Importance of Clinical Microbiologists for U.S. Healthcare Infrastructure

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ABSTRACT: Clinical microbiologists are highly skilled scientists within national hospitals and reference laboratories who diagnose patients with infections by emerging pathogens. Most advanced training for clinical microbiologists occurs at universities, where an individual can receive certification as a "Medical Laboratory Scientist" (MLS). Unfortunately, many MLS programs have closed in the United States and this has caused a shortage of clinical microbiologists at U.S. hospitals and reference laboratories. This paper explores the present crisis in MLS training and its ramifications for the emergence of antibiotic-resistant bacteria, the economics of hospitals, and the overall health of the nation, and provides resolutions for better public health policy with respect to MLS education.

INDEX TERMS: Clinical Microbiology, Public Health, Antibiotic Resistance

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INTRODUCTION

Public Health authorities have documented well the alarming rise of drug resistant bacteria, viruses and fungi.[1-3] Clinical microbiologists are the first line defense within national hospitals and reference laboratories against these emerging pathogens. They critically analyze patient specimens to identify the causative agents of disease, inform healthcare professionals on the life saving drugs needed to treat patients, and help monitor patient treatment. With regard to infectious patients, activities of clinical microbiologists can eliminate disease-causing microbes within these patients and prevent further spread of dangerous agents within society. Clinical microbiologists possess highly specialized skills that include, but are not limited to, collecting, examining and analyzing body fluids, tissues, and cells, and they require years of technical laboratory training in advanced courses in biology and chemistry to acquire these skills.[4] Originally, hospital personnel conducted clinical microbiology training, but during the 1970's and 1980's hospital programs closed as a result of enrollment shortages and rising costs in relation to profits. Today, most clinical microbiology education occurs at U.S. colleges and universities, where an individual receives certification as a "Medical Laboratory Scientist" (MLS). Unfortunately, many MLS programs have closed in the country. This paper explores the present crisis in MLS training and its ramifications for the emergence of antibiotic-resistant bacteria, the economics of hospitals, and the overall health of the United States, and provides resolutions for better public health policy with respect to MLS education.

Crisis of Medical Laboratory Science Program Closures in the United States

Recently, many Medical Laboratory Science (MLS) Programs that offer clinical microbiology training in America have closed due to the national economic downturn, state budget crises, and misguided planning on the part of university administrators. A look at the present situation in the western United States clearly reveals the problem. California used to have numerous MLS programs. Today, at the time of this writing,

according to the National Accrediting Agency for Clinical Laboratory Science (NAACLS) (www.naacls.org), California now possesses only *nine* university programs, but only *two* of these grant the B.S. degree in Medical Laboratory Science (Table 1). The vast majority are short-term programs (in some cases just 12 months) that merely help students prepare for the clinical license examination. Unfortunately, California is the most populated state in the nation with over 36 million people (www.census.gov), and these nine programs train the clinical microbiologists that handle specimens from the sick patients within this large population pool. After observing the nine programs, one finds that at California State University Dominguez Hills (CSUDH) only *one* faculty member teaches medical bacteriology—the author of this paper. Assuming one faculty member per program accredited by NAACLS for any given semester, there would only be nine medical bacteriology instructors for all of the university programs in the entire state of California. Though CSUDH offers two sections of medical bacteriology per year, class enrollments are capped due to laboratory space constraints, so CSUDH faculty cannot train more than 48 students annually. Similar circumstances exist elsewhere within other California MLS programs. In fact, some programs admit few new students. UC Irvine only accepts eight students per year. Similarly, San Francisco State and San Jose State Universities, which serve the entire San Francisco Bay area, accept no more than 60 incoming students annually. Unfortunately, only 50% of the medical bacteriology students immediately advance to clinical rotations that year, because others need to take more courses or even retake medical bacteriology due to poor performance. Course syllabi also indicate that CSUDH faculty, in comparison to faculty from other programs, train MLS students using a more extensive list of microbes, and thus better prepare clinical microbiologists to deal with a wide array of exogenous and opportunistic pathogens when they enter hospital labs.

Though the situation looks dire in California, it is far worse in other western states. Washington, with its 6.7 million inhabitants, has only a *single* MLS program within a university that offers the B.S. degree in Medical Laboratory Science (Table 1). Similarly, one finds few programs in Utah (only 3), Oregon (only 1), and New Mexico (only 1) (Table 1). Likewise, Nevada, which also has only one B.S. degree program, is experiencing a state budget crisis and education cuts within the University of Nevada. The MLS program at University of Nevada, Las Vegas (UNLV) may soon close.[5] Alarmed by the crisis, the American Society for Clinical Pathology launched a media campaign to educate university administrators, Nevada state legislators, and federal officials on the importance of saving the MLS program. The organization even petitioned the Department of Labor for a federal grant to provide the emergency funding to prevent the closure.[6] The crisis in Nevada is echoed in Arizona, with its 6.6 million people, where the MLS program at Arizona State University is near closure at the time of this writing (ASU website: www.asu.edu/budgetcuts/). Given these statistics, *seven* western states (Table 1), with a combined population of some 61 million, would possess only *eight* MLS programs offering the B.S. degree and less than 10 medical bacteriology faculty for any given year the courses are offered.

Table 1. Current MLS Programs Offering B.S. Degrees in Several Western States

Arizona	Arizona State University**
California*	California State University Dominguez Hills
	Loma Linda University
Nevada	University of Nevada Las Vegas**
New Mexico	University of New Mexico School of Medicine
Oregon	Oregon Health and Science University/ OR Institute of Technology
Utah	Weber State University
	Brigham Young University
	University of Utah Health Science Center
Washington	University of Washington at Seattle

* Remaining 7 institutions in CA offer only lower level certification in CLS
** ASU and UNLV are closing

The closure of MLS programs is a dilemma for both the state and federal governments. Essentially, training of clinical microbiologists is being thwarted or eliminated entirely at national universities and four-year colleges while a large demand still exists for a workforce of skilled diagnostic scientists. According to one article:

"The current vacancy rate in the clinical laboratory sciences field is 13 percent," said Dianne Cearlock,

CEO of NACCLS. In the next five years, 13 percent of the workforce is expected to retire, with 25 percent of the workforce retiring over the next 10 years.[7]

This article was published in May of 2009, and with the recent closures of MLS programs in the western states, the present demand for clinical microbiologists is even greater. Furthermore, the article states: "only two new clinical lab professionals enter the field for every seven who retire, and the average age of the laboratory professional is over 50".[7] Indeed, the Bureau of Labor Statistics projects a shortage of 138,000 clinical microbiologists by 2012.[4]

Effects of MLS Program Closure on the Rise of Antibiotic-Resistant Bacteria:

The lack of trained personnel within U.S. laboratories prevents them from rapidly and effectively diagnosing disease-causing agents. Consequently, hospital physicians end up treating patients without laboratory identification of the microbe causing patient ailments. As a result, most physicians prescribe "broad spectrum" antibiotics to resolve symptoms. Though this approach quickly offers some patients desired relief, antibiotic-resistant bacteria can emerge. Indeed, this is already seen in hospital and community surveillance. Methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant *Enterococcus faecalis* are two examples of bacteria that have evolved resistance.[8-9] MRSA causes many nosocomial infections[8-9] and it is now recognized that different strains of MRSA arose *independently* in the human community and the hospital setting.[9] The emergence of MRSA in separate environments reveals that evolutionary factors exist in both the natural and hospital settings that can contribute to the advent of dangerous bacteria. The appearance of bacterial species that have acquired virulence factors from more pathogenic species within their own genus is also concerning. For example, *Bacillus cereus*, a ubiquitous soil microbe that causes food poisoning, has recently acquired virulence factors from *Bacillus anthracis*, the deadly causative agent of anthrax.[10] This episode suggests cross species transfer of virulence factors that could contribute to antibiotic resistance and resistance to host immunity. Similarly, vancomycin resistant *Enterococcus faecalis* transferred episomal DNA to previously vancomycin susceptible *Staphylococcus aureus,*[11] revealing that antibiotic resistance can cross *both* bacterial species *and* genus barriers. The emergence of bacteria from the above scenarios provides challenges to physicians in the clinic, making treatment of bacterial infections exceedingly difficult. This can especially be the case if patients are reluctant to take their medicines at the appropriate times and for the appropriate duration.

The unwillingness of sick patients to take their medicines correctly is well documented.[12] Indeed, the Directly Observed Treatment, Short-course (DOTS) Program, whereby healthcare workers observe patients as they take their medications and provide follow up observation for *Mycobacterium tuberculosis* treatment, was designed precisely to prevent antibiotic resistant *M. tuberculosis*.[12] An analogous method is used for HIV treatment.[13] As stated already, clinical microbiologists inform healthcare professionals on the life saving drugs needed to treat patients, and help monitor patient treatment. However, nations with poor healthcare infrastructures do not have as many clinical microbiologists and are not able to monitor drug resistance. In addition, patients in these countries are not taking their drugs on time and for the appropriate duration.[12-13] Indeed, both multi-drug resistant *M. tuberculosis* (MDR-TB) and extensively drug-resistant *M. tuberculosis* (XDR-TB) are spreading around the world such as in Eastern Europe and South America.[12-14] Unfortunately, the lack of patient cooperation combined with the declining clinical microbiology workforce could lead to the appearance of drug-resistant *M. tuberculosis* or antiviral resistant HIV in the United States as it has in those nations with poorer national healthcare infrastructures.[12-14] An analogous problem could occur with less publicized pathogens, like the ubiquitous bacterium *Pseudomonas aeruginosa*, where antibiotic resistance has been detected in Japan[15] and could soon be problematical for U.S. hospitals if they lack the clinical microbiologists to survey for antibiotic-resistant bacteria. Pathogens do not stop at national boundaries, and the problems of the developing world or other nations could soon be the problems of the United States.

As already stated, pathogens can emerge almost anywhere. In addition to hospitals, natural

environments such as the oceans act as sites where novel microbes evolve. Sewage contamination and polluted river runoff could cause an increase in the numbers of bacteria in the waters and sands of the nation's beaches. For example, it is well documented that California's coastline is riddled with locations containing *Escherichia coli* or *Enterococcus faecalis*.[16] These are bacteria that environmental microbiologists can rapidly identify, but there needs to be a workforce of clinical microbiologists in the labs to perform surveillance and develop new diagnostic tests.

The advent of pathogens in *communities* was explicitly revealed following the September 11, 2001 terrorist attack. In that crisis, cases of reported anthrax reveal that bioterrorism is still possible. Hospital clinical microbiologists would be the first scientists responsible for determining any potential epidemic. In order to perform diagnostics well, these scientists would need extensive biological knowledge, advanced training, and broad clinical experience.

Given the many concerns stated above, a robust workforce of clinical microbiologists within the United States will be critical to handle the important challenges of disease in the near future.

Effects of MLS Program Closure on U.S. Healthcare Infrastructure and the Economics of Hospitals:
Elimination of MLS programs around the country is a crisis for many reasons. Firstly, it is hard to attract clinical microbiologists from other states to the state undergoing the cuts because there is already a national shortage in all states. Data from one survey reveals that 80-90% of lab technologists remain in the state from which they received their MLS training.[7] Consequently, states such as Arizona and Nevada, that are closing all of their programs, will experience the shortage of qualified personnel greater than states like California, that have some programs still operating.

Secondly, states that possess large senior populations, like Arizona and Nevada (www.census.gov), and which are reducing their clinical microbiology workforce, will experience difficulty handling elderly patients. Elderly patients have waning immune systems and are more susceptible to microbial infections and the complications that arise from such infections. Clinical microbiologists are critical for diagnosing the disease-causing organisms in these patients.

Thirdly, graduates from MLS programs are better trained in classical diagnostic procedures than their counterparts from other biology programs, and so it is important for improved healthcare that states have these graduates in the clinical workforce. Though most medical virologists use molecular technology, such as polymerase chain reaction (PCR) and the enzyme-linked immunosorbent assay (ELISA), to detect the viruses causing disease, medical bacteriologists, in contrast, still need training in classical microbial culture, serology and biochemical methods in order to more efficiently and effectively diagnose bacterial infections. For example, if bacterial fermentation and enzymatic physiological patterns are not consistent across experiments from API strips, selective culture media, and hospital computer surveillance databases, then the clinical microbiologist determines this problem and helps the laboratory troubleshoot. Clinical microbiologists possessing only molecular biological skills are less effective in interpreting data derived from classical diagnostic methods. Furthermore, for clinical work with some bacteria, there exist *no* molecular tools presently available and consistently used across all laboratories in a cost effective manner.[17] Or, the molecular tools are costly, may have a short shelf life, or work with them may require additional laboratory space (like with PCR). Additionally, bacterial isolates are still needed for antimicrobial susceptibility testing, for patient treatment monitoring, or for epidemiological subtyping for many pathogens.[17] Culture methods, therefore, are still the gold standard in many laboratories. Unfortunately, most graduates receiving degrees from biology programs at U.S. research universities are trained in molecular biology, but not in traditional methods commonly used in clinical labs. Consequently, many graduates cannot immediately enter the hospital workplace and begin diagnostic experiments.

Fourthly, the closure of MLS programs and the shortage of clinical microbiologists that are skilled in both classical and molecular methods, leads to fewer future clinical microbiology *faculty* because the pool from

which to acquire these potential faculty is shrinking. An analogous crisis is occurring in the nursing profession, where the U.S. is experiencing a shortage of both nurses and *nursing faculty* to teach at nursing schools. Indeed, California, with its enormous population, presently possesses only *ten* university medical bacteriology faculty who have training in both clinical and molecular microbiology and who are not mere adjunct instructors lacking full-time, tenured or tenure-track status. And, like hospital clinical microbiologists, the medical bacteriology faculties of the nation are disproportionately older scholars nearing retirement age.

States that have lost MLS programs at their four-year colleges and universities have responded by creating more two-year certificate programs at community colleges.[7] However, the philosophy that community colleges can train the nation's future clinical microbiologists given the field's requirement for broad-based expertise in medical bacteriology, molecular virology and fungal biology is simply unsustainable. A community college certificate in medical laboratory science barely exposes students beyond rudimentary microbiology. Laboratories in community colleges lack the technology or safety provisions required to train students in more advanced medical bacteriological methods. Even the microbes stored in community college laboratory freezers are not comparable in scope to those maintained in university departments. Many community college courses, for example, will introduce students to *E. coli* and *Staphylococcus* but not the many other bacteria frequently seen in hospital and reference laboratories. Indeed, some hospitals, like Los Angeles Harbor Hospital in Southern California, treat more underprivileged patients who typically lack quality healthcare and are more prone to infections with less commonly seen pathogens.[13] Because these microbes are more virulent, some need containment at "biohazard level two", but most community college departments lack advanced facilities and the trained laboratory personnel to manage them.

The lack of enough higher-level university MLS programs would force hospitals to train more of their workforce in basic skills. Hospitals have a duty to provide excellent rotations, but their personnel cannot be burdened with teaching new employees in basic biological theory and skills that all incoming clinical microbiologists should have already learned. Nor should they. Presently, hospitals are suffering from the national financial crisis, and they must focus their resources on *advance* training of employees. Additionally, interns at some hospitals, like Los Angeles Cedar Sinai and UCLA, must perform creative research and present their findings at a conference or symposium as a prerequisite to certification. Such interns will already need advanced training upon entering these more prestigious programs. Finally, the public health policy model of only "hospital-based programs" for MLS training was already eliminated in previous decades in the United States due to declining reimbursements and enrollments.[4] The enrollment problem is a particular concern because many college graduates and prospective high school students do not know that the field of clinical microbiology even exists and so do not pursue MLS training. Rather, they pursue medicine or science degrees.

Obviously, community colleges cannot provide an advanced workforce, and, as a result, hospitals must hire more advanced personnel beyond the doctorate level to supplement poorly trained staff. This, in itself, is costly. Additionally, because of the personnel shortage, hospital technicians must work overtime, and, given the fatigue that arises from overworked staff, errors made in disease diagnosis ultimately increase costs to hospitals. Such mistakes cause patients, especially elderly patients, to remain longer in hospitals and this increases the costs for hospitals, patients, health insurance companies, and society.[18-19] And, as many public health scholars have noted, the economics and human health of societies feed on and further exacerbate each other.[20] Indeed, the direct and indirect costs on foreign governments possessing poor healthcare infrastructures, which are partly characterized by a shortage of healthcare professionals, are well documented.[20] The United States, though it has a more robust healthcare system than many nations, is no exception. As a case in point, the problem of the nurse shortage on costs and health to the nation is already being realized.[18-19]

Resolutions

University administrators and state and federal governments need to consider the risks of not

supporting universities that offer Medical Laboratory Science Programs. Indeed, the spread of antibiotic resistant bacteria, the inability to handle future epidemics, the problem with patient care, the increase costs to hospitals and governments, and the poorer health of the nation are all the result of a reduction in MLS programs and the clinical microbiology workforce.

It is also important to recognize that most patients, and even many healthcare professionals, do not understand the kind of extensive training required of clinical microbiologists. Indeed, the media and public rarely notice excellence, while mistakes are publicized in a negative light. This perspective toward clinical microbiology must change. University administrators, and state and federal agencies must understand what goes on in the field of clinical microbiology and why it is important to national health, and public policy must reflect this. Furthermore, national organizations such as the American Society for Clinical Pathology and NACCLS must continue to positively promote the MLS field and articulate to the general public and funding bodies how clinical microbiologists intersect with and, indeed, affect other professionals within the healthcare industry.

In conclusion, university administrations and state and federal governments must increase and appropriate education funding such that Medical Laboratory Science Programs are maintained within four-year colleges and universities. Additionally, they must continually monitor how a shrinking MLS workforce and declining MLS programs affect the field of clinical microbiology and health of society overall.

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