

Teaching Environmental Carcinogens and Environmental Medicine in Medical Schools: Current Scope, Educational Strategies, and Opportunities for Curriculum Reform

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Abstract

Background: The global disease burden due to environmental risk factors such as Environmental Carcinogens (EC) is significant; but these exposures are not comprehensively covered in the medical school curricula. Meanwhile, physicians should have the ability to recognize exposure-related diseases, obtain environmental exposure histories and counsel patients. **Methods:** A review of peer-reviewed studies, institutional reports and opinion pieces that discuss teaching ECs in medical schools was conducted. **Results:** ECs are usually taught within the larger framework of environmental and occupational health modules. The content of courses varies widely; and emerging issues such as endocrine disruptors, the exposome, and environmental carcinogens are typically absent. In the US, less than 1 in 7 students believe they have been adequately trained in environmental medicine. Schools have followed various teaching methods for this content, including interactive, longitudinal programs to improve knowledge and self-efficacy, modules and several weeks of experiential learning to improved students' ability to counsel on environmental risks, elective courses and independent units on environmental topics. There are reports about evidence-based training on occupational carcinogens producing better test scores than learning impacted through peer teaching or small group discussions. **Conclusion:** Integrating knowledge about ECs into the medical school curriculum is vital in preparing future doctors, together with working methods based on active and continuous competency development. At the same time, programs must address emerging environmental challenges, and equip doctors with adequate skills for counseling patients. Environmental medicine education is particularly useful for the prevention of exacerbating problems caused by the health impacts of environmental carcinogens.

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Introduction

Environmental carcinogens are chemical, physical and biological agents that exist in the environment, in the air, water, soil, workplaces and even in consumer products. The International Agency for Research on Cancer (IARC) has evaluated various environmental and occupational exposures, including asbestos, benzene, silica, air pollution, and radiation, and classified these exposures as known or probable human carcinogens [1]. These exposures are the main contributors to the global cancer burden. The most recent GLOBOCAN report estimates that in 2020, 19.3 million new cancer cases and 10 million deaths happened worldwide, with environmental and

occupational exposures causing a noticeable increase of cancer incidence and mortality [2]. Environmental risks contributed to over 13.5 million global deaths in 2016, and the WHO reported that environmental risks contribute to nearly 28% of deaths among children under age five [3]. The Lancet Commission on Pollution and Health estimated that diseases caused by environmental pollution were responsible for approximately 9 million premature deaths in 2015, accounting for 16% of all deaths worldwide [4].

However, despite such importance, inconsistency in medical education on environmental and occupational

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health leaves future healthcare providers unprepared for exposure-related diseases. According to a survey of U.S. medical schools, only 13% of students believed their school provided adequate environmental medicine education, whereas more than 80% believed environmental medicine should be part of the core curriculum [3]. Others have reported that some US medical schools have no required environmental medicine content, and in those that have some environmental medicine content, only seven hours on average has been dedicated to this topic across the whole curriculum. Meanwhile the environmental medicine content in U.S. medical schools was limited and often dispersed across required courses rather than taught as a dedicated course [5].

Gehle et al. argue that despite the substantial contribution of environmental factors and toxic agents to diseases, environmental medicine education is largely omitted from U.S. medical education. They state that the lack of adequate education on how to prevent, diagnose, refer, or treat patients exposed to hazardous substances leads to missed opportunities for primary prevention and early intervention [6].

Basic education in environmental health, especially in the context of the health risks that come from exposure to the newly emerging contaminants that permeate the environment, needs to be revised and incorporated into medical school training in order to equip future medical professionals with the adequate knowledge to care for their patients.

To better understand the challenges of teaching environmental carcinogens and environmental medicine in medical education, this article reviews the historical integration of environmental health in medical schools, highlights current instructional approaches and programs, and explores key barriers to preparing future physicians to recognize and address environmental health risks.

Historical Institutional Perspectives

In 1986, the American Association for Cancer Education published specific goals for the medical curriculum to include exposure to the environmental and occupational personal determinants of risk, such as personal habits, occupational exposure, and chemical carcinogens found in pollution, and to adopt exposure history, patient counseling, and primary and secondary prevention [7]. Despite such recommendations, for decades, the domain of environmental medicine continued to be peripheral in medical education, and community and preventive medicine courses. Surveys continue to capture the absence of standardized competencies and limited coverage in the curricula, as approximately only half of U.S. medical schools included the health impacts of environmental risk factors in the mandatory sections of their courses [3]. In recent years, some schools have pioneered integrating health and the environment in their curriculum. The Paul L. Foster School of Medicine at Texas Tech University Health Sciences Center El Paso adopted a longitudinal curriculum where principles of environmental and occupational health are embedded in both the pre-clerkship and clerkship segments, and

students learn to take exposure histories and identify exposure-related illnesses [8]. These models in their infancy are a testament to how decades old appeals for the integration of these topics are now being realized in academic institutions.

Current Approaches to Teaching Environmental Carcinogens and Environmental Medicine

Bakemeier and Edwards identified environmental carcinogens, occupational exposures, radiation, infectious agents, drugs and genetic-environmental interactions as important cancer education topics for medical students, particularly within preventive oncology objectives. And although they mentioned that different departments should coordinate cancer education efforts across schools, they did not describe how these topics should be pedagogically delivered [7].

The delivery of environmental carcinogens and environmental medicine in curricula can vary widely from institution to institution. Many institutions deliver this material through lecture segments on various types of air pollution, radiation and industrial chemical exposures, which often have little clinical applicability. Other models of teaching involve a more integrative approach, with the teaching of environmental health over the course of medical school.

The Paul L. Foster School of Medicine of Texas Tech University includes Environmental and Occupational Health in the pre-clerkship curriculum and Environmental and Occupational Medicine as an elective course in the clerkship curriculum. The pre-clerkship sessions cover the most important routes of hazardous environmental exposures, including air, water, soil, and food pollution, and Occupational/Environmental hazards and carcinogens. In the fourth year elective, students learn more about Occupational/Environmental history taking, the more common Occupational/Environmental diseases, and hazardous industrial environments [8]. Institutions including the Université de Montréal offer rotations in community settings while Ghent University combines both lectures and apprenticeship-style learning [8].

There are institutions that have chosen a module-based teaching model, with different lengths of modules. At the Hackensack Meridian School of Medicine, in New Jersey; the environmental health module included a two-hour interactive large-group learning introductory lecture followed by a six-week student activity and small group activity, covering health effects of exposures to common toxins, avoiding carcinogens and endocrine disruptors, pesticides, healthier foods and personal care product choices, and identifying populations at risk for environmental health issues. Students at this school also used an app to evaluate the environmental safety of foods and personal care products, and they were given assessment tools to understand potential environmental exposure risks in their assigned community/family context. This approach gives the teaching a practical, patient- and community-facing dimension that can further fulfill the educational needs of medical graduates. After this educational intervention, students reported

significantly greater preparedness to advise patients on reducing exposure to pesticides and other environmental toxins in diet, reducing toxins in household and personal care products, and advocating about toxins affecting air and water quality [9]. At the University of Côte d'Azur, in France, medical students receive environmental preventive medicine teaching including topics such as endocrine disrupting chemicals, agricultural pesticides and human health, environmental epidemiology, exposome, biomarkers, and One Health, in different years [10]. On the stronger side of the spectrum there is the Harvard Medical School curriculum that involves a required four-year "Climate Change, Environment, and Health" curricular theme, creating a mandate to integrate required content throughout all four years of medical school on pathophysiology, clinical applications, structural reasons for inequities, as well as healthcare sustainability [11].

However, despite being feasible, the integrative models of curricular integration vary among institutions with many relying on separate lectures and electives.

Teaching Methods and Educational Strategies

Assadi compared three teaching approaches for occupational and environmental carcinogens and cancer prevention; evidence-based education, group discussion, and teaching to others; and found that students receiving evidence-based education had significantly higher exam scores than those taught through group discussion or teaching-to-others approaches. The author concluded that evidence-based education was the best method for introducing occupational and environmental carcinogens and cancer prevention to students [12]. However, in addition to gaining knowledge, it is essential to teach practical skills related to environmental medicine such as taking an environmental exposure history and managing possible adverse environmental health effects. Marshall et al states patients often ask physicians about carcinogenic exposures such as lead, air pollutants, and pesticides, but most primary care physicians lack training and knowledge in the clinical recognition, management, and avoidance of such exposures. They provide guidance on when and how to take an environmental exposure history using the CH₂OPD₂ mnemonic and describe approaches for interpreting exposure findings and managing suspected environmentally related illness [13].

Interaction through interactive learning and participation in practical experiences has been shown to help increase engagement and improve self-efficacy. For example, at Hackensack Meridian School of Medicine, a two-hour session with small-group discussions, case studies, mobile-app activities, and a six-week experience, resulted in significantly better preparation for advising patients about how to avoid exposures to pesticides, and household products, and survey items showed significant improvements [9]. Fénelich et al. describe a mandatory final-year environmental preventive medicine course at the Faculty of Medicine of the University of Côte d'Azur, developed through collaboration with Chiba University and attended by invited Chiba students. The

course covered early-life environmental determinants of later health, endocrine-disrupting chemicals, agricultural pesticides, climate change and health, the exposome, and One Health. After comparing pre- and post-test results, authors reported that correct responses improved across all quiz topics and student satisfaction was high [10].

Long-term and competency-based educational programs could serve as another approach to enhance learning on a particular topic. A good example is the Climate Change, Environment and Health curriculum at Harvard Medical School which includes a four-year-long series of lessons based on the principles of competencies, learning goals, and activities such as case studies, community projects, reflections on structural inequity, etc [11]. Reviewing programs for environmental medicine instruction in the United States shows that repeated and longitudinal programs have better outcomes than single lecture classes. For example, Case Western Reserve University's year one, five-week problem-based environmental medicine and occupational health learning block produced an average knowledge test score range of 70-95%, and Rutgers New Jersey Medical School's mandatory two-and-a-half-hour seminar in second year increased knowledge and self-assessment skills. However, even with the relatively high scores, many students report being not prepared to discuss the effect of environmental factors on health with patients [3].

Schenk et al. also found innovative educational approaches in some schools, including small-group case discussions, community-based clerkships, site visits, student-organized lunch discussions, interest groups, research opportunities, and combined-degree programs. These methods are well suited for teaching environmental carcinogens because case-based and community-based examples can link exposures such as radon, asbestos, benzene, arsenic, pesticides, air pollution, and polycyclic aromatic hydrocarbons to clinical outcomes [5].

Gehle et al. propose the exposure-disease continuum as a teaching framework. They show progression from exposure to internal dose, biologically effective dose, early biological effect, altered structure/function, clinical disease (cancer) and human health risk in a diagram. This is especially useful for teaching carcinogenesis because it links exposure assessment, dose, biological mechanism, susceptibility, prevention, and clinical disease in one conceptual model [6]. These authors also identify the Agency for Toxic Substances and Disease Registry's (ATSDR) educational materials as practical teaching resources. They suggest case presentations in Environmental Medicine for carcinogens, including polycyclic aromatic hydrocarbons, whose metabolites can interact with DNA and cause malignancy, and radon, which is described as a major cause of lung cancer. They also recommend ATSDR one-hour Grand Rounds/seminars [6].

Gaps and Challenges

Although there have been advancements in this area, several hurdles continue to hinder comprehensive teaching of environmental carcinogens. Some curricula focus on

one lecture or module of environmental health and fail to include new concepts like the emerging environmental carcinogens. There are no standardized competencies and assessment tools, making it difficult to assure consistency and adequacy. Some programs do not clarify the clinical practice aspects; and therefore, although students score highly on the knowledge assessment, yet their confidence in doing an exposure history, diagnosis of exposure-related illnesses, and counseling is quite low. Few teachers or faculty members are well trained in environmental health, especially in educational institutions that do not offer environmental medicine specialties. Other factors such as the overcrowded medical school curriculum and lack of prioritization by educational institutions make it even harder to incorporate new environmental health concepts to the already busy schedules.

Recommendations for Curriculum Reform

Integrate environmental content across courses

Environmental carcinogens and environmental medicine should be integrated with basic science, organ systems, and clinical coursework, as opposed to being separate components. As part of the teaching of oncology, physiological functions, or pharmacology, instructors can bring in relevant environmental exposures [5, 6, 14] such as environmental carcinogens. This curriculum weaving ensures the concept that humans always exist in interaction with their environment, preventing the burden of too many stand-alone courses from being placed on the students.

Adopt competency based frameworks

There should be institutionalization of standardized competencies that describe the skills, knowledge, and attitude that one requires in practicing environmental medicine. An example of a framework is that by Harvard University; it encompasses understanding of the pathophysiology involved, and application of concepts learned in clinical settings [11]. These competencies can be adapted directly to environmental carcinogens by teaching students to recognize carcinogenic exposures, take a cancer-focused exposure history, use resources such as IARC/ATSDR, communicate risk, and refer or report when appropriate [5]. Gehle et al recommends competency-based environmental health education, including understanding the influence of environmental agents on human health; taking an appropriately detailed environmental and occupational exposure history; recognizing signs, symptoms, diseases, and exposure sources related to common environmental agents; understanding epidemiologic, toxicologic, exposure, and risk-communication principles; identifying clinical and informational resources; and understanding legal, social, and ethical responsibilities. These competencies map well onto teaching environmental carcinogens in medical schools [6].

Utilize evidence based and experiential teaching methods

The use of evidence-based teaching has been shown to improve retention of information about occupational and environmental carcinogens [12]. Education initiatives

must preferably include both didactic and problem-based learning, discussion forums, simulation, field trips, and computer applications (such as mobile phone applications) for the detection of toxins and carcinogens in individuals. Extended sessions over the 4-year curriculum, probably promote more confidence than individual lecture classes, alone.

Provide practical resources for patient counselling and advocacy

Students can use concrete guidelines that link environmental knowledge with clinical applications. Learning curricula should include sample forms of taking histories related to exposures, common carcinogens' list, educational materials for patients, and referral to community resources. Educators should demonstrate approaches to counseling on the avoidance of carcinogens and choosing safe products.

Support faculty development and research

Institutions should invest in faculty training to enhance expertise in environmental medicine. Collaboration among medical schools, public health agencies and community organizations can facilitate resource sharing. Research is needed to evaluate teaching models, develop valid assessments and identify barriers and facilitators of curriculum implementation.

Limit curricular burden while maximizing impact

It is necessary to recognize that there is already an over crowdedness in medical schools' curricula. Strategies like embedding environmental health-related aspects in current classes and implementing self-directed computer-based courses can save time while maximizing learning benefits.

In conclusion, While there have been calls to include environmental aspects of disease into the medical curriculum, the actual instruction on these topics remains poor. Early goals set for cancer education recognized exposure to different factors as an essential element for assessing the risks; yet, a considerable number of medical students perceive themselves unprepared to diagnose environmental exposure related diseases or provide advice to their future patients. Based on the results of curricular intervention programs, it can be suggested that integrated and longitudinal education using proven approaches increases knowledge, preparation level, and satisfaction among students. To continue this process, medical institutions need to use their momentum by integrating the topic into the curriculum, using competence frameworks, employing active learning techniques, and providing the necessary tools for counseling and advocacy.

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