cilia, and their function in clearing mucus from the respiratory tract. In light of this information, explain why Lilly is susceptible to lung infections?
3. Review the normal location and functioning of CFTR in the cellular membrane, correlating CFTR structure with function. Briefly discuss the family of "ABC transporters" of which CFTR is a member.
4. Describe the post-translational events for CFTR, from the time it is made on the ribosome to when it is incorporated into the membrane. There is evidence that the most common CF mutation, the delta 508 mutation, activates the endoplasmic reticulum associated degradation (ERAD) and unfolded protein response (UPR) pathways. What are these?
5. Review and contrast the functions of CFTR in lung, pancreas, and digestive tract. Describe how mutations in the CFTR gene lead to problems with breathing, growth, digestion, and reproduction.
6. Discuss which parts of the diet are most affected by CF and why? (fat, protein, carbohydrates, vitamins).
7. Review several of the more common mutations in the CFTR gene including a description of how each mutation affects the ability of CFTR protein to function. (Note: The delta 508 mutation is a good place to start).

Adapted with permission form the University of North Dakota School of Medicine & Health Sciences

***Figure 3**: An example of how clerkships integrate research objectives into their goals and objectives at Virginia Tech Carilion School of Medicine.*

VTCSOM GOALS - COMPETENCIES	OBJECTIVES	THIRD YEAR REQUIRED ACTIVELY COORDINATED CLINICAL EXPERIENCE **GOALS AND OBJECTIVES** **RADIOLOGY**	VTCSOM COMPETENCIES Patient Care	Medical Knowledge	Communication/ Interpersonal	Professionalism	Practice Based Learning	System based Practice	METHOD OF DELIVERY L =Lecture, S =Seminar, SI =Simulation, ST = Standardized Patient, IP = Inpatient, OP = Outpatient, HP = History and Physical, CM = Computer Module, SS = Self Study,	METHOD OF ASSESSMENT OSCE = Objective Structured Clinical Examination, HP = History and Physical, PG = Progress Notes, SS = Self Study, CS = Computer Module, DO = Direct Observation, LO = Log, SH = Shelf Exam, 360 = Evaluation from peers, staff, patients, RE = Resident Evaluate
		RESEARCH								
		By the end of the clerkship students will be able to:								
III.II	3	Differentiate and give examples of the following as they relate to imaging procedures and research		X					L, IP, OP, SS	AE, SS
		a. True positive								
		b. False positive								
		c. True negative								
		d. False negative								
		e. Positive predictive value								
		f. Negative predictive value								
		g. Sensitivity								
		h. Specificity								

Table 2: *Medical Scholar Series Topics at the Virginia Tech Carilion School of Medicine (2012-13)*

BLOCK	RELATED CASES	METHODS IN LOGIC PAPERS	SEMINAR TITLE
I	Cystic Fibrosis	Rowe et al 2010, "DF508 CFTR processing correction and activity in polarized airway and non-airway cell monolayers." *Pulm Pharmacol Ther*. 23:268-278. Ramsey et al 2012, "Future directions in early cystic fibrosis lung disease research: an NHLBI workshop report." Am J Respir Crit Care Med. 185: 887-892.	Progress in Cystic Fibrosis Translational Research
	Down Syndrome Angelman Syndrome Hunter Syndrome	Hilaire et al 2011, "NT5E mutations and arterial calcifications." New Eng J Med. 364:432-42. Gahl et al 2012, "The National Institutes of Health Undiagnosed Diseases Program: insights into rare diseases." Gen in Med. 14:51-59.	Rare Disease Discovery in the National Institutes of Health Undiagnosed Diseases Program
II	Trisomy 18 Myocardial Infarction Cardiogenic Shock	Kang et al 2010, "Purkinje cells from RyR2 mutant mice are highly arrhythmogenic but responsive to targeted therapy." Circ Res. 107:512-519. Rentschler et al 2001, "Visualization and functional characterization of the developing murine cardiac conduction system." Develop. 128: 1785-1792.	The Cardiac Conduction System: From Development to Disease
	Muscular Dystrophy	Kwon et al 2011, "Increasing expression and decreasing degradation of SMN ameliorate the spinal muscular atrophy phenotype in mice." Hum Mol Gen. 20:3667-3677. Fernandez et al 2011, "Efficacy and safety of dutasteride in patients with spinal and bulbar muscular atrophy: a randomised placebo-controlled trial." Lancet Neurol. 10:140-147.	Developing Treatment for Hereditary Neuromuscular Diseases

III	Nephrotic Syndrome Diabetic Nephropathy	Zhang et al 2011, "Pharmacological inhibition of myostatin suppresses systemic inflammation and muscle atrophy in mice with chronic kidney disease." FASEB. 25:1653-1663. Mitch 1984, "The influence of the diet on the progression of renal insufficiency." Ann Rev Med. 35:249-64.	Muscle Protein Metabolism in Chronic Kidney Disease
	Polycystic Ovarian Syndrome	Tasali et al 2011, "Treatment of obstructive sleep apnea improves cardiometabolic function in young obese women with polycystic ovary syndrome." J Clin Endocrinol Metab. 96:365-374.	Polycystic Ovarian Syndrome
IV	Alzheimer's Disease	TBD	The Changing Medical View of Memory Disorders and Alzheimer's Disease

Table 3: *Representative research projects (total n=84) being performed by VTCSOM medical students (2010-2013)*

Basic lab-based research

1. Glutamate uncaging in temporally precise patterns for long term plasticity modulation.
2. Prevalence of inter-genogroup gene reassortment among human rotaviruses
3. Co-electrospun scaffold with gradients in fiber alignment and chemistry for the regeneration of ligament-bone transitions.
4. Molecular Mechanisms Behind Low Dose LPS Exposure
5. The role of RahU protein in pathogenesis of Pseudomonas aeruginosa in murine lung infection model

Computational modeling

6. Identification of the genetic basis of novel diseases using exome sequencing
7. Novel MD simulations to demonstrate the movement of anesthetics across the blood-brain barrier
8. Microsatellite variations unique to malignant melanoma

Translational research

9. Investigation of airway location as a risk factor for endobronchial fire with the use of neodymium-doped yttrium aluminum garnet laser photoresection in a swine model
10. Using Wireless Accelerometers to Quantify Infant General Movements
11. The Use of Joint Independent-Component Analysis for Multimodal Imaging Analysis in Patients with Mild TBI
12. Efficacy of perfusion in ex vivo preservation of cardiac tissue

Clinical research

13. A Randomized Controlled Trial of a Wait-and-See Approach to Reduce Antibiotic use in Emergency Department Abscess Treatment
14. Total Knee Arthroplasty after Bariatric Surgery: A Case Series
15. Introduction of the RAM cannula into the neonatal ICU: Effect on rate of chronic lung disease
16. The effects of sedation on the sensitivity of transbronchial needle aspiration flexible bronchoscopy
17. Clinical Outcomes in Elderly Patients Suffering from Acute Subdural Hematoma on Pre-Injury Antithrombotic Therapy

Community and population-based research

18. The effect of obesity on ED physician CT scan utilization rates
19. Schwartz Center Rounds: Creating a forum for resolving moral distress
20. Compliance with Caesarean section indications and guidelines in a rural hospital in Ghana
21. Neonatal abstinence syndrome incidence and treatment at Carilion Clinic Children's Hospital
22. Cost-effectiveness analysis of testing for latent TB against traditional screening protocols