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EDITORIAL

Moving Medical Education into the 21st Century: Commentary on A Worldwide Challenge†

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The vast body of scientific knowledge accumulated during the final decades of the 20th century has begun to revolutionize the practice of medicine. Transformative discoveries in genetics, molecular cell biology, immunology, and epidemiology, along with advancements in biotechnologies/bioengineering and informatics, are shifting the focus of disease studies from clinical observations and indirect laboratory analyses to real-time imaging of organ functions and direct analyses of tissue or liquid biomarkers [1-3]. Rapid dissemination of research findings via internet-based search tools is accelerating the implementation of both diagnostic and therapeutic innovations in disease management. Congruently, the 21st century information explosion has increased the complexity of preparation for a medical career, and is driving academic efforts worldwide to modernize student instruction [4-7]. The American Medical Association and other private institutions have encouraged 'curriculum reforms', and post-graduate licensure requirements for continuing medical education or maintenance of specialty certification have become more rigorous [8].

A prevalent approach to improvement of medical education involves shifting the traditional order of basic science classes followed by clinical apprenticeship into a more 'vertical integration' of curriculum content [9, 10]. Thus, studies of physical diagnosis, surgery, or diagnostic imagery are closely tied to the foundational subjects of anatomy/cell biology, biochemistry, genetics, microbiology/immunology, pharmacology and pathologic anatomy/pathophysiology. In this context, the teaching of disease processes and associated diagnostic skills remain the core elements; nevertheless, the allocation of instructional time and learning objectives must be judiciously prioritized to encompass the increasingly intricate and multilevel comprehension of pathogenic mechanisms. Furthermore, these mechanisms need to be explained with a sharpened focus on clinical relevance.

In this commentary we share several guidelines for reinforcing the pathology foundation of medical education: (a) coherent exposition of disease topics in a sequence designed to foster optimal student conceptualization of pathogenesis and pathophysiology; (b) promotion of student skills in objective data analysis and diagnostic reasoning by active participation in disease case studies; (c) integration of contemporary imaging technologies with conventional anatomic pathology and physical examination to strengthen the observational component of disease recognition; (d) intensified instruction in the genetic, molecular cell biologic and epidemiologic characteristics of disease for students attracted to careers in clinical specialties, medical education or translational research; (e) initiation of international exchanges that expose novice physicians to global disease problems.

Coherent Exposition of Disease Topics:

We contend that a strategically ordered exposition of disease topics is crucial to optimal student conceptualization of disease entities and subsequent recognition in practice. The traditional classifications of most common diseases originated in an era dominated by morbid anatomy and rudimentary microbiology, well before awareness of the versatile repertoire of pathophysiological, immunobiological, and cell biological responses to tissue injury. These play out under diverse conditions and in a range of tissue environments. Accordingly, current textbooks introduce the fundamentals of common disease reactions in early chapters. Even so, the established textbooks typically group disease-specific findings by organ systems or causative agents. A current challenge for pathology instruction is to transcend the lineal subject compartmentalization rooted in anatomy such that learning objectives of 'vertical integration' can be achieved [6, 9, 10]. Underlying principles of disease causations and pathophysiology need to be highlighted in relation to overall patterns of disease expression/progression, whether at tissue, organ or body levels. Realization of this goal depends upon a carefully calibrated syllabus which is designed to analyze fundamental disease mechanisms in a logical sequence.

Ideally, articulated disease modules should facilitate a stepwise maturation of medical logic and critical thinking. In the pathology track, diseases with major population impact, such as cardiovascular diseases and diabetes in the Americas, should take precedence in the order of student instruction. Diseases exemplifying broadly significant pathogenic mechanisms, infections, or epidemiologic characteristics also deserve high priority. In design of a cardiovascular module, for example, topics in hematology, hemodynamics, and tissue associated pathways for regulation of lipid and glucose metabolism or blood pressure would deserve coordinate attention. Pertinent textbook readings would be selectively prescribed as reference sources. Our experience suggests that observationally obvious and diagnostically characteristic disease manifestations need the most constant attention to ensure clear mechanistic conceptualizations and effective recall memory.

Premature emphasis of fine details or unusual disease manifestations or excessive textbook assignments in the early phase of disease studies often deflects student focus from features of major clinical relevance. There is an urgent need for critical reassessment of overly intensive factual assignments during disease introductions. This is indicated by gross observational deficiencies of novice practitioners which many seasoned observers recently have noted [11, 12]. We therefore urge that comprehensive redesigns of pathology syllabi engage the pedagogical perspectives and deliberation of all active and experienced faculty members. The curriculum outline of the Krishna Institute of Medical Sciences is exemplary [6]. Curriculum planning should include consultation with medical and surgical specialists at regular intervals to enable timely incorporation of emergent findings in diagnostic methodologies, molecular biology, disease prevention, or individualization of therapies. In essence, a modern curriculum design should facilitate the ongoing synthesis of current disease science into an evidence-based practice [13, 14]. Students should gain a multifaceted comprehension of disease pathogenesis, including critical molecular mechanisms, major pathophysiologic manifestations, typical patterns of disease presentation, pathways of natural progression and potential complications.

Promotion of Student Skills in Objective Disease Analysis and Diagnostic Reasoning:

For a lifetime career in medicine, students must learn how to translate clinical observations of disease and cogent scientific findings into practical applications [12-16]. A reasoned approach to differential diagnosis depends upon stratifying and evaluating medical evidence from multiple sources and constructing a hierarchy of disease probabilities. The prerequisites of critical thinking and continuous self-learning are acquired skills which need to be honed by active problem solving. Interactive disease case-studies with student presentations or discussion and faculty-student exchanges are necessary to promote objective analysis of medical evidence and create a vivid multidisciplinary perspective. Participatory exercises emphasizing the convergence of disease science and clinical medicine should reinforce a coordinate integration. Supervised student analyses of actual or synthetic case narratives can effectively stimulate the habits of self-education, improve the recognition of complex disease processes, and foster development of sound medical judgment. Interactive disease studies also can be centered around live appearances or video presentations of authentic patients or actor substitutes. Interactive video-based distance learning is a potential alternative, and physical models simulating disease conditions may eventually become available for participatory demonstrations of pathophysiology and responses to treatment.

To the extent that staffing and logistics permit, periods devoted to interactive exercises should yield an exponential educational impact. In general, commitments of faculty time and energies are well rewarded by increased student enthusiasm and participation. We have found that sessions of 1-2 hour duration scheduled at regular intervals for 10-20 students are most effective when they illuminate disease entities aligned to the established syllabus direction. These sessions lend balance to textbook descriptions of disease mechanisms which can be overwhelming when studied in isolation. Fine details gain value after students have developed strong concepts of disease inter-relationships and patterns of expression through active learning and contacts with disease sufferers. Accordingly, we urge that interval quizzes or examinations lean most heavily on the lessons of active learning experiences as means to probe the true depth of student understanding. Answer choices should guide students in self-reassessments of their knowledge of disease processes rather than memory of outlying facts. Sole reliance on multiple choice examinations often motivates short term memorization, and undue emphasis on test-directed reviews can blunt intellectual exploration and diminish the investigative learning which is a major objective of a medical education.

Integration of Imaging Technologies with Anatomic Pathology:

As the landscape of medical education changes, instructors must seek the most effective methods for fostering enduring recollections of complex and multidisciplinary disease information. Physicians in practice are keenly aware that the most potent understanding of disease processes often evolves from physical observations [11]. Active observational experiences tend to impart more indelible impressions than the passive auditory stimuli of lectures / webinars or reading and ultimately promote 'observational competence'. In the traditional curriculum, gross anatomical studies of diseased organs, combined with microscopic observations of tissue pathology and handwriting of notes, served as active learning tools which provided ample room for independent

discovery. Computer based examination of digitized slides in many American medical schools is a step once removed from the classic methodology, yet still very effective in stimulating curiosity and encouraging individual observations.

Since current students are more visually oriented than former generations, deployment of modern imaging and videography tools can offer exciting opportunities to facilitate conceptualization.

A tighter linkage of contemporary imaging technologies with conventional anatomic pathology would serve to enhance durable recollections of cardinal disease patterns. Advanced techniques of endoscopy, laparoscopy, computerized tomography, MRI and ultrasonography make it feasible for students to observe disease processes *in situ* under dynamic physiologic conditions, and kinetic biomarkers are of increasing practical value [1]. The implicit drama of multimodal visual explorations is likely to open avenues of active student inquiry. As with all observational exercises, students need opportunities to problem solve by comparing tissues in normal and diseased conditions. The skill to discern pathological conditions from normal variation is an essential for medical practice. In this light, observational materials should be diligently selected to compare disease with normal.

Supplemental Instruction for Students Electing Careers in Medical Education, Clinical Specialties or Translational Research:

The future practice of high quality medicine will require timely and appropriate implementation of new and validated scientific findings related to one or more specific diseases[13, 14]. In this context the medical profession needs to encourage recruitment of capable students motivated toward academic careers: consultation, research, or teaching. An advanced track of disease study for such students is essential to the advancement and transmission of medical knowledge [17]. In career leadership roles, graduates will be positioned to disseminate state-of-the-art information to medical colleagues and public health personnel. We propose that capable and motivated students be provided with an elective 1-2 years of subsidized instruction in the molecular biology of disease including a laboratory practicum. Physician graduates drawn from these ranks should populate the advance corps of specialists in every discipline of medical practice as well as research. Models of stratified disease instruction may be especially useful in regions of the world where highly trained graduates are needed to assume regional consultative roles or to direct collective health services or when the physician supply is no sufficient to offer patient centered care.

International Exchanges for Novice Physicians:

From the international perspective, an important role of medical education is to impart novice physicians with a meaningful appreciation of global disease problems and the regional or societal variations in disease presentations or methods of evaluation. To this end, we propose bilateral faculty and student exchanges to broaden international cooperation. In particular, this should involve exchanges of 4th or 5th year students from the group attracted to academic or investigative disease interests (see above). One long term goal would be to develop a multinational cadre of physician practitioners with recognition of the diversity in regional medical care and capability of acting in response to global disease emergencies. Transcontinental epidemics of both known and new infectious agents have the potential to inflict large scale morbidity or mortality, but represent only one facet of global medical problems. Urgent efforts are needed to reduce the endemic incidence of malaria and tuberculosis, the excess of maternal mortality [18], and the

mortality of infants and children. Many cardiopulmonary and gastro-enteric diseases reflect lack of education and preventive care. There also is a growing need for physicians with 'cultural competence'. This skill represents sensitivity to unique problems of minority populations and cognizance of socioeconomic differences in patterns of disease prevalence or presentations. For example, endemic diseases of East Asia, such as cardiomyopathy, osteochondropathy, or neurodegeneration, deserve greater attention [19-21]. In India, breast cancer has a relatively high prevalence in women of Parsi origin and many women suffer vitiligo. Pioneering investigations of the mesothelioma related to eriotinite mineral fibers and familial susceptibility in Turkey [22], suggest the possibility of environmental-genetic factors in other diseases. As medical travelers, novice physicians may be motivated to assess non-traditional preventive measures or treatments or develop unique perspectives [23].

To Summarise:

The increased understanding of disease pathogenesis has advanced the medical aspirations of disease prevention or of early detection to allow preemptive moderation. Populations worldwide have benefited on an unprecedented scale. Current challenges in medical education nevertheless exceed those encountered by Flexner more than 100 years ago, an era when the addition of scientific rigor to clinical apprenticeship radically improved health care quality [5]. The incredibly swift progress of medical science and biotechnology has provided such a bounty of useful knowledge that we must again examine the parameters of a formal medical education. Medical care continues to embody interpersonal arts, psychological insights, ethics and rational judgments, but disease recognition is the critical element which must be baked into the educational process during a fixed period of supervision. At present, the spectrum of disease knowledge optimal to fledge a high quality medical career only can be gauged pragmatically. We need gradually to learn if any portions of the scientific armamentarium, traditionally imparted within medical school, can be safely deferred for self-learning during active practice. While some educators assert that students can pursue foundational self-learning of diseases as early as pre-clinical clerkships, we contend that the skill sets of clinical reasoning must be firmly set during the period of formal studies. This period should include the dynamic challenges of student-faculty exchanges and vital deployments of imaging technologies to strengthen observational competency.

Styles of student learning vary, and differences in pedagogical approaches may depend upon the extent of secondary school or college preparation in the sciences, as well as contemporary cultural norms. Faculty insight into the level of student aptitude and motivation on entry to medical school is obviously critical to an intelligent alignment of the curriculum. Syllabus contents and teaching methods may further be subject to local faculty resources or historical experiences. We therefore have not advocated any fixed didactic approach to disease study, but rather offered experiential insights conducive to a steady improvement of instruction. Licensure testing provides one measure of instructional success; however, the real world impact of educational retooling on physicians' retention of cogent disease knowledge and the shaping of medical practice will require frequent reassessment as we progress through the 21st century [cf. 10-12].

†*The opinions expressed herein are those of the authors and should not be construed as official or reflecting the views of the Uniformed Services University of the Health Sciences or the Department of Defense.*

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