Establishing a clinical pharmacology fellowship program for physicians, pharmacists, and pharmacologists: a newly accredited interdisciplinary training program at the Ohio State University

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Abstract: Studying the effect of drugs on humans, clinical pharmacologists play an essential role in many academic medical and research teams, within the pharmaceutical industry and as members of government regulatory entities. Clinical pharmacology fellowship training programs should be multidisciplinary and adaptable, and should combine didactics, applied learning, independent study, and one-on-one instruction. This article describes a recently developed 2 year clinical pharmacology fellowship program – one of only nine accredited by the American Board of Clinical Pharmacology – that is an integrative, multi faceted, adaptable method for training physicians, pharmacists, and scientists for leadership roles in the pharmaceutical industry, in academia, or with regulatory or accreditation agencies. The purpose of this article is to provide information for academic clinicians and researchers interested in designing a similar program, for professionals in the field of clinical pharmacology who are already affiliated with a fellowship program and may benefit from supplemental information, and for clinical researchers interested in clinical pharmacology who may not be aware that such training opportunities exist. This article provides the details of a recently accredited program, including design, implementation, accreditation, trainee success, and future directions.

Keywords: clinical pharmacology education, clinical pharmacology fellowship

Introduction

The American College of Clinical Pharmacology defines clinical pharmacology as the promotion of the rational use of medications in humans, innovative research, development and regulation of medications, and the education of health care professionals and patients on the optimal utilization of medications.1 Established in 1991, the American Board of Clinical Pharmacology (ABCP) promotes the discipline of clinical pharmacology, accredits clinical pharmacology training programs, and certifies individual clinical pharmacologists.2–4 The ABCP awards certification in either Clinical Pharmacology (MD or DO candidates) or Applied Pharmacology (PhD or PharmD candidates) to individuals who have successfully completed rigorous postdoctoral training, and who have met requirements for experience in the field, and who have passed the ABCP examination in clinical pharmacology. Their official website, http://www.abcp.net, details the specific requirements for board eligibility and lists the primary areas of emphasis for the board examinations.5 The ABCP also registers and accredits clinical pharmacology training programs6 (currently accredited programs are listed in Table 1).
Table I  Clinical pharmacology fellowship training programs with ABCP-accreditation

<table>
<thead>
<tr>
<th>Program, location</th>
<th>Year accreditation granted by ABCP</th>
<th>Website, program highlights</th>
</tr>
</thead>
</table>
| Baylor College of Medicine Houston, TX, USA | 2003 | https://www.bcm.edu/departments/medicine/sections-divisions-centers/hypertension-and-clinical-pharmacology/education/hypertension-and-clinical-pharmacology  
• Research program focuses on regulation of vascular function in health and disease  
• Clinical rotations include Clinical Pharmacology Research and Diagnostic Clinic, Hypertension and Clinical Pharmacology Consultation Service, and Clinical Pharmacokinetics Core Laboratory at Baylor College of Medicine or Texas Children’s Hospital  
• Trainees, in conjunction with the faculty in one of several departments or internal medicine divisions within the College, determines an area of interest |
• The only pediatric clinical pharmacology program accredited by the ABCP in the US  
• Opportunity to conduct research alongside pediatric subspecialist physicians and biomedical scientists committed to the evaluation of pediatric pharmacotherapies  
• New (2012) pediatric clinical research unit with state-of-the-art facilities for research and clinical trials |
| Dartmouth-Hitchcock Medical Center Lebanon, NH, USA | 2006 | No external website, contact Lionel.Lewis@Dartmouth.edu  
• Extensive training in oncology drug development  
• Research strengths in pharmacokinetic and bioanalytic methodology  
• Opportunity to participate on Clinical Pharmacology and Toxicology consult services http://medicine.upui.edu/clinpharm/fellowship  
• Pediatric, obstetric, and general clinical pharmacology specializations  
• Research strengths in personalized medicine and pharmacogenetics for cancer, HIV, and cardiovascular disease  
• Seven NIH-funded fellowship positions |
| Indiana University, School of Medicine Indianapolis, IN, USA | 2003 | http://medicine.iupui.edu/clinpharm/fellowship  
• Core curriculum includes courses in Pharmacogenomics, Personalized Medicine, and Clinical Pharmacokinetics  
• Emphasis is placed on conducting research in special populations, including women, children, geriatrics, and members of ethnic minorities  
• Salary support provided through the National Institute of General Medical Sciences (NIGMS) T32 Clinical Pharmacology Postdoctoral Training Program grant  
• Clinical research curriculum available as an auditing-only track, a year certificate program in clinical research, or a Master of Science (MS) degree in Clinical Research http://cppbbsd.uchicago.edu  
• Clinical and basic research projects in pharmacogenomics, drug development, clinical pharmacology, genetics of drug abuse, and clinical trial design  
• Core curriculum includes courses in Pharmacogenomics, Personalized Medicine, Advanced Clinical Pharmacology, and Patient-Oriented Research  
• Experience serving on the University’s Biological Sciences Division Institutional Review Board, Pharmacy and Therapeutics Committee, and Clinical Pharmacology Consultation Service  
• Three training tracks: Clinical Therapeutics, Clinical Therapeutics in Oncology, and Clinical Therapeutics in Industry |
| The Ohio State University, College of Medicine Columbus, OH, USA | 2009 | http://www.medicine.osu.edu/pharmacology/graduate-programs/pages/fellowship-programs.aspx  
• Associated with the Center of Pharmacogenomics, OSU College of Medicine  
• Instruction, clinical experience, and research are tailored to trainee’s experience and interests  
• Master’s degree in Pharmacology incorporated into fellowship http://www.jefferson.edu/jmc/departments/pharmacology/education/fellowship.html  
• Opportunity to concentrate in adult or pediatric clinical pharmacology http://wrair-www.army.mil/OtherServices_ClinicalPharmacology.aspx  
• Available to US Army active-duty PhDs/PharmDs and US Army physicians who are board eligible/certified in a primary specialty; civilians can be considered but must join the US Army and successfully compete for their fellowship position  
• Conduct laboratory, animal, and clinical research under the supervision of a mentor  
• 3 month rotation at the FDA http://icptp.k30.ucla.edu  
• Broad, interdisciplinary, program focused on clinical pharmacology and experimental therapeutics  
• Salary support provided through the National Institute of General Medical Sciences (NIGMS) T32 Clinical Pharmacology Postdoctoral Training Program grant  
• Emphasis is placed on conducting research in special populations, including women, children, geriatrics, and members of ethnic minorities  
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• Three training tracks: Clinical Therapeutics, Clinical Therapeutics in Oncology, and Clinical Therapeutics in Industry |
| Thomas Jefferson Medical College, Department of Pharmacology and Experimental Therapeutics Philadelphia, PA, USA | 2006 | http://www.jefferson.edu/jmc/departments/pharmacology/education/fellowship.html  
• Training within a dedicated academic phase 1 unit  
• Training experience with a pharmaceutical company, with the editorial board of the Annals of Internal Medicine journal, and with the US Food and Drug Administration  
• Opportunity to concentrate in adult or pediatric clinical pharmacology http://wrair-www.army.mil/OtherServices_ClinicalPharmacology.aspx  
• Available to US Army active-duty PhDs/PharmDs and US Army physicians who are board eligible/certified in a primary specialty; civilians can be considered but must join the US Army and successfully compete for their fellowship position  
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• Three training tracks: Clinical Therapeutics, Clinical Therapeutics in Oncology, and Clinical Therapeutics in Industry |
| Uniformed Services University of the Health Sciences and Walter Reed Army Institute of Research School of Medicine Silver Spring, MD, USA | 2004 | Available to US Army active-duty PhDs/PharmDs and US Army physicians who are board eligible/certified in a primary specialty; civilians can be considered but must join the US Army and successfully compete for their fellowship position  
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• Three training tracks: Clinical Therapeutics, Clinical Therapeutics in Oncology, and Clinical Therapeutics in Industry |
| University of California at Los Angeles David Geffen School of Medicine Los Angeles, CA, USA | 2005 | http://icptp.k30.ucla.edu  
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• Three training tracks: Clinical Therapeutics, Clinical Therapeutics in Oncology, and Clinical Therapeutics in Industry |
| University of Chicago, Division of Biological Sciences Chicago, IL, USA | 2002 | http://cppbbsd.uchicago.edu  
• Clinical and basic research projects in pharmacogenomics, drug development, clinical pharmacology, genetics of drug abuse, and clinical trial design  
• Core curriculum includes courses in Pharmacogenomics, Personalized Medicine, Advanced Clinical Pharmacology, and Patient-Oriented Research  
• Experience serving on the University’s Biological Sciences Division Institutional Review Board, Pharmacy and Therapeutics Committee, and Clinical Pharmacology Consultation Service  
• Three training tracks: Clinical Therapeutics, Clinical Therapeutics in Oncology, and Clinical Therapeutics in Industry |

Abbreviations: ABCP, American Board of Clinical Pharmacology; FDA, US Food and Drug Administration; HIV, human immunodeficiency virus; NIH, National Institutes of Health; OSU, the Ohio State University.
Fellowship programs in clinical pharmacology should offer a multidisciplinary training experience combining didactics, applied learning, independent study, and one-on-one instruction in pharmaceutical science, personalized medicine, general pharmacology, drug development, toxicology, pharmacogenomics, special-populations (including women, children, geriatrics, and members of ethnic minorities) pharmacology, and clinical trial design and regulation. Designed to meet those requirements, the 2 year clinical pharmacology fellowship program at the Ohio State University (OSU) provides an example of a successful, recently established, accredited training program for physicians, pharmacists, pharmacologists, and those with doctoral degrees in other pharmacology-related disciplines. Variety exists among clinical pharmacology fellowship training programs. The program at OSU, however, effectively illustrates the general training components of a 2 year ABCP-accredited clinical pharmacology fellowship program. It provides an adaptable framework for shaping an entirely new program or for enhancing an existing program. Likewise, the program description may be of particular interest to individuals interested in clinical pharmacology and to those considering fellowship training in clinical pharmacology.

**Fellowship training year 1**

The first year of fellowship training at OSU is composed mostly of didactic learning; fellows are required to obtain a Master of Science (MS) degree in Pharmacology. Courses are taught by faculty members from the Colleges of Medicine, Pharmacy, and Public Health. The required courses in biostatistics, pharmacokinetics, general pharmacology, ethics, and clinical-trial science are described in Table 2. First year fellows are also required to complete additional assessments, certifications, online tutorials, and training in early-phase clinical trials. These additional learning components, listed in Table 3, complement the formal course work and provide comprehensive training in clinical pharmacology.

Trainees also participate in the National Institutes of Health (NIH)’s online teleconference course, Principles

<table>
<thead>
<tr>
<th>Course Description</th>
<th>Credit Hours</th>
<th>Course Description</th>
<th>Text</th>
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</thead>
<tbody>
<tr>
<td>Pharmacology 5600, Introduction to General Pharmacology</td>
<td>3</td>
<td>Online instruction; organ systems approach; focuses on drug mechanisms of action</td>
<td>Lippincott’s Illustrated Reviews: Pharmacology, R Harvey (Lippincott Williams &amp; Wilkins), required</td>
</tr>
<tr>
<td>Pharmacology 7250, Pharmacogenomics</td>
<td>2</td>
<td>Discussion- and presentation-based; focuses on basic-science approaches for biomarker development and clinical implications</td>
<td>Principles and Practice of Clinical Research by J Galin and F Ognibene (Academic Press), required</td>
</tr>
<tr>
<td>Pharmacology 8250, Clinical Trials I</td>
<td>7</td>
<td>Lecture and discussion based; focuses on clinical trial design and federal regulations</td>
<td></td>
</tr>
<tr>
<td>Pharmacology 8260, Clinical Trials II</td>
<td>7</td>
<td>Lecture and hands-on-experience based; focuses on clinical trial document preparation and implementation strategies</td>
<td></td>
</tr>
<tr>
<td>Pharmacology 7510, Professional and Ethical Issues in Biomedical Sciences</td>
<td>2</td>
<td>Lecture and discussion based; focuses on developing and evaluating professional behaviors in biomedical science</td>
<td></td>
</tr>
<tr>
<td>Pharmacy 6220, Drug Delivery II</td>
<td>3</td>
<td>Lecture-based; focuses on pharmaceutical dosage forms, ionization, solubility, and stability</td>
<td></td>
</tr>
<tr>
<td>Pharmacy 7310, Clinical Pharmacokinetics I</td>
<td>3</td>
<td>Lecture-based; focuses on modeling absorption, distribution, metabolism, and elimination of pharmacokinetics and on inter- and intra-patient variability in pharmacokinetics</td>
<td>Clinical Pharmacokinetics and Pharmacodynamics: Concepts and Applications by M Rowland and T Tozer (Lippincott Williams &amp; Wilkins) and Applied Biopharmaceutics and Pharmacokinetics by L Shargel, A Yu, and B Wu-Pong (McGraw-Hill Medical), recommended</td>
</tr>
<tr>
<td>Pharmacy 7320, Clinical Pharmacokinetics II</td>
<td>3</td>
<td>Lecture-based; focuses on the pharmacokinetic–pharmacodynamic relationship of pharmaceutics</td>
<td></td>
</tr>
<tr>
<td>Public Health: Biostatistics 6210, Design and Analysis of Studies in the Health Sciences I</td>
<td>3</td>
<td>Lecture-based; focuses on basic data-summary methods, estimation, and hypothesis testing</td>
<td>Fundamentals of Biostatistics by B Rosner (Cengage Learning), recommended</td>
</tr>
<tr>
<td>Public Health: Biostatistics 6211, Design and Analysis of Studies in the Health Sciences II</td>
<td>3</td>
<td>Lecture-based; focuses on analysis of variance methods and computer-based statistical methodology</td>
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**Notes:** A minimum of 30 credit hours is required for the Master’s degree; *pharmacology 7510 is not required for the Master’s degree but is a requirement of the fellowship program; *students are required to select one of these courses. **Abbreviation:** OSU, the Ohio State University.
Table 3  Additional training requirements of first year fellows in the OSU Clinical Pharmacology Fellowship

<table>
<thead>
<tr>
<th>Requirement</th>
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<tbody>
<tr>
<td>American Heart Association Basic Life Support (BLS) certification; case simulation and written examination</td>
</tr>
<tr>
<td>American Heart Association Advanced Cardiac Life Support (ACLS) certification; case simulation and written examination</td>
</tr>
<tr>
<td>American Heart Association Pediatric Advanced Life Support (PALS) certification; case simulation and written examination</td>
</tr>
<tr>
<td>Standard Operating Procedures (SOP) for Clinical Trial Implementation; written examination</td>
</tr>
<tr>
<td>Good Clinical Practice (GCP); written examination</td>
</tr>
<tr>
<td>Collaborative Institutional Training Initiative (CITI) course in the protection of human subjects; computer-based examination</td>
</tr>
<tr>
<td>Good Laboratory Practice (GLP); written examination</td>
</tr>
<tr>
<td>Code of Federal Regulations (CFR); written examination</td>
</tr>
<tr>
<td>Environmental Health and Safety Certificate of Completion for Blood-Borne Pathogens; written examination</td>
</tr>
<tr>
<td>Health Insurance Portability and Accountability Act (HIPPA) training; computer-based examination</td>
</tr>
<tr>
<td>Environmental Health and Safety Certificate of Completion for Lab Standards – 29 CFR; written examination</td>
</tr>
</tbody>
</table>

Note: *Required of physicians only.

Abbreviation: OSU, the Ohio State University.

of Clinical Pharmacology. Covering the fundamentals of clinical pharmacology as a translational scientific discipline focused on rational drug development and utilization in therapeutics, the course comprises a series of approximately 30 weekly lectures, complementing the primary text by Atkinson and reinforcing the participant’s basis of knowledge for successful completion of a training program in Clinical Pharmacology and potential ABCP certification. Courses are taught by faculty members from the NIH, the US Food and Drug Administration, the pharmaceutical industry, and several academic institutions from across the US.

Fellowship training year 2

The second year of fellowship training involves mostly hands-on learning. Fellows assist in the design, implementation, and direction of a variety of early- and late-phase pharmaceutical trials at OSU’s Comprehensive Cancer Center, pediatric clinical trials at OSU-affiliated Nationwide Children’s Hospital, and lifestyle- and nutritional-intervention clinical trials at OSU’s NIH-sponsored Center for Clinical and Translational Science Research Center. Clinical-experience objectives to be completed during the fellowship are listed in Table 4. Fellows broaden their basis of knowledge in pharmacology while gaining teaching experience as they assist in the instruction of graduate courses in clinical-trial science (Pharmacology 8250 and 8260) and give lectures and workshops to OSU medical students. Learning experiences in pharmacoanalytic methodology and pediatric pharmacology include didactic and independent instruction as well as clinical learning, and these complete the required training of the final year of the fellowship.

Pediatric clinical pharmacology rotation

This 1 month full-time rotation, led by the pediatrics residency director, incorporates didactic lectures, core reading, and clinical experience at Nationwide Children’s Hospital.

Table 4  Clinical-experience objectives for the Clinical Pharmacology Fellowship at OSU

<table>
<thead>
<tr>
<th>Objective</th>
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<tr>
<td>Witness and conduct dosing of investigational pharmaceuticals</td>
</tr>
<tr>
<td>Support the design and submission of clinical study protocols for review by the Institutional Review Board</td>
</tr>
<tr>
<td>Obtain medical and medication histories from adult and pediatric subjects and patients</td>
</tr>
<tr>
<td>Perform physical examinations for determining participant eligibility</td>
</tr>
<tr>
<td>Interpret electrocardiograms and real-time cardiac telemetry</td>
</tr>
<tr>
<td>Obtain informed consent (adults) and assent (children and adolescents) from potential clinical-trial participants</td>
</tr>
<tr>
<td>Supervise research staff in the implementation of clinical-trial activities</td>
</tr>
<tr>
<td>Collect, process, and store biological samples</td>
</tr>
<tr>
<td>Assess, document, and treat adverse events; assist with assigning causality of adverse events</td>
</tr>
<tr>
<td>Collect and document data as well as assist with data query resolution</td>
</tr>
<tr>
<td>Perform quality assurance checks of source documents and case report forms</td>
</tr>
<tr>
<td>Design and implement strategies to recruit patients</td>
</tr>
<tr>
<td>Interact and develop professional relationships with representatives from pharmaceutical companies and regulatory agencies</td>
</tr>
<tr>
<td>Perform drug preparation, dispensing, and accountability</td>
</tr>
<tr>
<td>Supervise and implement laboratory analysis of biological samples</td>
</tr>
<tr>
<td>Perform analysis and modeling of pharmacokinetic and pharmacodynamic data</td>
</tr>
<tr>
<td>Evaluate standardized study-specific meals ensuring specific caloric and nutritional requirements</td>
</tr>
</tbody>
</table>

Note: *Restricted to licensed physicians.

Abbreviation: OSU, the Ohio State University.
in Columbus, Ohio. Didactic lectures and core reading assignments focus on the following topics: history of pediatric regulations and legislation; assent and consent in pediatric trials; management of adverse events in pediatric trials; balancing risks and benefits in pediatric trials; current trends in pediatric therapeutics, vaccines, and counterterrorism measures; benchmarks in pediatric drug development; physiologic and enzymatic differences between pediatric and adult populations; regulatory differences between pediatric and adult clinical trials; scientific issues relating to the pediatric population, including pharmacokinetics, extrapolation, bridging, safety studies, endpoint analysis and validation; and child growth and developmental issues related to clinical trials. Additional topics addressed during this rotation include pediatric-specific concerns regarding informed consent, protocol requirements, recruitment strategies, scheduling, advertising, coercion, special accommodations, and payment procedures. Clinical experiences during the pediatric rotation focus on current laboratory techniques for pediatric clinical trials, and direct interactions with pediatric patients and their families.

Pharmacoanalytical methodology rotation

This 6 month part-time rotation is supervised by the technical director of the OSU Pharmacoanalytical Shared Resource (PhASR) laboratory. The PhASR laboratory provides investigators with pharmacoanalytical and bioanalytical services for preclinical and clinical drug development, and PhASR laboratory activities in experimental design and data analysis primarily support clinical research in the Experimental Therapeutics program at OSU’s Comprehensive Cancer Center. During this rotation, fellows receive training and gain hands-on experience in the design and analysis of clinical pharmacokinetic and pharmacodynamic correlative studies. They become directly involved in various phases of multiple clinical trials in order to gain experience in the following areas: pharmacokinetic study design, drug disposition, pharmacodynamic study design, bioanalytical assay development and validation, supply of drug and metabolite standard materials, individual and population pharmacokinetic–pharmacodynamic modeling, and comparison of preclinical real-time and post-trial data.

During the second year, fellows also attend monthly Pharmacology and Therapeutics Committee meetings at OSU’s College of Pharmacy, weekly Oncology Phase Clinical Trial meetings at OSU’s Comprehensive Cancer Center, and weekly Internal Medicine Grand Rounds lectures at the OSU medical center. Fellows also participate in clinical pharmacology and pharmacy consultations pertaining to drug-dosage adjustments in organ dysfunction and drug–drug interactions. Table 5 provides a list of additional expectations during the Clinical Pharmacology Fellowship.

The final component of the Clinical Pharmacology Fellowship is one-on-one instruction focusing on board-preparation for the ABCP certification examination. Major areas which are reviewed include biostatistics, pharmacokinetics, pharmacodynamics, pharmacogenomics, adverse drug reactions, drug interactions, toxicology, therapeutic drug monitoring, clinical trial design and regulation, drug metabolism and receptors, bioanalytical assays, and therapeutics in pediatric and geriatric populations. Goodman & Gilman’s The Pharmacological Basis of Therapeutics is the primary reference text for both the fellowship training program and board examination preparation.

<table>
<thead>
<tr>
<th>Table 5 Additional expectations during the clinical pharmacology fellowship</th>
</tr>
</thead>
<tbody>
<tr>
<td>Write commentaries, abstracts, or manuscripts suitable for publication in peer-reviewed journals</td>
</tr>
<tr>
<td>Write investigator-initiated protocols and study-related documents</td>
</tr>
<tr>
<td>Write original grant proposals suitable for submission to the National Institutes of Health or private foundations</td>
</tr>
<tr>
<td>Attend Institutional Review Board meetings (for both Biomedical Sciences and Behavioral Sciences)</td>
</tr>
<tr>
<td>Attend an Institutional Health Insurance Portability and Accountability Act privacy board meeting</td>
</tr>
<tr>
<td>Participate in monthly journal clubs, presenting and critiquing research relevant to clinical pharmacology</td>
</tr>
<tr>
<td>Establish an interactive multidisciplinary network of research and professional collaborators</td>
</tr>
<tr>
<td>Explore potential career pathways in academia, the pharmaceutical industry, clinical research organizations, and regulatory agencies</td>
</tr>
</tbody>
</table>

Conclusion

The fellowship program at OSU exemplifies a multidisciplinary learning experience that prepares clinical pharmacologists for careers in academic medicine, the pharmaceutical industry, or with regulatory or accreditation agencies. Graduates should be board eligible in Applied Pharmacology (PharmDs and PhDs) or Clinical Pharmacology (MDs and DOs) with the ABCP. In addition, physician graduates should be eligible to become Certified Physician Investigators with the Association of Clinical Research Professionals.
The OSU Clinical Pharmacology Fellowship program is continually exploring additional collaborations to provide further experience-based learning opportunities for fellowship trainees. Optional rotations are being considered in nonclinical research at the OSU College of Veterinary Medicine, basic-science research at the OSU Center for Pharmacogenomics, regulatory training by the US Food and Drug Administration, and industry training/partnership with pharmaceutical companies.

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Disclosure
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