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ASCLS Core Values
Core Values include enhancing quality standards and patient safety; providing professional development opportunities; promoting expanded roles and contributions of clinical laboratory professionals to the healthcare team; increasing the diversity in the profession; and expanding the voice and role of under-represented individuals and groups.

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<td>$80</td>
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WASHINGTON BEAT

Government Affairs: What does it mean to me?

LESLIE MARTINEAU, ANGELA PHILLIPS, KYLE RIDING

When someone asks what ASCLS does for its members, a very typical first response includes a description of the advocacy performed on our behalf. The clinical laboratory profession is a complex net of scientific information that is difficult in and of itself to understand. When the rules and regulations to which the government requires us to adhere are thrown in with the science, the result is a complex governmental system, intermingling with a complex scientific body of knowledge.

As ASCLS members attend a continuing education conference, we enter topic areas with which we are all comfortable, since educational programs tend to be geared towards the scientific aspects of our profession. On the other hand, when someone attends the first Legislative Symposium in Washington, DC, that individual enters a world that very few of our colleagues realize exists, a world focused on the governmental and regulatory issues to which we all adhere but don’t often discuss. Acronyms and unfamiliar terminology begin to fly at you. Regardless of whether you know all of these terms or not, they are ones that affect your day-to-day routine.

Clinical laboratory professionals often see ourselves as the guardians of quality. We understand what it takes to ensure precise, accurate test results are obtained. The government, watching over the public it serves, understands that we do have a pivotal role in patient care and, for that reason, takes steps to protect the public. While those writing governmental legislation and regulation attempt to do their best to safeguard the public, from the clinical laboratory perspective, they sometimes fall short of the mark.

For that reason, ASCLS members must keep two important goals in mind. First, we must make it our mission to understand how government works and how to speak its language as fluently as we speak the language of our scientific disciplines. Secondly, once we have the language of the government under our belts, we must make our voices heard when new legislation or regulation that affects our profession is before any branch of government. We must provide our legislators with the knowledge of laboratory science they need to assist them in making the right decisions that directly affect the quality, access and cost of laboratory results for the American public.

The Focus articles in the Spring 2009 issue of Clinical Laboratory Science sought to make the first mission easier by providing insight into how the government works and how to speak its language. They showed how you, as a clinical laboratory professional, fit into the government. We hope the articles demystified the world of governmental acronyms, and gave you insight into clinical laboratory reimbursement today. Armed with this information, you will now be ready to understand the most current hot topic in government affairs, the modernization of the clinical laboratory fee schedule. Educate yourself, learn the language, and be part of the system.

The most-rewarding part of getting involved in government affairs is advocating for clinical laboratory services to government officials. How many times in conversation do you find that people do not know what we do? It is no different in the world of government affairs. Government representatives need to be enlightened through conversations with you and me, experts in clinical laboratory services, about the valuable services we provide to our patients, communities, and our states.

As the newest members of the Government Affairs Committee, we understand how difficult it is to grasp the vast amount of information contained within these pages. Fortunately, we are lucky to have such a great group of leaders within ASCLS who are willing to clarify the tangled web the government weaves. Thanks to this leadership and the rest of the ASCLS Government Affairs Committee, we and all ASCLS members, can truly make a difference.

Leslie Martineau, Angela Phillips, and Kyle Riding are new members of the ASCLS Government Affairs Committee.
**ABSTRACT**
A 67-year-old African-American male presented with nausea, vomiting, diarrhea, fever, and knee pain. Four sets of blood cultures were collected and resulted in the growth of *Bacteroides fragilis* in all anaerobic bottles. Later, a fluid and tissue sample from the patient’s knee grew the same species of bacteria. The patient was placed on intravenous antibiotics to fight the infection.

**ABBREVIATIONS:** CT = computerized tomography; NIDDK = National Institute of Diabetes and Digestive and Kidney Diseases; PMNs = polymorphonuclear neutrophils; BUN = blood urea nitrogen; CBC = complete blood count; BAP = blood agar plate; BBE = *Bacteroides* bile esculin; Ref = Reference; Adm = Admission; C = critical result; NA = not applicable; BCC = blood cultures collected

**INDEX TERMS:** *Bacteroides fragilis*; bacteremia; septic arthritis; anaerobic infection; gout

**CASE HISTORY**
A 67-year-old African-American male was admitted to a local hospital two days after seeing his primary physician with the chief complaint of pain in his knee. Since this patient had a history of severe tophaceous gout, his primary physician administered a shot of Depo-Medrol to relieve some of the pain caused by the gout flare. The patient had a history of hypertension and chronic renal insufficiency as well. Besides pain in his left knee, he also was experiencing symptoms of nausea, vomiting, diarrhea, fever and some chills for about a week. After a few more days of not feeling well, the patient was advised to go to the hospital. After his initial blood work came back abnormal, he was admitted to the hospital.

On admission, he was diagnosed with anion gap metabolic acidosis which correlates with the laboratory results in Table 1. The severe anion gap quickly improved after admission, as depicted by the laboratory results from Day 1 in Table 2.

Also striking were laboratory results correlating with acute renal failure. As evident in Table 2, an elevated white blood cell count, as well as a shift in the white cell differential and a high sedimentation rate, most likely encouraged the collection of blood cultures on this patient. Four sets of blood cultures were drawn over two consecutive days. As a result, the laboratory isolated *Bacteroides fragilis* from the anaerobic bottles of all four sets. The patient’s symptoms and laboratory results were consistent with bacteremia as well. Moreover, the patient’s knee was still very painful and swollen, so a physician aspirated synovial fluid. The fluid from his left knee was thick and opaque with a green tint and a foul odor. The purulence

**Table 1. Arterial Blood Gases on Admission**

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Result</th>
<th>*Ref Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH blood</td>
<td>7.29</td>
<td>7.35-7.45</td>
</tr>
<tr>
<td>PCO2</td>
<td>28</td>
<td>35-45 mmHg</td>
</tr>
<tr>
<td>PO2</td>
<td>101</td>
<td>80-100 mmHg</td>
</tr>
<tr>
<td>HCO3</td>
<td>13</td>
<td>22-26 mmol/L</td>
</tr>
</tbody>
</table>

* Ref = Reference
**CHARACTERISTICS OF Bacteroides fragilis**

*Bacteroides fragilis* is an obligate anaerobe which will appear as a gram negative bacillus on a gram stain. It is part of the normal flora of the human gastrointestinal tract. *Bacteroides* species comprise about 30% of the bacterial population in the lower intestine (1). Moreover, *B. fragilis* is the most commonly isolated organism in anaerobic infections (1).

Although this organism is an anaerobe, it can tolerate oxygen and even grow in the presence of nanomolar concentrations of oxygen. Studies have attributed the aerotolerance and oxidative stress response of *B. fragilis* to enzymes which detoxify and protect the bacterium from oxygen radicals. These detoxification enzymes include catalase and superoxide dismutase (3). Interestingly, there are also reports of certain genes for metabolic enzymes on *B. fragilis* that are actually stimulated by oxygen exposure. One such gene is involved in starch utilization (1). One thing is certain: its aerotolerance allows its survival in a spreading infection and contributes to its virulence (3).

Other potent virulence factors include its complex polysaccharide capsule, fimbriae, adhesions, enterotoxin, and proteolytic enzymes. The capsule of *B. fragilis* mediates resistance to death by both complement and phagocytosis, and it initiates the host immune response known as abscess formation. Although abscess formation is an attempt to isolate an infectious organism, it can ultimately lead to further spread of the infection if left untreated. Also, *B. fragilis* may possess peritrichous fimbriae and lectin-like adhesions. These cell surface structures are involved in the adherence of the organism to tissues, hence initiating its destruction. *B. fragilis* enterotoxin in some strains may destroy tight junctions in intestinal epithelium, resulting in diarrhea (3).

**PATHOGENESIS**

Anaerobic infections are usually polymicrobial, and *Bacteroides fragilis* is commonly isolated in such infections. The most common cause is of a gastrointestinal nature because that is where *B. fragilis* is naturally found in humans. Infections by *B. fragilis* are often initiated when the mucosa of the intestinal wall is disrupted, such as in gastrointestinal surgery, perforated or gangrenous appendicitis, diverticulitis, or inflammatory bowel disease. Therefore, the most common infection caused by *Bacteroides* species is intra-abdominal sepsis of the peritoneal cavity surrounding the intestines. If the infection progresses, it can cause further complications such as bacteremia and rarely septic arthritis like the patient described in this case study. If an abscess were to form in the large intestine initiated by the *B. fragilis* capsule, it could expand and cause an intestinal obstruction, erosion of blood vessels, and a fistula to form between organs. If the abscess were to rupture first, it could also result in bacteremia and possibly a disseminated infection (3).

The cause of the bacteremia and septic arthritis by *B. fragilis* in this case study was unclear to the physicians at the hospital. Upon admission, the 67-year-old male received a computerized tomography (CT) scan of his abdomen and pelvis. The CT scan showed an anomaly of both kidneys believed to be a congenital defect, but there was no evidence of hydronephrosis. It also showed a non-obstructive bowel diverticulosis without evidence of acute diverticulitis or an abscess. During his hospital stay, he also received a colonoscopy. Although some areas of the ascending and descending colon were not looked at thoroughly, the examiner noted significant diverticulosis of the left colon and a few diverticula on the right. Furthermore, no lesions were seen.

According to the National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK), diverticulosis increases with age and about 50% of people over the age of 60 have diverticulosis. Diverticula are pouches that bulge outward where the lining of the colon has weakened. A majority of people with diverticulosis do not show symptoms or any discomfort. It is when diverticula become inflamed that symptoms arise corresponding to diverticulitis. Symptoms include abdominal pain, nausea, vomiting, fever, chills, and a change in bowel habits (4). The patient in this case study was experiencing almost all of these symptoms even though there was no CT or colonoscopy evidence of diverticulitis or an abscess.
The significant diverticulosis in the left colon, where *Bacteroides fragilis* is prominent, appears to be the most likely source of this infection. A peritoneal fluid culture may have aided in this investigation. Whether directly or through the peritoneal cavity, *Bacteroides fragilis* spread to this patient’s blood and caused bacteremia. On average, anaerobic organisms cause about 4% of bacteremias (range of 0.5% to 9%). One study shows that incidence of positive anaerobic blood cultures has decreased. However, within those positive cultures, the percentage caused by *Bacteroides fragilis* has increased. This is most likely due to the virulence and increased resistance of *Bacteroides fragilis* to antibiotics compared to other anaerobes (5).

Ultimately, *Bacteroides fragilis* was also cultured from the patient’s left knee. Although septic arthritis is rare, it is more common among patients with a chronic joint condition (3). It becomes clear that this patient is at high risk for septic arthritis because of his history of tophaceous gout. Although it is fairly easy to differentiate between septic arthritis and gout, it becomes more difficult when they coexist. Patients can present with fever, joint pain and swelling in both conditions; therefore, it is important to promptly culture synovial fluid when a joint is acutely inflamed during a gout flare. In general, synovial fluid in septic arthritis has a white cell count greater than 50 x 10^9/L with polymorphonuclear neutrophils (PMNs) exceeding 90% (6).

**CORRELATION OF LABORATORY RESULTS**

At admission, the patient’s chemistry laboratory results correlated with the diagnosis of anion gap metabolic acidosis. He presented to the hospital with a severe anion gap of 32.0 mmol/L, but this was quickly resolved after admission. The arterial blood gas results at admission in Table 1 are consistent with metabolic acidosis because the blood pH was less than 7.35, and bicarbonate was significantly decreased (7). Bicarbonate accounts for a majority of the total carbon dioxide found in blood. Therefore, the decrease in bicarbonate explains the decreased carbon dioxide level present at admission (8). Causes of metabolic acidosis include diarrhea increasing the loss of bicarbonate and renal failure compromising the excretion of acids (7).

More striking in Table 2 was the increase in blood urea nitrogen (BUN) and creatinine after admission, indicating a renal or postrenal condition. In this case, the patient was diagnosed with acute renal failure. Therefore, decreased glomerular filtration due to kidney failure compromised the excretion of urea and creatinine causing elevated levels in the blood (9). Although BUN and creatinine levels remained elevated, they began to slowly decrease over the days to follow. Potassium and carbon dioxide levels also significantly increased from admission to Day 1. Electrolytes such as potassium and carbon dioxide are regulated by the kidneys, so acute renal failure also contributed to their elevation. Moreover, in metabolic acidosis, hydrogen ions replace intracellular potassium ions causing an increase of potassium in the plasma (8).

Hematology results were also significant in this case. The presence of uric acid crystals in two synovial fluids from the patient’s left knee confirmed the presence of gout. The patient’s symptoms, an elevated white cell count with a majority of neutrophils, and an increased sedimentation rate most likely encouraged the collection of blood cultures. Although generalized, the patient’s symptoms of fever, nausea, vomiting, and diarrhea are consistent with sepsis. Complete blood count (CBC) results at admission and over several days are available in Table 2. Neutrophilia is often present in a bacterial infection. This is supported by laboratory evidence in Table 2, which shows a significant increase in neutrophils from admission to Day 1. Deposits of uric acid crystals, which collect in the joints of a patient suffering from gout, attract neutrophils to the site. The release of toxic substances during the process of phagocytosis and death helps mediate an inflammatory process (10). The inflammation in the patient’s knee at the time explains the increased sedimentation rate of 100 mm/hr (11).

A nucleated cell count and differential was also performed on two synovial fluids, one before and one after treatment for the *Bacteroides fragilis* infection was started. The first synovial fluid had a nucleated cell count of 256 x 10^9/L with 99% neutrophils. This is consistent with septic arthritis (6). The second synovial fluid collected after treatment had a significantly decreased nucleated cell count of 30.4 x 10^9/L with 99% neutrophils. The patient’s white blood cell count remained elevated throughout the progression of the infection. In addition, the red blood cell count, hemoglobin and hematocrit results in Table 2 are consistent with anemia.

A total of four anaerobic bottles in blood culture sets, as well as, synovial fluid and tissue from the patient’s left knee, grew the organism *Bacteroides fragilis*. Once received in the laboratory, blood culture bottles were placed in an automated machine. The blood culture machine at this hospital detects bacterial growth via a colorimetric reaction initiated by pH changes caused by the production of carbon dioxide by bacteria. The synovial fluid was directly inoculated onto
the appropriate media, including blood agar, chocolate agar, MacConkey agar, and thioglycollate broth. The tissue was ground up first and then inoculated. Plate media was streaked for isolation of bacteria. Then, the inoculated media was placed in the appropriate incubator set at 35 to 37 degrees Celsius, with or without carbon dioxide. Before going into the incubator, anaerobic plates were placed in either an anaerobic pouch or jar in order to maintain the appropriate environment for the growth of anaerobes (12). Gram stains of the positive blood culture bottles and the synovial fluid revealed a gram negative bacillus. No organisms were seen on the tissue gram stain.

*Bacteroides fragilis* can be cultured with a variety of media. *B. fragilis* grows towards the bottom of the thioglycollate broth because it is an anaerobe, and it only grows on the anaerobic blood agar plate (BAP). Also, this bacterium usually grows on anaerobic BAP supplemented with the antibiotics, kanamycin and vancomycin, indicating resistance. The colonies on anaerobic BAP are white to gray, circular, convex, and nonhemolytic. On *Bacteroides* bile esculin (BBE) agar, *B. fragilis* colonies appear to be light to dark gray and are surrounded by a dark gray zone, indicating esculin hydrolysis. Another characteristic of *B. fragilis*, which aids in its identification, is that it is resistant and therefore grows in 20% bile (12). In addition, rapid identification system kits can be used to identify anaerobic bacteria. The system is based on microbial degradation of various substrates, and a number is calculated based on the reaction results. The number is then entered into a computer program which identifies the organism. The *B. fragilis* isolates in this case were determined to be beta-lactamase positive; no other susceptibility testing was performed.

**TREATMENT**

There are currently no automated methods for determining

### Table 2. Chemistry, Hematology and Microbiology Laboratory Results

<table>
<thead>
<tr>
<th>Analyte</th>
<th>1^Adm</th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>2^Ref Range</th>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BUN</td>
<td>6.8</td>
<td>33.2</td>
<td>24.3</td>
<td>19.3</td>
<td>21.4</td>
<td>2.9-9.3 mmol/L</td>
</tr>
<tr>
<td>Creatinine</td>
<td>150</td>
<td>292</td>
<td>203</td>
<td>221</td>
<td>239</td>
<td>44-106 mmol/L</td>
</tr>
<tr>
<td>Sodium</td>
<td>139</td>
<td>134</td>
<td>133</td>
<td>136</td>
<td>140</td>
<td>135-145 mmol/L</td>
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<tr>
<td>Potassium</td>
<td>3.9</td>
<td>5.9</td>
<td>5.6</td>
<td>5.7</td>
<td>5.7</td>
<td>3.6-5.0 mmol/L</td>
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<td>Chloride</td>
<td>101</td>
<td>110</td>
<td>105</td>
<td>103</td>
<td>107</td>
<td>98-111 mmol/L</td>
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<tr>
<td>CO2</td>
<td>6</td>
<td>16</td>
<td>21</td>
<td>24</td>
<td>25</td>
<td>21-31 mmol/L</td>
</tr>
<tr>
<td>Anion Gap</td>
<td>32.0</td>
<td>8.0</td>
<td>7.0</td>
<td>9.0</td>
<td>8.0</td>
<td>2.0-19.0 mmol/L</td>
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<tr>
<td><strong>Hematology:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>RBC count</td>
<td>4.33</td>
<td>3.69</td>
<td>3.5</td>
<td>3.41</td>
<td>3.18</td>
<td>4.2-5.5 x 10^12/L</td>
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<tr>
<td>Hemoglobin</td>
<td>132</td>
<td>96</td>
<td>95</td>
<td>92</td>
<td>85</td>
<td>130-170 g/L</td>
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<tr>
<td>Hematocrit</td>
<td>0.41</td>
<td>0.30</td>
<td>0.29</td>
<td>0.28</td>
<td>0.27</td>
<td>0.38-0.50 L/L</td>
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<tr>
<td>Platelet count</td>
<td>489</td>
<td>454</td>
<td>505</td>
<td>517</td>
<td>533</td>
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<tr>
<td>WBC count</td>
<td>17.3</td>
<td>12.7</td>
<td>13.1</td>
<td>20.8</td>
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<td>4-10.5 x 10^9/L</td>
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<td>Neutrophils</td>
<td>50.0</td>
<td>87.6</td>
<td>87.9</td>
<td>88.8</td>
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<td>43.0</td>
<td>7.3</td>
<td>5.7</td>
<td>4.6</td>
<td>3.0</td>
<td>16-46 %</td>
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<td>Monocytes</td>
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<td>4.9</td>
<td>6.3</td>
<td>6.6</td>
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<td>1-13 %</td>
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<tr>
<td>Eosinophils</td>
<td>0.0</td>
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<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0-8 %</td>
</tr>
<tr>
<td>Basophils</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
<td>0.0</td>
<td>0.0</td>
<td>0-2%</td>
</tr>
<tr>
<td><strong>Microbiology:</strong></td>
<td>4^NA</td>
<td>NA</td>
<td>2^BCC</td>
<td>2 BCC</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

1^Adm = Admission

2^Ref = Reference

3^C = critical result

4^NA = not applicable

5^BCC = blood cultures collected
the susceptibility of anaerobes; however, three techniques are presently practiced and give reproducible results. These susceptibility methods are agar dilution, broth microdilution panels, and the Etest (AB Biodisk). For treatment of anaerobic bacterial infections, clindamycin is considered to be the gold standard. However, Bacteroides fragilis' antibiotic resistance to clindamycin has increased over the years. It was reported that 26% of B. fragilis strains were resistant to clindamycin in 2000. Moreover, B. fragilis have the highest occurrence of resistance to beta-lactams among all anaerobes because of the production of beta-lactamase. For example, greater than 97% of B. fragilis strains are resistant to penicillin G. Therefore, beta-lactam/beta-lactamase inhibitor combination treatments are usually most effective. In fact, it was reported that nationally less than 2% of B. fragilis strains were resistant in 2000. These combination treatments include ampicillin/sulbactam, ticarcillin/clavulanate, and piperacillin/tazobactam. The most potent of all the beta-lactam agents are three carbapenems including imipenem, meropenem, and ertapenem. Worldwide, less than 0.2% of B. fragilis strains are resistant (13).

The 67-year-old patient with B. fragilis bacteremia and septic arthritis was treated with Zosyn (piperacillin/tazobactam) at first. However, after continuing to spike fevers while on the treatment, physicians placed him on clindamycin instead. Ultimately, the patient was placed on meropenem (1g IV every 8 hours), as recommended by the infectious disease specialist at the hospital. As discussed above, meropenem displays the least resistance among B. fragilis organisms and most likely ensures a successful elimination of the bacterial infection. Four more sets of blood cultures and another synovial fluid culture resulted in no growth and therefore confirmed the antimicrobial treatment worked.

CONCLUSION
When the patient was discharged, he was successfully treated for the Bacteroides fragilis infection in both his blood and left knee. He also had a successful surgery to remove gouty deposits and drain his left knee, relieving the pain and swelling. However, physicians at the hospital could not exactly pinpoint the source of the B. fragilis infection because there was no evidence of diverticulitis, an abscess, or lesion during the CT scan or colonoscopy. Therefore, there is a possibility that this patient could have a recurrent infection.

Clin Lab Sci encourages readers to respond with thoughts, questions, or comments regarding this article. Email responses to westminsterpublishers@comcast.net. In the subject line, please type "CLIN LAB SCI 22(3) TM MARTIN". Selected responses will appear in the Dialogue and Discussion section in a future issue. Responses may be edited for length and clarity. We look forward to hearing from you.

REFERENCES
Integration of the CLS Doctorate into the Healthcare Organization

ISAAC MONTOYA, OLIVE KIMBALL

OBJECTIVE: A review of how the doctorally prepared CLS fits into the healthcare organization.

DESIGN: Literature review.

BACKGROUND: Numerous national studies have called for a reshaping of the health care delivery system and the need to improve patient outcomes. Because of unprecedented advances in laboratory related technology as well as the need for economic retrenchment strategies in health care, with its significant influence on patient care, the laboratory has become the subject of intensive study. It has been concluded that the traditional organizational structure of the laboratory information process and the required personnel skills both need rethinking. In order to foster change in the laboratory, an advanced degreed CLS laboratory professional is needed, one already equipped with a broad scientific base developed via a baccalaureate/masters level of education.

CONCLUSION: With the addition of advanced technical expertise, basic medical skills, data interpretation skills and patient interaction abilities, and medical research experience, this laboratory professional can enhance the effective and efficient use of laboratory information and ultimately improve patient care. The clinical doctorates in CLS are educationally and experientially prepared to recommend support and enhance appropriate testing. They translate and transform complex laboratory data into an understandable product necessary for clinicians to be able to assess the validity of current and new assays to ensure better patient care. In addition, they assist in reducing questionable test usage, thereby reducing costs for both the patient and the laboratory.

INDEX TERMS: Clinical Doctorate, Clinical Laboratory Scientist, Pathologist


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INTRODUCTION

The velocity of change in health care has increased and there is a growing need to shift the emphasis from how laboratory information services are delivered (i.e. test results) to a focus on their direct contribution to patient care.1 Without a significant change in the way that these services are rendered, the increasing personnel shortages at all levels may foster the factory mentality in the laboratory to the detriment of patient care.2 Further, without additional understanding of new testing capabilities and constraints, it may be left to clinicians to rely on outdated and incomplete information when ordering tests. This would increase the use of inappropriate and multiple tests, thus increasing costs.

Addressing these laboratory issues is paramount to improving patient care and is critically important to economic considerations. It is evident that there is no organizational model that previously worked and that now works effectively and efficiently.3 The breadth and depth of laboratory services have dramatically expanded to the point that the need for a new professional with additional professional skills has been demonstrated.4

Laboratory professionals at all levels must be able to provide assurance that the correct test is performed on
the right person, at the right time, as well as that the test produces accurate and timely results. This chain of events enables clinicians to make correct diagnostic and therapeutic decisions using the appropriate level of health care resources. Repeated studies have shown that clinicians and patients may not always be receiving optimal laboratory services because of a significant gap in the provision of these services within the profession. The gap lies between the increasing number of scientific tests available and the lack of expertise to clinically manage the data emanating from these tests.

Because of this gap, the organizational structure of laboratory services and how these services are provided are changing. A perspective of how the doctorate in clinical laboratory science provides a vehicle for this change follows.

BACKGROUND
Traditionally, the laboratory has been recognized as a critical component in the provision of information to clinicians as they assess patient health status. Early on, the pathologist was the singular laboratory professional who provided information to clinicians. More recently, however, the increasing numbers and sophistication of complex tests fostered the need for development of additional professionals who could augment the pathologist’s capability. Now most laboratories of any size have a rich mix of necessary staff at many professional levels. These include technicians, technologists, and scientists at a variety of educational levels. The non doctoral clinical laboratory scientists are the most broadly educated in depth within the laboratory fields and are not confined to addressing one specific discipline. These scientists are prepared to rotate through the many scientific testing fields within the laboratory. They have experience and understand testing protocols for blood bank, chemistry, genetics, hematology, immunology, microbiology, molecular diagnostics and virology. They can assure that the correct test is preformed at the right time producing the best information. However, their expertise is not always requested and clinicians may look only to the data on paper and not appropriately use their professional interpretive capabilities.

The clinical pathologist most often remains the final authority for laboratory test interpretation and, when available is clearly needed for consultation and interpretation. However, as critical as this professional is to laboratory medicine, they are drastically diminishing in numbers at a time when the responsibilities within the laboratory are increasing in complexity. Given a conservative estimate of 2,000 or more possible laboratory tests available to clinicians for interpretation, it is now obvious that clinicians, and to an increasing extent even clinical pathologists, cannot be versed in all tests. While it is reported that 60 – 70% of objective medical decisions are based on laboratory data, inappropriate utilization of testing can range from 10 – 50% of test volume at any given time. This is due in large part to the lack of appropriate laboratory consultation available to clinicians before, during and after testing.

Professional organizations related to the laboratory have been monitoring these issues over time and have developed initiatives to counteract the negative effects projected for patient care. The American Society for Clinical Laboratory Science (ASCLS) developed position papers that proposed a clinical doctorate in CLS to address the future need. The National Accrediting Agency for Clinical Laboratory Sciences (NAACLS) promoted extensive discussion of the changing laboratory roles at several national conferences and invited broad professional input. In 2005 ASCLS appointed a task force to determine the feasibility of such a doctorate. When, after numerous broad based debates, it appeared that the doctorate was needed and generally accepted, NAACLS developed accreditation Standards to be used to carefully evaluate programs producing graduates with these appropriate skills. An exploration of who these doctoral prepared individuals are and how they fit into the clinical laboratory and health care system follows.

Structure and Integration of the Clinical Doctorate
Fitting into the Organizational Structure
Pathologists and other doctorally prepared individuals (e.g. Ph.D. microbiologist, clinical chemist) in the laboratory are engaged in a myriad of focused activities. For pathologists, these include obligations to hospital administration as well as serving on numerous organizational committees. They also include conducting research in addition to their consultation responsibilities in clinical pathology and the overall testing operations within the laboratory.

However, while the Ph.D. prepared individuals are helpful as specialists, they have doctoral education in the specific field and may not have a generalist background to enable them to provide for broad based consultation beyond their field.

The CLS doctorate, prepared with broad generalist education plus the additional medical and information skills, can be
available as the physician's 24/7 consultant. This doctoral graduate is knowledgeable regarding appropriate ordering, carrying out and interpreting tests. It is timely that pathologists recognize what can be shared with well-trained and appropriately credentialed colleagues.

The doctorally prepared CLS can fit into a number of roles within the organizational structure. In the laboratory, the individual may serve as director of laboratories, as the head of a specialty laboratory, or other roles that utilize their expertise (e.g. director of clinical trials testing, director of community education & screening programs, director of new testing methods). Within the healthcare organization, but beyond the laboratory, the individual may:

- serve as an academic officer;
- serve on organizational committees.

Within the community, the CLS doctorate can function in numerous settings such as:

- a reference laboratory;
- a public health department at the local or state level;
- a federal agency (e.g. CDC, FDA, NIH);
- an academic setting;
- private industry;
- a veterinary setting.

**The CLS Doctorate Education**

**Entry Requirements** - Applicants to programs providing education for the CLS doctorate are required by accreditation Standards to be certified and experienced at the generalist level via appropriate certifying agencies. They must have licensure in any state that licenses the clinical laboratory scientist at the baccalaureate or masters level. Applicants must demonstrate proficiency in all major areas of the clinical laboratory as outlined in the Standards.

**Technical Expertise** - At the doctoral level, technical expertise is based upon advanced scientific areas that directly impact patient care. These professionals have expertise to assess the validity of current and future laboratory assays and to institute corrective measures when problems arise. This requires an understanding of 1) principles of test methodology, 2) evaluation of new instrumentation and techniques, and 3) knowledge of appropriate specimen collection and processing.

**Medical Knowledge** - Medicine may best be described as the art and science of healing. The mission of medicine supports a wide range of health care practices aimed to maintain and restore individual and community health through the prevention and treatment. The practice of today's medicine integrates both science and art in combination with scientific intuition in determining the best treatment plan.

Central to medicine is the patient-physician relationship that is established when a person seeks a physician's help. Other health professionals similarly establish a relationship with a patient and may perform various interventions (e.g. clinical laboratory scientists, nurses, pharmacists, and therapists). Working together as a team, many highly-trained healthcare professionals besides physicians are involved in the delivery of modern health care. Examples include but are not limited to nurses, pharmacists, paramedics, speech language pathologists, physical therapists, radiographers, and bioengineers. The scope and sciences underpinning medicine overlap many other fields. For example, dentistry while a separate discipline from medicine, is considered a medical field. Veterinary medicine has also adopted a very similar model of medicine, including using some of the various health professionals described above.

When a patient is admitted to hospital, it is usually under the care of a specific physician or team based on the patient's primary presenting problem, (e.g. internal medicine, cardiovascular, surgery). These physicians may then interact with other specialties, (e.g. radiology, infectious diseases, hematology) to help diagnose or treat the medical issues and any subsequent complications / developments. Two of the specialties that physicians, nurses and others consult with are the clinical laboratory scientist and the pathologist and often their specific expertise may be confused. Their expertise may best be described as:

Clinical laboratory scientists provide the clinical diagnostic services which apply laboratory techniques to the diagnosis and management of patients. The personnel that work in the clinical laboratory are educated in clinical laboratory
sciences. These are the individuals who actually perform the tests, assays, and procedures needed for providing the specific services. Subspecialties include transfusion medicine, clinical chemistry, hematology, clinical microbiology, clinical immunology, virology and molecular genetics. These individuals consult on the appropriate use and interpretation of laboratory test.

Pathology is a medical specialty and is the branch of medicine that deals with the study of diseases and the morphologic and physiologic changes produced by them. As a diagnostic specialty, pathology can be considered the basis of modern scientific medical knowledge and plays a large role in evidence-based medicine.

Since clinical laboratory doctoral graduates function as liaisons between clinicians and the laboratory and can assist in patient assessment, in addition to their basic science understanding, doctoral graduates have considerable exposure to clinical medicine. This is obtained through service on grand rounds as a member of the medical team as well as access to the literature on pertinent laboratory issues related to patient management.15

Health Services Research - Health services researchers examine health care quality, effectiveness, efficiency, patient outcomes, access to care, health care costs, financing, primary and managed care, new technologies, and other critical topics. Health services researchers are employed in many settings, including academia, professional organizations, health policy groups, clinical settings, and in Federal, State, and local agencies.

Clinical laboratory scientists may be employed as health services researchers who focus on some of the most complex and challenging issues currently affecting health care in the world. Findings from health services research inform the health care policymaking process, lead to improvements in clinical practice, and help shape the manner in which health care is to be delivered and paid for in the future.

Structured education in basic science, clinical care, and research methods are fundamental educational components of the doctoral graduate in clinical laboratory science and prepare the individual to integrate these skills into clinical trials and other types of research. The graduates’ strength in research design, statistics, grant writing, as well as knowledge of the protection of human subjects and research ethics are added benefits to managing clinical laboratory data.16

Communication and Policy Development - A variety of opportunities for teaching experiences are required in the education programs for the doctoral CLS. These experiences provide for skills necessary to function in direct patient care with diverse communities of patients and family members as well as with other health care practitioners. There are opportunities to enhance presentations skills and present clinical cases to professional groups.15

In addition, the doctoral CLS will have documented experience in policy development. That includes knowledge in development, interpretation and application of overall health care policy and legislation as they apply to the laboratory and patient care. These would include reimbursement policies, medical liability exposure, licensure, ethics, tort, and patient privacy protection.17

The CLS Doctorates Responsibilities and Relationships
As the presence and understanding of the CLS Doctorate becomes more evident, increasing communication with clinicians must occur. For example, blood bank requires communication with anesthesiologist, blood donors, patients and clinicians. CLS doctorates will follow patients to investigate transfusion reactions and/or screen patients for aphaeresis. In microbiology and hematology, CLS doctorates will attend ‘grand rounds’ with physicians. Since every patient is managed with data from clinical chemistry, there is the potential for a large number of questions and interpretations that CLS doctorates will be able to address in a succinct and professional way.14

For the Pathologists the CLS doctorate fills the gap between the clinician concerned about what tests to order given the patient’s status, and interpretation of results of the test for the clinician. As such they provide significant consultant and educator expertise for the physician. To the undergraduate and masters level CLS professionals they can be mentors and colleagues and serve once again as in-house consultants. For other health professionals (specialty doctorates in the laboratory, nurse practitioners, physician’s assistants, etc.) they can serve as colleagues, educators and consultants. To patients and the general public they are educators and consultants plus givers of care in the broadest sense.7

CONCLUSIONS
The CLS clinical doctorate provides for an individual with a broad generalist’s understanding of the total laboratory assay
functions and impact but with added skills. This emerging professional has broad consulting and teaching skills and the ability to move outside the physical boundaries of the laboratory to function knowledgeably as an integral part of a patient-oriented professional team. They are actively involved in promoting better test ordering, test utilization and test evaluation. All of these are critical components of quality health care. The CLS doctorate’s capabilities can significantly improve patient outcomes and patient safety. In addition they can significantly reduce the overall costs of health care.\textsuperscript{3, 16}

Clin Lab Sci encourages readers to respond with thoughts, questions, or comments regarding this article. Email responses to westminsterpublishers@comcast.net. In the subject line, please type “CLIN LAB SCI 22(3) I MONTOYA”. Selected responses will appear in the Dialogue and Discussion section in a future issue. Responses may be edited for length and clarity. We look forward to hearing from you.

REFERENCES
13. NAACLS Standards for Clinical Laboratory Science Doctorates. 2005

ERRATA: The Spring 2009 volume of Clinical Laboratory Science was published with some misspellings in several locations of the journal. ASCLS and Clinical Laboratory Science regret this oversight in proofing the journal. It is our intent to provide the most professional journal possible for the profession and we apologize to the authors and readership.
Rhodococcus equi Infection in a Surgical Wound

STUART R. PAASCHE

ABBREVIATIONS: ED = Emergency Department; WBC = White Blood Cell Count; BAP = Sheep’s Blood Agar Plate

INDEX TERMS: Rhodococcus equi, surgical wound infections


ABSTRACT: A 35-year-old male presented with abdominal pain one month after receiving a routine ventral hernia repair. Over the course of two months, repeated wound cultures were ordered and eventually produced growth of Rhodococcus equi. Appropriate antibacterial therapy was initiated to resolve the infection.

OBJECTIVES: Review the history, pathogenesis, diagnosis, and treatment of non-pulmonary R. equi infections; inform laboratory professionals of the possibility and severity of R. equi infections, and what can be done to facilitate prompt diagnosis and recovery.

ACKNOWLEDGEMENTS: The author wishes to thank Dr. Susan Leclair and the department of Medical Laboratory Science at the University of Massachusetts, Dartmouth along with the laboratory staff of Jordan Hospital for helping make this case study possible.

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A 35-year-old diabetic male received routine day surgery to repair a ventral hernia. The surgical wound, upon follow-up visits, appeared to be healing properly. One month later, however, the patient presented to the ED with complaints of abdominal pain, after the patient had received an undisclosed minor trauma to the wound, while working outdoors for the local school department. The patient began having occasional feverish episodes along with erythema and the drainage of purulent material from the wound thereafter. There was no evidence of a pathogenic infection in the wound, as cultures yielded only ‘normal skin flora’, which included coagulase negative Staphylococcus and diphtheroids. Cephalexin was prescribed and the patient returned home.

One week later, the patient returned to the ED with what was described as a “non-healing surgical wound.” The wound was cleansed and packed with gauze. With both wound and blood cultures appearing negative for significant bacterial growth, anti-fungal treatment was initiated due to the patient’s continued failure to heal under the antibiotic treatment.

Due to the persistent infection, the wound was surgically re-opened two weeks later, and the infected periumbilical patch was removed by an open approach. A gram stain from a sterile swab of the wound yielded no organisms. Two days later, the patient returned to the ED with severe abdominal pain. Additional microbiological workup was ordered on wound specimens collected using sterile swabs and anaerobic culturettes for both aerobic and anaerobic cultures, along with acid fast stains and cultures. Table 1 outlines the numerous tests ordered along with their corresponding findings.

LABORATORY RESULTS

The area surrounding the surgical wound was largely inflamed and erythemic with purulent discharge coming from the wound site. The patient’s WBC count was slightly elevated at 13.7 x10³/µL (3.9-10.0 x10³/µL), though he was afebrile. Swabs taken from the wound, now over a month after the infection began, grew small, mucoid colonies on BAP, which at nearly 4 days after planting, developed a distinctive pink pigmentation. The colonies were gram-stained and showed long, gram-positive bacilli. An acid-fast stain was performed on the colonies, and the organisms were variably positive.
The organisms were catalase positive, oxidase negative, and urea positive. A CAMP test on BAP was performed using a streak of *Staphylococcus aureus* with a perpendicular streak of the organism in question. A striking zone of beta-hemolysis was noted near the intersection of the two streaks. A Remel™ Rapid CB Plus strip was inoculated yielding a 99.9% identification of *Rhodococcus equi*. The culture was sent to the State Laboratory for confirmation, and a preliminary identification of *R. equi* was reported. The State Laboratory later verified the identification.

**BACKGROUND**

The genus *Rhodococcus* is in the family *Nocardiaceae* in the suborder *Corynebacterineae* of the *Actinomycetales* order. *R. equi* was originally termed *Corynebacterium equi* due to its morphological characteristics representing diphtheroids. It wasn’t until 1980, however, that the organism’s cell wall composition and biochemical reactions were found to be more closely related to *Nocardia* and *Mycobacterium* than *Corynebacterium*, that the genus was changed to *Rhodococcus* (“red-pigmented coccus”).

*Rhodococcus equi* can be found in all continents of the world except Antarctica, and can flourish in both fresh and saltwater environments, and also within the intestines of bloodsucking arthropods. *R. equi*, however, is more commonly associated with zoonotic infections mostly from horses, but also sporadically from cattle, sheep, pigs, goats, deer, dogs, wild birds and even cats. *R. equi* colonizes the gastrointestinal tract of grazing mammals, and can be isolated from the manure and soil. Exposure to *R. equi* can be via the oral route by ingesting products contaminated with soil or manure, inhalation of airborne organisms in dust, or direct inoculation due to trauma with soil or manure containing the organism.

**Table 1:** Wound Cultures and Tests Ordered. There were no issues associated with the surgery, performed on 9/10, and for a month thereafter. However, after the patient received trauma to the wound, perhaps contaminating the wound with dirt, an infection began that persisted for nearly two months. This table outlines the course taken, involving repetitive wound cultures and gram stains, until the final, confirmed ID of *Rhodococcus equi* was reported, and the patient was properly treated allowing for full recovery.

<table>
<thead>
<tr>
<th>Date</th>
<th>Test Ordered</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/5</td>
<td>Wound Gram Stain</td>
<td>Few WBC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No organisms seen</td>
</tr>
<tr>
<td></td>
<td>Wound Culture</td>
<td>Light growth “Skin Flora” (Coagulase negative <em>Staphylococcus</em> &amp; diphtheroids)</td>
</tr>
<tr>
<td>10/12</td>
<td>Wound Gram Stain</td>
<td>Few WBC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No organisms seen</td>
</tr>
<tr>
<td></td>
<td>Wound Culture</td>
<td>Light growth “Skin Flora”</td>
</tr>
<tr>
<td>10/29</td>
<td>Wound Gram Stain</td>
<td>Few WBC</td>
</tr>
<tr>
<td></td>
<td>Blood Culture</td>
<td>No Growth @ 5 days</td>
</tr>
<tr>
<td>10/30</td>
<td>Wound Gram Stain</td>
<td>Few WBC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No organisms seen</td>
</tr>
<tr>
<td></td>
<td>Anaerobic Wound Culture</td>
<td>Light growth “Skin Flora”</td>
</tr>
<tr>
<td></td>
<td>Blood Culture</td>
<td>Few WBC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No organisms seen</td>
</tr>
<tr>
<td></td>
<td>Wound Culture</td>
<td>No Anaerobes Isolated</td>
</tr>
<tr>
<td>11/6</td>
<td>Wound Culture (reference lab)</td>
<td><em>Rhodococcus equi</em> (Preliminary ID reported 11/6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Rhodococcus equi</em> (Confirmatory ID reported on 11/25)</td>
</tr>
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</table>
About 80-90% of patients with *R. equi* infections are immunocompromised. Causes for immunosuppression can range from the most commonly seen AIDS/HIV, to malignancy, transplantation, chronic renal disease, alcoholism, immunosuppressive therapy (including prednisone, azothiopine and corticosteroid therapies) or, as in this case, diabetes mellitus. On rare occasions, however, an infection with *R. equi* may be acquired in the immunocompetent. About 50% of the cases in the immunocompetent patient are due to trauma.

*Rhodococcus equi* infections have ranged from necrotizing pneumonia, to “wound infections, subcutaneous abscess, thyroid abscess, retroperitoneal abscess, peritonitis, osteomyelitis, endophthalmitis, lymphadenitis, lymphangitis, septic arthritis, osteitis, bloody diarrhea, and fever of unknown origin among others.”

*Rhodococcus equi* is a facultative intracellular pathogen. The pathogenicity of *R. equi* is based upon its ability to infect and live within macrophages, inhibiting their phagocytic capabilities, and eventually destroying them. *R. equi* will cause inflammation, cell destruction and purulent granulomas. *R. equi* has the ability to disseminate from an initial infection site to many other sites in the host. Due in part to its intracellular capability, *R. equi* is sometimes difficult to fully eradicate, and is commonly associated with relapse.

Infections with *Rhodococcus equi* are associated with significant mortality due to the difficulty to eradicate the organism. The overall mortality rate of these infections is 25%, 50-55% in HIV patients, 20-25% in non-HIV, immunocompromised patients, and 11% in immunocompetent patients. There are no racial differences in incidence of *R. equi* infections, however, there is a 3:1 male to female ratio, and the mean age of infection is 34-38 years old. The strong prevalence of infection in males of this age group may be largely due to the fact that many occupations susceptible to soil and manure exposure, such as farming and landscaping, are mostly dominated by this population. A history of direct exposure to horses or pigs, however, is only present in one third of all patients with *R. equi* infections.

**LABORATORY IDENTIFICATION**

Due to numerous shared characteristics, *Rhodococcus* is commonly misidentified as diphtheroid contaminant and normal flora, *Mycobacterium, Nocardia, Bacillus, Micrococcus* organisms or even fungi. The organism’s acid-fast nature can commonly result in a misidentification of other acid fast bacterium such as *M. tuberculosis*, which often causes more trouble for the patient’s recovery. More often, however, *R. equi* is overlooked or ignored due to its diphtheroid-like morphology and the slow development of its characteristic pigmentation, often leading to the misdiagnosis as a contaminant. *R. equi* can also be confused with *Nocardia* spp. because of its acid-fast nature, and fungal characteristics, such as the formation of aerial hyphae. A misidentification of *R. equi* could lead to inappropriate antibiotic treatment, and if left untreated, death.

*R. equi* grows well on nonselective media when incubated aerobically at 37°C. On blood agar plates, large, smooth, irregular, mucoid colonies can appear within 48 hours, how-

<table>
<thead>
<tr>
<th>Test</th>
<th>Reaction</th>
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<tbody>
<tr>
<td>Gram Stain</td>
<td>Gram positive bacilli</td>
</tr>
<tr>
<td>Ziehl-Neelsen acid-fast stain</td>
<td>Variably positive</td>
</tr>
<tr>
<td>Motility</td>
<td>Negative</td>
</tr>
<tr>
<td>Catalase</td>
<td>Positive</td>
</tr>
<tr>
<td>Urea</td>
<td>Positive</td>
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<tr>
<td>Alpha-Glucosidase</td>
<td>Positive</td>
</tr>
<tr>
<td>Alkaline Phosphatase</td>
<td>Positive</td>
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<tr>
<td>Nitrate Reduction</td>
<td>Positive</td>
</tr>
<tr>
<td>Oxidase</td>
<td>Negative</td>
</tr>
<tr>
<td>Citrate</td>
<td>Negative</td>
</tr>
<tr>
<td>Indole</td>
<td>Negative</td>
</tr>
<tr>
<td>Esculin</td>
<td>Negative</td>
</tr>
<tr>
<td>“Equi Factors” with CAMP method</td>
<td>Positive (zone of beta hemolysis)</td>
</tr>
</tbody>
</table>
ever less mucoid forms are possible. At 24 hours, colonies can be 1 to 2 mm in diameter, though are not distinctive.\textsuperscript{3} \textit{R. equi} will not grow on most types of MacConkey agar.\textsuperscript{5} Generally, with \textit{R. equi}, a salmon to coral pink pigmentation will develop after 4-7 days of incubation and is rarely seen in cultures < 4 days old, although, the colonies may also be light yellow to colorless.\textsuperscript{2,5,6} As seen in Figure 1, the gram stain of \textit{R. equi} reveals pleomorphic, gram-positive bacilli varying from coccoid to long, curved, clubbed forms, often resembling diphtheroids.\textsuperscript{2} Gram stains made from cultures on solid media, or purulent material from the patient will often show more coccoid forms, however long rods and branching filaments may be observed in stains made from liquid media.\textsuperscript{5} The organisms may be acid-fast with the Ziehl-Neelsen stain, however, this too depends on its growth media and the age of the culture.\textsuperscript{2} \textit{R. equi} is non-motile, non-fermentative, and positive for catalase, urease, alpha-glucosidase, alkaline phosphatase and nitrate reduction, but is negative for oxidase, indole, citrate assimilation and esculin hydrolysis.\textsuperscript{1} \textit{R. equi} has been known to produce “equi factors” that interact with the beta-toxin of \textit{Staphylococcus aureus} to produce a zone of beta-hemolysis that can be observed using the CAMP technique on BAP.\textsuperscript{2} (Fig. 2). Table 2 summarizes \textit{R. equi}’s different reactions to numerous laboratory tests.

**TREATMENT**

\textit{Rhodococcus equi} is frequently difficult to treat due to its ability to thrive within the macrophage thus inhibiting its bactericidal functioning. \textit{R. equi} is, however, susceptible to erythromycin, ciprofloxacin, vancomycin, aminoglycosides, rifampin, imipenem, and meropenem. Resistance has been observed to penicillins, ampicillin, carbenicillin and treatment is not suggested with such drugs, even if the organism appears susceptible, as rapid acquisition of resistance is possible.\textsuperscript{2,6} \textit{R. equi} has also shown moderate resistance to both first and second-generation cephalosporins.\textsuperscript{2,5} It is often recommended to treat \textit{R. equi} infections using a synergistic approach, with drugs such as erythromycin and rifampin together.\textsuperscript{2} Antibiotics and lipophilic drugs with intracellular penetration capabilities are the most beneficial in treating these infections.\textsuperscript{2} Failures in treatment have been associated with the poor penetration of macrophages by drugs such as gentamicin and penicillin.\textsuperscript{2} Many patients suffering from an infection with \textit{R. equi} should receive intravenous antibiotics for a minimum of 2 weeks, after which oral antibiotics can be substituted and continued, as long as positive cultures and symptoms have resolved.\textsuperscript{6}

**Figure 1.** \textit{Rhodococcus equi} gram stain at 1000x, showing gram positive bacilli which appear similar to diphtheroids in morphology.

**Figure 2.** CAMP test for cholesterol oxidase produced by \textit{R. equi}. R = Rhodococcus; S = lecithinase producing, hemolytic \textit{Staphylococcus aureus}. Arrows point to additional zones of beta-hemolysis where secreted cholesterol oxidase works with lecithinase secreted by the \textit{Staphylococci} to cause hemolysis of sheep RBCs in the media.

From Lynn Bry, M.D., PhD. available at http://labmed.bwh.harvard.edu/microbiology/teaching/cases/bacteriology/rhodococcus. Used with permission.
DISCUSSION

This case classically defines the difficulties involved with the proper identification and treatment of Rhodococcus equi infections. Retrospective analysis of this case allows us to follow the diagnosis process; from a possible bacterial infection which failed to heal after treatment with cephalexin, to the question of a fungal invasion which failed to improve. We can now see why R. equi did not dissipate initially, as cephalexin is a first-generation cephalosporin, to which it was resistant. Finally the diagnosis of Rhodococcus equi was established, and was found to be susceptible to the prescribed doses of erythromycin. With the appropriate treatment, the patient was able to successfully eradicate the persistent infection that lasted over 2 months.

The difficulty in identification of a Rhodococcus equi infection lies in its ability to mimic other, more common, organisms. In this case, due to various reasons, there was a delay in finalizing the latest wound culture beyond 3 days, which was laboratory policy for wound cultures that were not producing any pathogenic growth or appeared to be contaminated with just skin flora. Since the characteristic pink pigmentation of this organism didn’t develop until the fourth day of incubation, this delay, in turn, helped lead to the identification of R. equi. It is likely that R. equi was present in the previous cultures, but misidentified as normal skin flora, as they were all completed within 3 days, too soon for the pigmentation development needed to catch the eye of the laboratory scientist.

It is because of misidentification that R. equi can be so dangerous. According to the European Journal of Clinical Microbiology and Infectious Disease, “during the past decade an increase in the incidence of reported human R. equi infections has been noted, possibly because of greater attention being given to this pathogen, but certainly also because of the rising number of immunocompromised patients”1. The ability for laboratory professionals to properly recognize this organism, and produce, at minimum, a preliminary identification pending confirmation, will eliminate time needed to determine the proper treatment for the patient. Together, with appropriate laboratory work-up facilitating the physician’s selection in proper treatment, a potentially dangerous organism can be easily eliminated and the patient cured.

Clin Lab Sci encourages readers to respond with thoughts, questions, or comments regarding this article. Email responses to westminsterpublishers@comcast.net. In the subject line, please type “CLIN LAB SCI 22(3) SR PAASCHE”. Selected responses will appear in the Dialogue and Discussion section in a future issue. Responses may be edited for length and clarity. We look forward to hearing from you.

REFERENCES


SUGGESTED READING

A Practical Approach to Master’s Level Clinical Laboratory Science Education

LINDA ROSS, LEILANI COLLINS

ABBREVIATIONS: Clinical Laboratory Science (CLS), Master of Science (MS), Bachelor of Science (BS), University of Tennessee Health Science Center (UTHSC), Medical Technology (MT), Medical Laboratory Technicians (MLT), Grade Point Average (GPA), Advanced Practice (AP)

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INTRODUCTION AND RATIONALE

In 2002, Beck and Doig surveyed laboratory managers, educators, practitioners and students to assess the need for a career entry-level Master of Science (MS) degree in Clinical Laboratory Science (CLS). Survey results indicated that educators, practitioners and managers agreed that the scope of CLS practice did not warrant an entry-level MS degree. Students, however, indicated that they would be interested in an entry-level MS in CLS if it led to higher pay and additional job opportunities. Students with a previously earned baccalaureate degree expressed more interest in the entry-level MS than those without the degree. The authors suggested that in an era of laboratory manpower shortages, clinical laboratory science educators should consider multiple career entry choices to attract potential students into the profession.¹ Li et al determined that clinical laboratory practitioners with advanced degrees had higher salaries, greater job mobility and increased management authority. Master of Science degree recipients had authored more external publications and made significant professional contributions as compared to their baccalaureate level colleagues.²

In July 2005, the American Society for Clinical Laboratory Science (ASCLS) commissioned a task force to examine practice levels and the educational needs of clinical laboratory personnel. Development of a comprehensive career ladder was among the goals of the task force. The new practice model will help establish new standards of practice through a national career ladder model with multiple points of entry and advanced levels of practice.³⁴

The University of Tennessee Health Science Center is an academic health science center that offers health education programs in medicine, dentistry, nursing, pharmacy, and allied health sciences. Students take pre-requisite courses at other colleges and universities. The Department in Clinical Laboratory Sciences offers a BS degree in Medical Technology (MT). The UTHSC baccalaureate degree program in medical technology is a 2 + 2 program that is 21 months in length with clinical rotations integrated throughout the curriculum. Program capacity is 20 students in each year of the program. Potential applicants to the MT program are recruited from area colleges and universities. Competition exists for good science students and the faculty and advisors of the “feeder institutions” are reluctant to promote the UTHSC medical technology program because of the potential loss of students and tuition dollars. As the number of applicants for the Medical Technology program decreased, multiple options for attracting students were considered. These included an option for medical laboratory technicians (MLT) to complete a BS degree in MT. While that option does improve the skills and training of individuals, it does little to alleviate the personnel...
shortage since it does not increase the number of laboratory practitioners in the field. Online programs were considered but the faculty discussed the difficulty of teaching the visual arts of hematology and microbiology online and there was concern about maintaining the program's high standards. The faculty also discussed the practice in universities of having bachelor/master students or master/doctoral students enrolled in the same course with additional assignments made for the higher degree.

Medical Technology program officials noted that often the entering medical technology students had previously earned a BS degree in the sciences. (Table 1) Many qualified potential applicants expressed an unwillingness or the financial inability to complete a second baccalaureate degree but were enthusiastic about pursuing a graduate degree. On inquiry, it was found that additional financial aid is available to students in graduate programs.

Upon consideration of all these factors, the University of Tennessee Health Science Center (UTHSC) Program in Medical Technology developed an option for students who have earned a baccalaureate degree in biology, microbiology or chemistry from a regionally accredited college or university and desire national certification as a MT/CLS. The career entry-level Master of Science program graduates laboratorians with advanced practice skills and provides value-added graduates in the workforce. Despite the lack of broad support nationally to change career entry practice from the BS to the MS level, there is need for graduates who can think critically and who can apply higher level cognitive skills to today's problems. Although career entry-level salaries are similar for both the BS and MS graduates, UTHSC medical technology faculty anticipated that the "value-added graduate" would be recognized early in their career and that employers would see the potential of these graduates to assume leadership roles in the laboratory. Furthermore, the chance to ascend a career ladder could lead to job enrichment and retention of practitioners in the medical laboratory profession.

**CURRICULUM PLAN**

UTHSC program officials consulted with the CLS faculty of Rush University, Chicago, IL and Louisiana State University Health Science Center, New Orleans, LA where similar programs existed and thrived. With the advice and the experiences of faculty in these programs, the UTHSC BS curriculum was modified to include graduate level content.

Students in the new career-entry option earn a Master of Science in Clinical Laboratory Science following 24 months.

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**Table 1. UTHSC Enrollment Data**

<table>
<thead>
<tr>
<th>BS Program in Medical Technology – 21 months</th>
<th>Class entering</th>
<th>MS in Clinical Laboratory Science Program – 24 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applicants</td>
<td>17</td>
<td>14</td>
</tr>
<tr>
<td>Enrolled</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Previously Earned B.S.</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>% with BS</td>
<td>66%</td>
<td>33%</td>
</tr>
<tr>
<td>BS MT Graduates</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>MS in CLS Graduates</td>
<td>7</td>
<td>5</td>
</tr>
</tbody>
</table>

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of study. Students interested in the MS degree apply for admission to the BS program initially. In addition to their BS degree requirements, qualified applicants must meet requirements for admission to the BS program including successful completion of a minimum of 30 pre-requisite semester hours in the math and science courses that are required for medical technology students in the state of Tennessee. (Tennessee law requires medical laboratory personnel, facilities and training programs to be licensed.) After admission to the program, students who desire entrance to the MS program take all courses with BS students and must complete forty-four (44) semester hours of the undergraduate professional medical technology courses. A cumulative GPA of 3.0 or higher on a 4.0 scale must be maintained for a student to be considered for admission to the MS program. The professional behavior of these students based on performance in classes and student labs is assessed by the faculty. The evaluation includes attendance, punctuality, attitude, adherence to policy, class participation, and timeliness of assignment completion. Additionally, students eligible for the MS program write a short essay expressing their desire to change their status from BS to MS and a willingness to perform the extra assignments involved. There is no mechanism for returning to the BS status, so students are made aware of this policy and sign a contract attesting to their understanding. Students who have successfully met these requirements are admitted to the Advanced Practice (AP) track in the Medical Technology program beginning in the second year. (Table 2)

Second year courses focus on a case-based approach to laboratory medicine and patient care as laboratory data is integrated across disciplines with patient history and physical findings. Master’s level courses are taken with the BS students in the second year but have higher cognitive level learning objectives to improve the learner’s critical thinking and problem solving skills. To achieve these objectives, graduate students have additional assignments in each didactic course and clinical rotation. These assignments include, but are not limited to: additional reading assignments, essay type test questions, journal article critiques, case study presentations, research papers and independent learning assignments. Advanced Practice (AP) graduate students complete all BS coursework and have additional learning opportunities in management and education with online exercises. The Molecular Diagnostics course for AP students includes two weeks of clinical experience in molecular laboratories instead of the one week requirement for BS students. In the research methods course, students critically analyze current journal articles and are given additional writing assignments. Advanced Practice graduate students have the opportunity to develop presentations and improve their presentation skills. For example, in Hematology, each student must determine a diagnosis based on case history and differentials on peripheral blood and bone marrow specimens. They prepare a case presentation for fellow students and faculty. While on their clinical rotation in the hematology laboratory, graduate students are required to present their hematology case study as a continuing education session for the hematology laboratory staff at their rotation site.

During the Winter/Spring semester of the second year, graduate students begin work with a faculty mentor on a four-week Master’s level project which is subsequently written in a format suitable for publication in a clinical journal. Projects are presented to faculty and fellow students upon completion. Having met all the requirements for national certification examinations and laboratory personnel licensure in Tennessee in late summer, graduate students are eligible for employment.

### Table 2. UTHSC requirements to enter the MS in CLS advanced practice program

<table>
<thead>
<tr>
<th>Requirement</th>
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</thead>
<tbody>
<tr>
<td>1. An earned BS degree in biology, chemistry or a related field including all pre-requisite courses</td>
</tr>
<tr>
<td>2. Cumulative GPA of 3.0 or higher in first year BS medical technology coursework</td>
</tr>
<tr>
<td>3. Letter of intent to enter the MS in CLS AP program</td>
</tr>
<tr>
<td>4. Signed acknowledgment of the requirements of students in the graduate program</td>
</tr>
<tr>
<td>5. Positive faculty assessment of professional behavior</td>
</tr>
</tbody>
</table>

**PROGRAM CONCERNS AND SOLUTIONS**

Implementation of a novel program and curriculum has not been without issues.

1. Concerns were expressed by the UTHSC Registrar and Financial Aid officials. UTHSC Registrar’s Office staff was concerned that while initially enrolled in the BS in medical technology program, students who met the criteria for the AP track were shifted to the MS program after 12 months. Different course numbers and course descriptions had to be developed for the MS level courses. Frequent communication with the Registrar and her staff over the past two years, including providing a list of students accepted in the AP...
track and a list of specific courses in which they are enrolled each semester, has minimized problems. Initially unknown to program officials, graduate students must be enrolled in 9 semester hours or more to receive federal financial aid so the second year summer/fall semester was developed with 10 semester hours to allow qualified students to receive federal financial aid.

2. Originally, first year clinical rotation grades were included in the GPA calculations of the AP class which allowed two minimally qualified students with borderline GPAs to enter the MS program. When it was realized that there was limited consistency in the clinical laboratory experience as far as testing of students and types of patient specimens encountered, the decision was made not to include the rotation grades in the GPA requirement for the AP program. Currently, the students’ cumulative GPAs are considered after the first two semesters of didactic courses which include lecture and student lab.

3. After the second year of the program it was decided that an assessment of student’s professional behavior and attributes should be completed by the didactic faculty to assure that students demonstrate the acceptable professional demeanor required of a graduate student in clinical laboratory science.

4. Clinical instructors discussed feeling a bit threatened by career entry-level MS students. They expressed concerns that new graduates with a MS degree might command higher entry-level salaries and voiced apprehension that new MS graduates would become laboratory supervisors early in their career. MT program faculty assured them that the MS graduates were career entry-level technologists and that they needed 4 years of clinical experience and continuing education to become eligible for a laboratory supervisor license in the state of Tennessee. Dialogue among laboratorians, lab managers and program educators has alleviated the concerns of the clinical instructors and laboratory staff.

5. Still being considered are the questions of the program’s recourse if a graduate student does not maintain a GPA of 3.0 or higher while in the program or if a graduate student demonstrates a lapse in professional conduct. At this time, students will be considered by the progress and promotions committee of the program on a case-by-case evaluation.

6. The Graduate Record Examination (GRE) is under consideration as a requirement for the MS in CLS Advanced Practice program.

OUTCOMES
Since the acceptance of the first group of students into the AP program in 2006, support and approval has been strong with positive outcomes in the quality and quantity of applicants. There has been wide acceptance for the MS in CLS Advanced Practice Program from faculty and advisors from feeder institutions and these individuals now recruit students for the program. The opportunity for students interested in laboratory science to obtain a Master’s degree has led to an increase in viable applicants, near capacity enrollment and an alternate list of candidates into the program. Scores of AP graduates on national registry examinations have been >9% higher than BS students in the two classes that have graduated. (Table 3) Laboratory managers and supervisors have noted the potential for the MS in CLS graduates and have promoted some to higher level positions, such as the MT II level, with only one year of experience instead of the 2-3 years usually required of a BS medical technologist. Graduates of the AP track have had job opportunities in laboratory information systems, point of care testing coordination, compliance and higher education.

CONCLUSION
Development of the career-entry Master of Science in Clinical Laboratory Science Advanced Practice program at the University of Tennessee Health Science Center has proven its worth in a brief time. The offer of a MS degree in CLS has led to greater student interest, increased enrollment and employer acceptance and support. Future plans include a survey of employers of AP graduates to determine if a difference in BS and MS prepared clinical laboratory scientists exists, as well as a survey of the AP graduates themselves to assess their preparation and readiness to assume laboratory leadership roles. As noted previously, during a time of national laboratory workforce shortage, a choice of career entry

<table>
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<tr>
<th>Table 3. Mean certification exam scores</th>
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<tbody>
<tr>
<td>Graduates</td>
</tr>
<tr>
<td>2007</td>
</tr>
<tr>
<td>ASCP BOR-BS</td>
</tr>
<tr>
<td>ASCP BOR-AP</td>
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<tr>
<td>% difference</td>
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options helps draw potential students and prepare them for their careers in the 21st century clinical laboratory.

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Warfarin Pharmacogenetics: Ready for Clinical Utility?

LINNEA M BAUDHUIN

ABBREVIATIONS: CYP2C9 = cytochrome P450 2C9; INR= international normalized ratio; PGx = pharmacogenetic; VKOR = vitamin K epoxide reductase; VKORC1 = vitamin K epoxide reductase, complex 1; AERS = Adverse Event Reporting System

INDEX TERMS: pharmacogenetics, warfarin, CYP2C9, VKORC1

Despite the reservations about warfarin PGx testing, there are several subsets of patients for whom such testing could be beneficial.

BACKGROUND

Warfarin sodium is a commonly prescribed anticoagulant used for the prevention of thromboembolic events and treatment of thromboembolic disorders. The annual number of outpatient warfarin prescriptions increased by 45% from 1998 to 2004 in the U.S., from 21.1 million to 30.6 million. With the aging population and projected increased prevalence of atrial fibrillation, the number of warfarin prescriptions is predicted to continue to increase.

There are many challenges in regulating warfarin dosing. Warfarin has a very narrow therapeutic window and when the prothrombin time or INR falls outside of target range, there is an increased risk for major bleeding or thrombotic complications. Typically, the INR during warfarin treatment should optimally fall between two and three for most patients, although the target INR may vary depending on indication for treatment. A large study demonstrated that the minimum number of deaths and brain vessel events occurs at INRs of 2.24 and 2.38, respectively. Warfarin is the most frequent drug implicated in U.S. emergency department visits. From 1993 to 2005, based on data from the FDA’s Adverse Event Reporting System (AERS), warfarin-associated cases had rates of 86% for bleeding with serious outcome and 10% fatal bleeding. This is in contrast to all drugs reported to the AERS for that same period in which 30% of the cases had serious outcomes and 7% had fatal outcomes.

Warfarin therapy often requires multiple titrations to achieve a stable, target INR. There is a large inter-patient range of warfarin dosing requirements, with doses on the low end of the range associated with warfarin sensitivity and doses on the high end of the range associated with warfarin resistance. Age, weight, concomitant medications, co-morbidities, and genetics, play into the variability of warfarin dosing; many of these are related to the metabolism of warfarin.
Genetics is an important factor in warfarin dosing variability, especially as it relates to warfarin sensitivity. Using clinical factors alone, one study demonstrated the ability to control 17–22% of warfarin dosing variability; when genetic factors were added, 53–54% of warfarin dosing variability was abrogated. Other studies have shown the genetic contribution to warfarin dosing variability to be as high as 40%. Because of the relatively high contribution of genetics to warfarin dosing variability, in addition to other factors, the FDA relabeled warfarin in August 2007 to recommend PGx testing for warfarin therapy.

**WARFARIN PHARMACOGENETICS**

Warfarin is a racemic mixture of S- and R-enantiomers, with S-warfarin providing about 70–80% of its activity. Most S-warfarin is metabolized by the cytochrome P450 enzyme CYP2C9, which is encoded for by the CYP2C9 gene. Two polymorphic regions in CYP2C9, *2 (Arg144Cys) and *3 (Ile359Leu), are associated with warfarin sensitivity. These polymorphisms lead to decreased CYP2C9 enzymatic activity, resulting in slower S-warfarin clearance, longer half-life of S-warfarin and a prolonged interval to steady state. As vitamin K antagonists, both R- and S-warfarin inhibit vitamin K epoxide reductase (VKOR), encoded for by the vitamin K epoxide reductase, complex 1 (VKORC1) gene. A common VKORC1 promoter polymorphism at 1639G>A, resulting in decreased promoter activity and decreased production of VKOR, is associated with warfarin sensitivity. Another gene, CYP4F2, has recently been described to contribute to an approximately 1 mg/day decrease in necessary warfarin dose between wild type individuals and those with the variant allele. Other genes have additionally been implicated in contributing to warfarin dosing variability, but on a much smaller scale than CYP2C9 and VKORC1. Most of the current state of knowledge regarding warfarin pharmacogenetics relates to warfarin sensitivity attributed to CYP2C9 and VKORC1, and several clinical laboratories now offer PGx testing for warfarin sensitivity based on these polymorphisms.

Meanwhile, interest in the genetic basis for warfarin resistance is gaining momentum. A recent report demonstrated that VKORC1 variants associated with warfarin resistance occur at a higher frequency than previously thought. With increased evidence for genetic bases for warfarin resistance, PGx testing in this arena may eventually become a reality.

**CLINICAL UTILITY OF WARFARIN PGX**

**Clinical Outcomes.** Whether warfarin PGx testing reduces clinical complications and shortens time to stable INR will likely have a major impact on its uptake in the clinical setting. Multiple retrospective analyses have demonstrated associations between CYP2C9 and/or VKORC1 variants and bleeding risk. Other studies have not shown an association, however, many studies failed to consider the cumulative effect of CYP2C9 and VKORC1 variants. Schalekamp et al demonstrated heterozygous carriers of VKORC1 and CYP2C9 variants have a much higher risk of severe over-anticoagulation, compared to individuals with none or one variant. The cumulative effect of CYP2C9 and VKORC1 variants on time to first INR >4 has also been illustrated.

A prospective, randomized controlled trial by Caraco et al, investigated outcomes in 185 patients with CYP2C9 genotype-informed vs. genotype-uninformed warfarin therapy, from initiation of dosing through stabilization of therapy. Individuals with CYP2C9 genotype-guided therapy reached a shorter interval to first therapeutic INR (2.73 days, *p*<0.001) and stable anticoagulation (average of 18 days earlier, *p*<0.001), longer time spent in the therapeutic range (80.4 vs. 63.4%, *p*<0.001), and a lower bleeding incidence (3.2 vs. 12.5%, *p*<0.02), compared to the genotype-uniformed group.

Percent out-of-range INRs from another prospective, randomized controlled trial did not differ significantly between genotype-guided vs. genotype-uninformed treatment arms for the entire study population (*n*=200). However, results were significantly different between wild-type and multiple variant carriers, and the genotype-guided treatment arm required fewer and smaller dose adjustments and fewer INR measurements compared to the genotype-uninformed treatment arm.

While many studies have demonstrated associations between CYP2C9 and/or VKORC1 variants and, for example, bleeding risk or out-of-range INRs, there is still controversy regarding these studies. Additionally, the two randomized controlled trials performed to date had small study populations and had some conflicting results. Thus, it is clear that large, multicenter randomized controlled trials are needed to more accurately determine whether pharmacogenetic-guided warfarin treatment has a significant impact on clinical outcome.

**Impact of timing.** There is disagreement about whether optimal warfarin dosing should include genotyping prior to initiation of therapy. Variants in CYP2C9 and VKORC1 may affect the time for plasma warfarin concentration to achieve therapeutic levels (VKORC1) and steady state (CYP2C9).
Reynolds et al maintain that it is not critical to incorporate genotyping results into the initial warfarin dose estimate because of delayed time to steady state due to CYP2C9 variants. However, the impact of the timing of CYP2C9 and VKORC1 genotyping is probably not yet fully understood, and whether incorporating genetic information into the initial warfarin dose is ultimately beneficial for the patient remains to be determined. Nonetheless, limits in technology and resources may prohibit many laboratories from providing one-day turnaround for pharmacogenetic tests. Additionally, many hospitals and clinics rely on send-out pharmacogenetic testing. Thus, at the present stage, genotyping results will likely be available on days 2-4 following specimen receipt.

Genotype-guided warfarin dosing. Although CYP2C9 and VKORC1 variants are associated with warfarin dose variability, there is no current clinically validated dosing algorithm that incorporates genotype. However, many research-based dosing algorithms that incorporate clinical and genetic factors have been developed and published. Some may fail to account for all genotypes (e.g. CYP2C9 *1/*2 vs. *1/*3), genes (e.g. CYP2C9 and VKORC1); and they may not include logarithmic transformation for warfarin dose. In addition, many dosing algorithms apply to only one ethnic or racial group, reflecting the variable allele frequencies among such groups.

Despite these limitations, warfarin dosing algorithms that incorporate genetic information have been shown to predict up to 62% of the variability in warfarin dosing. By reviewing INRs after three warfarin doses, up to 79% of warfarin dosing variability can be controlled by an algorithm (found at www.warfarindosing.org). This algorithm was developed on data from 1015 patients and was prospectively validated in 292 additional patients. It is comparatively comprehensive in the clinical and genetic factors it accounts for; further, it allows for the inclusion of INR values with or without genotyping information.

Studies examining clinical outcomes related to prospective dosing of warfarin based on genetic and non-genetic factors are limited. For example, a recent prospective study evaluating a dosing algorithm incorporating CYP2C9 and VKORC1 genotypes and clinical parameters in a warfarin naïve Hans-Chinese population improved time to stable INR and reduced adverse events with the evaluated dosing algorithm. However, this study lacked a control group of non-pharmacogenetic dosed individuals. Thus, while many pharmacogenetic-based dosing algorithms are available, in order to assess whether these algorithms result in improved clinical outcomes, large randomized controlled trials are necessary.

PUTTING WARFARIN PGX TESTING INTO PRACTICE

Despite many of the unanswered questions and gaps in knowledge regarding warfarin PGx testing, there have been many published examples in which such testing has been proven to be beneficial. Furthermore, while standard of care is questionable, there are also several subgroups of patients for whom warfarin PGx testing could be considered currently. First are individuals with a family history of difficult warfarin titration. These individuals are more likely to have a genetic predisposition to warfarin sensitivity (or resistance). Second are pre-surgery patients receiving total joint or valve replacement whose circumstances, including altered diet, concomitant medications, and inactivity, could confound warfarin dosing variability in this group of patients. By genotyping these patients, at least approximately 30-40% of the dosing variability could be controlled for. Furthermore, genotyping can be performed prior to initiating warfarin treatment in this set of patients, thereby providing for more optimal pre-treatment counseling. A third group of individuals for whom warfarin PGx testing could be beneficial in its current state are individuals who may have a longer wait until their first INR measurement because of the timing of their initial visit to the coagulation clinic (e.g. before a weekend or holiday). A fourth group of individuals might be non-local patients who will be returning to their local setting where their follow-up care is uncertain. Thus, while limited clinical outcomes data has supported warfarin PGx testing for routing clinical care, certain subpopulations of patients could benefit from genetic testing.

CONCLUSION

As described previously, the three main hurdles to translating validated PGx markers into clinical practice are Reluctance, Regulation, and Reimbursement. Warfarin PGx is certainly no stranger to the three Rs, and until clinical outcomes data and other important issues as described above can be better addressed, it is likely that warfarin PGx testing as standard of care will remain controversial. Proven clinical utility in multiple patient populations using clinically validated dosing algorithms will help determine whether or not warfarin PGx testing will become part of standard clinical practice. In the meantime, genotyping of specific subgroups of patients being initiated on warfarin therapy could prove beneficial.
REFERENCES


OBJECTIVE: To determine the effects of incorporating a blood center tour in the immunohematology course on the confidence and knowledge of students

DESIGN: In-class lecture on the major blood center activities and tour of the Red Cross. Pre- and post- tests administered. To compare levels of understanding, confidence and overall tour impact, paired T-test and Chi-Square analyses were performed and frequencies calculated.

SETTING: Medical Technology program at Austin Peay State University, Clarksville TN American Red Cross in Nashville TN

PARTICIPANTS: Fifteen students who registered in immunohematology course.

INTERVENTION: Two phases: First, a brief introduction, description and observation of the donation activities. Secondly, explanations and observation of blood components preparations, labeling, storage, distribution, and quarantine. Both phases included question and answer sessions.

OUTCOME MEASURES: Comprehension of blood center activities; self confidence; increase knowledge of job alternative.

RESULTS: Students showed an increase in course content knowledge; 62% on the pre-test and 69% on post-test (P=0.004). Although the post-test score was better than the pre-test, 69% is not a great score. Students probably did not take the exam seriously since there was no grade involved. More students felt good (40%) about their confidence in facing the blood bank clinical rotations and ultimately the national certification exam. The tour perfectly complemented lectures. Interaction with other medical technologists was very informative (53%). Levels of understanding of major blood center activities increased (P<0.05) except for the phlebotomy stage (P=0.07).

CONCLUSION: A blood center tour incorporated into the immunohematology course is a valuable addition to the learning experience of students. Students have the opportunity to interact with employees in their workplace, with potential employers, and they build self confidence in the subject area.

ABBREVIATIONS: MT=medical technology

INDEX TERMS: Blood center tour, job alternative, confidence


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INTRODUCTION
Clinical rotations in Medical Technology (MT) programs are an asset to students. Students traditionally rotate through four departments: hematology, blood bank, chemistry and microbiology. These rotation sites, not only expose students to valuable experiences, but also enable them to interact with potential employers and colleagues.1,2 Clinical rotations have been shown to increase hiring opportunities for students.2 A high percentage of students eventually work at the sites where they did their rotations.3,4 One area that has been underexplored by some MT programs is incorporating blood centers rotations into the curriculum. Blood centers screen donors,
draw donor blood, perform tests, process donor units, label and store these products at appropriate temperatures. These units are then distributed to hospitals. On the other hand, most hospital blood banks, where students do their clinical rotations, purchase the blood products; hence, no extensive processing is experienced.

Often, students are only lectured on blood centers activities as described above, so they can only imagine what happens and answer questions on class exams. As a result, students do not fully appreciate how these processes are conducted. Students only see the already prepared and labeled components in the hospital refrigerators, counter tops and freezers when they complete their hospital blood bank rotation, but they never see how these neatly packaged components are prepared. Hence this study is vital to determine the effects of having a blood center tour on students’ confidence and knowledge.

Some university and hospital-based clinical laboratory science programs have their students tour blood or tissue centers. Students in most programs do not tour blood or tissue centers for many reasons including a lack of time in the schedule for extra “field trips”, distance and/or lack of cooperation of personnel at the blood center. The MT program at Austin Peay State University is one of those programs that did not incorporate visits to blood centers in its curriculum. It is understandable that carving out the time for rotations to blood centers may be a problem since time is always limited. On the other hand, scheduling a tour to a blood center might be beneficial to students and so it could be “time well spent”. This study examined the effects of incorporating a blood center visit into the immunohematology course.

This study was designed to answer the following questions:

- Will incorporating a blood center tour in the immunohematology course lead to greater comprehension of blood and blood component processing?
- Will this experience increase students’ confidence both for their blood bank clinical rotation and for the national certification exams?
- Is this tour able to increase job alternatives?

**MATERIALS AND METHODS**

This study was approved by the Austin Peay State University’s Institutional Review Board. The blood center chosen was the American Red Cross facility in Nashville, which serves several counties in Tennessee. This blood center was especially chosen because of its proximity to Clarksville, Tennessee. Pre- and post-tests and questionnaires were administered to students.

**Participants and setting**

All fifteen students who registered for the immunohematology class participated in the study. They all signed informed consent forms, which were then securely kept in a locked file cabinet in the departmental office.

**Method**

Prior to the tour of the Red Cross, the donation, preparatory and storage processes of blood and its components were discussed in class using powerpoint slides with pictures included. Pre- and post-tests and questionnaires were administered to assess comprehension of blood donation, preparation of components, appropriate storage conditions and confidence level of the tour before and after the visit in preparation for the blood bank clinical rotation and the certification exam. The pre- and post-tests each had twenty five multiple choice questions. These questions were designed to assess content knowledge level. Results from pre- and post-tests were then compared to see if there was a significant difference. The questionnaire, which was based on a Likert scale (poor=1, fair=2, good=3, very good=4 and excellent=5), was intended to assess the confidence felt with regards to the donor screening, testing, apheresis, whole blood donation, component preparation and storage processes. The overall impact and experience of the Red Cross tour on the students were also assessed. Letters were assigned to each pre- and post- test questionnaire for anonymity. Each participant was assigned a number linked to the same letter code on both questionnaires. Participants were not asked to include their names or any biographic information. The pre-test was administered two days prior to the tour and after the lecture about blood center activities. The post test was administered three days after the tour. Each student got the same lettered questionnaire and test on the pre- and post-tests. Test and questionnaire results could not be linked back to the student; so there was no way of knowing which letter or number corresponded to which student. The master list was not kept.

**The tour**

The tour consisted of two phases: the first phase of the tour included a brief introduction and description of the activities of the Red Cross and importance of blood donation. Students were given an explanation of the donation process which included the information given to donors, health exam/testing, and the actual donation phases. They observed how whole blood and apheresis components were collected into appropriate bags. The second phase of the tour included observations of the following activities: blood components preparations and labeling, storage, distribution, and quar-
antine of all products. Both of these phases were explained and demonstrated by the Red Cross staff. After the tour, students and staff had question and answer sessions. The tour was completed in three hours.

Data Analysis
All data entry and statistical analyses were performed using MINITAB version 14.0 (Pearson Education, Inc.). The multiple choice questions were evaluated as either answered correctly or incorrectly. A score, representing the number of correct content knowledge questions out of twenty-five questions was calculated for each student. A pre and post test comparison on the scores was performed using a paired T-test while frequencies with associated percentages were calculated for the Likert scale items. The paired T-test analysis was performed at a 5% significance level (alpha = .05). A Chi-Square analysis was performed to test whether the students’ understanding of donation center’s activities before and after the tour differed.

RESULTS
The pre-test mean knowledge score was 62% and the mean knowledge post-test score was 69%. The mean percentage difference was 7% (t = -3.03; df: 14; P < 0.004). The pre-test and post-test mean scores showed increased course content knowledge on the processes involved in the donation, processing, and storage of blood and its components. Table 1 shows the percentages of the levels of understanding of some donor center activities. The pre-test results show that 33% of students reported that they fairly comprehended the donor

<table>
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<th>Variables</th>
<th>Poor</th>
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<th>Very Good</th>
<th>Excellent</th>
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screening process with only 7% reporting excellent comprehension. The post-test results on this item showed opposite results, with 27% reporting excellent comprehension and only 6% reporting a fair comprehension of the screening process (P= 0.03). The P-values for the Chi-Square analysis for level of understanding of the donor screening, testing, apheresis, component preparation and storage processes were significant at alpha =.05 (P<.05) except for the whole blood donation (Table 1).

On confidence level, at least 73% of students felt good or very good on their confidence in facing blood bank clinical rotations and national certification exams after the tour compared to at least 33% before the tour. The pre-tour results on confidence in facing the national certification exam showed that 60% of the students felt fairly prepared and 33% felt good on their preparedness level with no student reporting feeling very confident (Table 1). After the tour, 33% of the students reported that they felt very good, 40% reported that they felt good and 20 % reported that they felt fairly prepared for the national certification exam. There was a significant increase (P=0.022) in confidence level after the tour. Those who felt very confident in facing the exam increased from 0% to 33% and those who felt good increased from 33% to 40%. On confidence in facing their blood bank clinical rotations, 40% reported that they felt very good in their confidence post-tour compared to 0% pre-tour (Table 1). In addition, 67% of the students reported that they were only fairly confident pre-tour with a drop to 20% post-tour on confidence in facing the blood bank clinical rotation.

Forty-seven percent of the participants reported that the tour was an excellent complement to lectures, while only 6% reported it was a fair complement to lecture. Fifty-three percent of participants reported that their interactions with other medical technologists were very good, 27% reported excellent interactions, while 20% reported fair interactions. On working for a blood donation center, 46% reported a fair chance and 40% reported a good chance they might work for a blood center (Figure 1). The overall tour experience was positively rated with 47% of the students rating the tour as being very useful and informative and 27% reporting that the tour was an excellent experience.

DISCUSSION
This study revealed that students’ levels of confidence in facing blood bank clinical rotation and national certification examination increased after the blood center tour. Confidence is a very important factor when facing the unknown and being able to succeed. It was observed that students were more knowledgeable on the activities of the Red Cross after the tour since there was a significant difference in the pre- and post- test scores (P=0.004). The pre-test mean score of 62% compared to 69% post-test score showed that the students were less knowledgeable on certain concepts before the tour. This increase in knowledge is confirmed by studies which reported on the benefits of educational interventions in teaching important concepts. Students were more likely not to work for a blood center compared to those who would consider working for a blood center (see Figure 1). Most of them probably want to gain some experience in a hospital setting before working for a blood center. It is not surprising that hospital settings have been the desired sites both for clinical rotations and employment.

Overall, students were very satisfied with the tour and acknowledged that it was a beneficial addition to lectures except for observing the actual whole blood donation (P=.07). This is probably because they have observed other students, friends and family members donate blood without being involved in the processes prior to the actual blood donation. Additionally, these students perform phlebotomy on each other during laboratory sessions, so they do not see anything extraordinary in whole blood donation that they have not already learned in their phlebotomy class.

Many students rated their interaction with medical technologists as very useful and informative while very few students felt their interaction with staff at the Red Cross was fair. Students did not only ask questions about employment pros-
pects, job vacancies, and other employment requirements, but they became aware of what the jobs entail and what a potential working environment looks and feels like.  It is especially important to have an idea of the working atmosphere such as level of independence and level of interaction with other employees before employment decisions are made.  

CONCLUSION
This study confirms that blood center tours complement lectures. MT programs that have not incorporated a tour or rotation through a blood center need to be aware of the benefits to students. Tours not only expose students to a working atmosphere that is different from hospitals, but also give students the opportunity to interact with potential employers and other medical technologists, increase their confidence for their blood bank clinical rotations and subsequently the national certification exam.

Clin Lab Sci encourages readers to respond with thoughts, questions, or comments regarding this article. Email responses to westminsterpublishers@comcast.net. In the subject line, please type “CLIN LAB SCI 22(3) EK JATOR”. Selected responses will appear in the Dialogue and Discussion section in a future issue. Responses may be edited for length and clarity. We look forward to hearing from you.

REFERENCES
The following abstracts have been accepted for presentation at the 2009 American Society for Clinical Laboratory Science (ASCLS) Annual Meeting and Clinical Laboratory Exposition to be held July 21 through 25 in Chicago, IL. Abstracts are reviewed by appropriate representatives of the ASCLS Abstract Review Committee. They are the final authority in selecting or rejecting an abstract.

Papers, case studies and posters will be presented during the following times at the annual meeting. Room assignments will be listed in the final program.

**ORAL RESEARCH AND CASE STUDY PRESENTATIONS**
Friday, July 24, 9:15-10:15am and 3:00-4:00pm at the Renaissance Chicago Hotel

**POSTER PRESENTATIONS**
Tuesday and Wednesday, July 21 and 22, 10:00am-4:30pm; Thursday, July 23, 9:30am-Noon at the McCormick Place Convention Center; Authors will be present on Wednesday, July 22, 2009 from 10:30-11:30am to discuss their work and answer questions.

**ORAL RESEARCH ABSTRACTS**

**A Comparison Study of Scholarly Research of Clinical Laboratory Science Faculty – 1985, 1996, 2008**
Kathy V. Waller, PhD, CLS(NCA), Jill Clutter, PhD, The Ohio State University, Columbus, OH; Karen R. Karni, PhD, CLS(NCA), University of Minnesota, Minneapolis, MN

To what extent are CLS faculty fulfilling a research mission of their institutions and contributing to and advancing the body of knowledge of the profession? In 2008, an electronic questionnaire was distributed to 448 faculty members from 106 colleges and universities offering CLS baccalaureate programs. Responses were received from 275 faculty members (61%). This study (2008) compares CLS faculty members’ research and scholarship data to that obtained in similar studies conducted in 1985 and 1996. Since 1985, numbers of faculty holding doctorates have increased (26% in 1985, 46% in 1996, and 52% in 2008). By rank, senior faculty (associate and full professors) increased from 38% to 49% and 54%, respectively. The numbers of presentations have increased from 10% presenting four or more times in 1985; to 25% presenting 11 or more times in 1996; and 34% in 2008. Number of publications in refereed journals has increased over time from only 2% publishing seven or more times in 1985; to 14% publishing 11 or more times in 1996; and 33% publishing in 2008. Total grant funding increased from $23 million in 1996 to $62 million in 2008. However, teaching remains a primary responsibility, which for all faculty averaged 22 hours per week both in 1996 and 2008. Time in a faculty position of more than 16 years rose from 44% in 1996 to 53% in 2008, suggesting further graying of the professoriate. Since 1985, CLS faculty have made progress in fulfilling the academic missions of their institutions and moving forward the profession.

**Glucosamine Joint Supplement Suppresses Platelet Aggregation**
David L. McGlasson, MS, CLS/NCA, Wilford Hall Medical Center, Lackland AFB, TX; George A. Fritsma MS MT (ASCP), The Fritsma Factor, Birmingham, AL

A healthy 47-year old female has frequently donated blood to provide normal platelet aggregometry controls for aspirin response studies. Aggregometry results using her platelets were consistently normal. On two occasions, ADP-induced light transmittance (LTA) and whole blood aggregometry (WBA) results were suppressed, yielding the following results: LTA with ADP 20µM, 43.0% (Normal: 60.0-100.0%); WBA with ADP 10.0µM and 5.0µM, 0.0 and 5.0 ohms aggregation (Normal: >8.0 ohms). The aggregation results on the second date gave an LTA with ADP 20µM of 51.0% and the WBA with 10.0µM and 5.0µM were 0.0 ohms, respectively. Response to collagen was normal (>8.0 ohms). A CBC with platelet counts were normal. For both dates the PFA-100 ADP/COLL and EPI/COLL results were normal and the Accumetrics cartridges had a normal response for detection of aspirin and Plavix response. The subject reported she had begun taking a daily dose of 1500 mg of glucosamine with 1500 mg celadrin approximately 4 weeks prior to the first testing. A literature search generated one article involving human subjects demonstrating that glucosamine suppressed
platelet ADP receptors, but not collagen or thrombin receptors. Two articles using guinea pigs and dogs, respectively, also showed effects of glucosamine on platelet function. The subject stopped the supplement and was reanalyzed after two weeks. The results were ADP 20µm, 73.0% LTA and 8.0 and 0.0 ohms WBA aggregation. We concluded that glucosamine supplements suppress ADP-induced platelet aggregation. A population study may help establish risk for glucosamine supplements when taking anti-platelet functional drugs such as Plavix or aspirin.

**Inhibition of Thromboxane Synthase Leads to Cell Cycle Arrest and Apoptosis in Lung Cancer Cells**

George G. Chen, PhD, Kin C. Leung, PhD, Michael K.Y. Hsin, MB, Malcolm J Underwood, MD, Department of Surgery, The Chinese University of Hong Kong, Hong Kong

Thromboxane synthase inhibitors are involved in apoptosis and tumor metastasis. This study investigated whether and how 1-Benzylimidazole (1-BI), a thromboxane synthase inhibitor, influenced the growth of lung cancer cells. Three lung cell lines were used in the study, NCI-H460, NCI-H23 and CRL-2066. p53 in NCI-460 is wild type but in the other two cell lines are mutated. The result showed that 1-BI arrested the cells in G0/G1 in two p53-mutated cell lines, and significantly induced apoptosis in wild-type p53 NCI-H460. 1-BI induced the expression of p53 and BAX in NCI-H460 but not in the other two. p27 was elevated in all three cell lines tested. In NCI-H460, I-BI-mediated p53 upregulation was suppressed by PFT-alpha, a p53 inhibitor. Levels of the nuclear p27 and the cytosolic BAX induced by 1-BI were further increased in the presence of PFT-alpha and such an increase was accompanied by the enhanced G0/G1 cell cycle arrest, suggesting that the cell cycle arrest caused by 1-BI may be mediated by p27. Although caspase-3 was activated by 1-BI, cell death was not abolished by caspase inhibitors (Z-VAD-FMK and DEVD-CHO), suggesting that the anti-tumor effect triggered by 1-BI is independent of caspase. Collectively, our data demonstrated that 1-BI could significantly arrest lung cancer cells in G0/G1 stage and induced apoptosis by a caspase-independent mechanism which is associated the p53 status, increased p27 and BAX. (This work was supported by a direct grant from the Chinese University of Hong Kong, No: 2007.2.045).

**Methicillin Resistant Staphylococcus aureus: Carriage Rates and Characterization of Students in a Texas University**

Rodney E. Rohde, MS, SV, SM, MP(ASCP), Rebecca Denham, MT(ASCP), Aaron Brannon, Texas State University-San Marcos, CLS Program, San Marcos, TX

OBJECTIVE: To evaluate the carriage rates of *Staphylococcus aureus* and methicillin resistant *Staphylococcus aureus* (MRSA) in a university student population and describe associated risk factors.

**DESIGN:** Cross-sectional study. (IRB approval)

**SETTING:** Texas State University-San Marcos, San Marcos, TX.

**PARTICIPANTS:** Two-hundred and three samples - December 2007 to July 2008.

**RESULTS:** Of the 203 participants who were screened, 60 (29.6%) carried *S. aureus*. Univariate analysis found that only hospitalization in the past 12 months was significantly associated with the risk of being a *S. aureus* carrier (OR=3.0, 95% CI 1.28-7.03). Of the 60 participants that carried *S. aureus*, 15(7.4%) were identified as MRSA carriers. Hospitalization in the past 12 months (OR = 4.2, 95% CI 1.29-13.36) and recent skin infection (OR = 4.4, 95% CI 1.07-18.24) were significantly associated with the risk of being a MRSA carrier. No unique antibiotic susceptibility patterns were identified with MRSA isolates.

**CONCLUSIONS:** This is one of the first documented studies of *S. aureus* and MRSA in a university population. While the carriage rate of *S. aureus* is consistent with similar studies, MRSA carriage in this study appears high as compared to the general population. The investigators identified a strong association with past hospitalization for *S. aureus* colonization; past hospitalization and recent skin infection with MRSA colonization. Surprisingly, no significance for MRSA carriage was identified between dormitory and non-dormitory students but university officials need be aware of potential transmission risks in this population.

**ORAL CASE STUDY ABSTRACTS**

**Hindsight into Chronic Vitamin A Toxicity**

Lester Hardegree, Ed.D., MT(ASCP), Qatar University, Doha, Qatar

This retrospective case study concerns a 67 year-old male, concerned with losing his eyesight, with a presumptive diagnosis of chronic Vitamin A toxicity. Seven years prior to his present condition, he had received a liver transplant due to an alpha-1-antitrypsin deficiency. Eight to ten weeks prior to the on-set of his present condition, he had implant lens surgery in both eyes. This active and medically stable live-alone man began to experience extreme photosensitivity, migraine-like pain, and other neuropathic pain syndrome manifestations occurring 2 to 3 times daily. Despite medical examination by 2 ophthalmologists, a neurosurgeon, and...
an internist, no diagnosis nor satisfactory treatment was identified. At this point, he contacted this author to review his medical laboratory results and medications in hope of finding something to explain his increasingly worsening symptoms. Upon verbal examination about his meds and over-the-counter (OTC) supplements, it was determined that he likely had Vit. A toxicity. Laboratory testing of his blood revealed an elevated level. Within weeks of stopping intake of all multivitamins and supplemental Vitamin A, his episodes of pain began to diminish until completely resolved. Chronic Vitamin A toxicity in individuals should be considered as a potential risk given that there is no warning provided on the OTC vitamin.

The Impact of I-clickers™ on Student Performance
Eileen Carreiro-Lewandowski, MS, Department of Medical Laboratory Science, University of Massachusetts Dartmouth, N Dartmouth, MA

Studies indicate that individual classroom response systems, such as i-clicker™, employed during large lecture courses improves student engagement and active learning. This case study explores the impact of such a system on student participation, satisfaction, and performance in a medium size (approximately 50 students) Medical Laboratory Science analytical instrumentation class. Participation is tracked, electronically, using a web-based on-line course site. Student satisfaction was assessed using a standard teacher evaluation form, anecdotal comments, and completion of an on-line survey. The results showed that ninety-seven percent of the respondents thought i-clicker™ use was a useful lecture tool and one hundred percent agreed that it helped in their understanding key concepts and keeping them actively involved in the class. Class participation was very high for those in attendance (ninety-nine percent, on average) compared to a traditional lecture class response to questions (approximately twenty-five percent on average). Ninety-seven percent of the respondents felt that this system improved their grade. Student performance on graded work compared to that of students enrolled in another section of this class not using the i-clicker™ system, showed no significant differences. The instructor found that the additional required technology could be problematic and question inclusion needed careful pre-planning. Both students and instructor appreciated seeing the answer display for immediate feedback purposes and further clarification as needed. i-clicker™ use improved student in-class performance and participation, but did not increase overall course grades.

POSTER PRESENTATION ABSTRACTS

ASCLS Members’ Perceptions Regarding Research
Kristy Shanahan, MS, CLS(NCA), Lillian Mundt, EdD, CLS(NCA)SpH, Rosalind Franklin University of Medicine and Science, North Chicago, IL

Research is one of the benchmarks of a profession. However, in the Clinical Laboratory Science (CLS) profession, few manuscripts are submitted to the American Society for Clinical Laboratory Science (ASCLS) journal, Clinical Laboratory Science, on a regular basis. The problem is that perceptions regarding research, and the role of laboratory professionals as researchers, held by ASCLS members may be contributing to the low number of manuscript submissions. To assess these perceptions, an anonymous Likert-scale survey was developed and delivered online using Survey Monkey. Members of ASCLS, with email addresses, were chosen to participate in this survey because they may be most likely to contribute manuscripts for a journal by their own society. About 10% of the 7,000 members who were invited by email chose to participate in this study. Most participants agreed that 1) there is important information to be gathered from research on clinical laboratory specimen results (99.6%), 2) research contributes valuable information to the body of CLS knowledge (99.2%), and 3) conducting research is one of the benchmarks of a profession (92.4%). The majority of participants felt that there are inadequate resources (68.8%) and not enough time (83%) available to conduct research in the clinical laboratory setting. Most participants recognize that many laboratory activities constitute research (86.2%), but only a few are willing to publish research findings on their own (29.2%). These results show an opportunity exists for ASCLS to foster collaborations between bench technologists and educators willing to assist with the publication process.

Bid Promotes Apoptosis of Hepatocellular Carcinoma Cells and Is a Potential Agent to Treat This Malignancy in-vivo
George G Chen, PhD, Shihong Ma, Mphil, Gang Song, PhD, Davor Chau, BS, Paul BS Lai, MD, Department of Surgery, The Chinese University of Hong Kong, Shatin, NT, Hong Kong

Bid is a pro-apoptotic molecule which bridges the death receptor and the mitochondrial pathways amplifying the apoptotic signals. Our previous study has shown that Bid is decreased in hepatocellular carcinoma (HCC) and that the
enhancement of Bid level induces apoptosis in HCC cells in culture models and in the subcutaneous tumor model. However, it is unclear how Bid travels to its functional site – mitochondria and whether Bid can inhibit the growth of tumor in liver. We thus monitored how Bid translocated from the nucleus to the mitochondria and how this process affected cell death. We also tested the effect of Bid in an orthotopic hepatic tumor model. The result showed that Bid itself was unable to relocate from the nucleus to the mitochondria in p53-deleted HCC cells. However, Bid traveled together with p53 from the nucleus to the mitochondria when HCC cells were transfected with a wild-type p53 and stimulated by DNA damage agents. Bid translocation sensitized HCC cells to apoptosis. In the mouse model of liver tumor, we found the administration of adenoviral Bid significantly inhibited the growth of liver tumor. Further, such an inhibitory effect of Bid was negatively paralleled to the level of alpha-fetoprotein. In conclusion, our data support that Bid inhibits the growth of HCC cells by promoting apoptosis. Bid is a potential agent for treatment of HCC. (This work was supported by the Research Grants Council of the Hong Kong Special Administrative Region, No: CUHK 4534/06M).

**Biofilm Evaluation in Bacteria from Clinical Isolates**

Rita M. Heuertz, PhD, MT(ASCP), Uthayashanker R. Ezekiel, PhD, Saint Louis University, St. Louis, MO

Bacterial biofilms are increasingly important in the medical community due to their increased resistance to antimicrobial treatment and increasing presence in intensive care patients. Medically important biofilms include those from indwelling medical devices, dental plaque and the respiratory system, to mention a few. It is crucial that reliable and consistent protocols be developed to identify biofilm-producing bacteria, quantify the amount of biofilm present and identify/develop therapeutics effective in treating biofilm-producing bacterial infections. A reliable method for biofilm quantitation is under development. Preliminary results indicate that clinical bacterial isolates have varying abilities to produce biofilm. Preliminary data also suggest that 50% of *Pseudomonas aeruginosa* tested (n=8) and 40% of *Klebsiella pneumoniae* tested (n=10) produce large, demonstrable amounts of biofilm. A preliminary assay has been developed that quantitates biofilm accumulation on glass tube surfaces when grown in tryptic soy broth, incubated (overnight, 37°C), stained with crystal violet and then measured at A590 after dye elution. These results indicate that further studies are necessary to elucidate the role of biofilm-producing capabilities of bacterial isolates from hospitalized patients. Experiments are currently being conducted to further refine the methodology, ascertain physiological requirements for biofilm development, assess different types of clinical isolates for biofilm-producing capability and evaluate different agents for therapeutic effects on biofilm prevention.

**Comparison of Four Methods for Fluconazole Susceptibility in *Candida* species**

Lynda A. Britton, PhD, Hilary Tice, PharmD, Ellen D. Rambin, MS, LSU Health Sciences Center, Shreveport, LA

*Candida* species is the fourth most common cause of bloodstream infections and causes 40-60% mortality in some patient populations. *Candida* resistance to fluconazole has been reported to range from one to sixteen percent depending on the species and patient population. Because fluconazole is a safe, effective treatment for *Candida* infections in hemodynamically-stable, non-neutropenic patients and is available generically, we wanted to know if fluconazole resistance was a problem in our patient population. If resistance was not high, pharmacy costs could be saved by using fluconazole instead of more expensive antifungal drugs. We also wanted to determine which FDA-approved method would be most easily, accurately and economically performed in our laboratory. We identified 79 viable *Candida* sp. isolated from blood cultures from patients treated with antifungal drugs. Each isolate was tested by CLSI disk diffusion (DD), E-test (ET), Sensititre YeastOne (YO), and Vitek 2 (V) methods. Results were read and interpreted by two experienced technologists and photographed. Agreement between readers was 97.3%. Categorical agreement between methods was 91.1% for ET versus V and DD versus V, 92.4% between YO versus V, and 93.7% between DD versus ET, DD versus YO, and DD versus YO. Discrepancies and reduced susceptibility were seen only in tests for *Candida glabrata* with 11.4% demonstrating susceptible-dose dependent results. We concluded that resistance to fluconazole was negligible in our institution and accuracy of the four methods was acceptable although each method has technological and economic advantages and disadvantages.

**Comparison of Methods Used to Detect Antinuclear Antibodies**

Janelle M. Chiasera, PhD, Audrey D. Baker, MS, Linda H. Jeff, MA, The University of Alabama at Birmingham, Birmingham, Alabama

The gold standard and most common method used to detect antinuclear antibodies (ANAs) is the indirect fluorescent an-
tobody assay (IFA). The IFA is a subjective screening method that provides only limited information about the ANAs present. The recent development of fluorescent, flow cytometric bead-based assays provides the simultaneous screening and detection of multiple ANAs eliminating the need for reflex testing. Few studies have compared these new systems with IFA to detect ANAs. The purpose of this study was to compare AtheNA Multi-Lyte ANA, AtheNA Multi-Lyte ANA II, and AUTOFLUOR systems for the detection of antinuclear antibodies. Four hundred and forty-four serum specimens were assayed by all methods. The percent agreement between each method and sensitivities and specificities were calculated using the IFA (AUTOFLUOR) as the reference method. Highest overall agreement (73%) was seen between the AtheNA Multi-Lyte and AUTOFLUOR systems with the AtheNA Multi-Lyte system showing better specificity (95%) in detecting ANAs. Based on the high specificity, The AtheNA Multi-Lyte ANA system would be ideal for reflex testing once a more sensitive screening method, such as IFA reveals a positive ANA result. However, the AtheNA Multi-Lyte ANA system might be an acceptable substitute for an IFA method for simultaneous screening and reflex testing in laboratories that perform large volumes of ANA testing.

Comparison of Multiple Methods for Monitoring Tobacco Smoke Exposure

Barbara A MacKenzie, Raymond E Biagini, Belinda C Johnson, William J. Moorman, Shirley A Robertson, Susan Reutman, Deborah L Sammons, Jerome P Smith, Cynthia A Striley, John E Snawder, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Cincinnati, OH

Reliable tools are needed to evaluate exposure to environmental tobacco smoke and to verify the smoking status of an individual. The only significant source of nicotine in man is from the tobacco plant, *Nicotiana tabacum*. When the leaves are smoked or chewed, nicotine is rapidly absorbed and metabolized to cotinine and nicotine-N-oxide. Unlike other determinations, such as carboxyhemoglobin and thiocyanate, nicotine and cotinine are both specific to tobacco; however, cotinine is a more reliable biomarker because it has a longer half-life. Using archived urine samples for which smoking histories were also reported, we examined the cotinine values as measured by TobacAlert™, a semi-quantitative lateral flow based dipstick, the Immulite’ 2000 nicotine metabolite assay, the cotinine enzyme linked immunosorbant assay (ELISA) kit from Bio-Quant, and gas chromatography-mass spectrometry (GC-MS) cotinine determinations. Laboratory based tests were compared to one another and to the point of care dipstick. The immuno-based methods show good correlation with one another. The correlation between the Immulite’ 2000 and the Bio-Quant assay was $R=0.970$, $p<0.001$. The correlation between the Immulite’ 2000 and the GC-MS method was $R=0.954$, $p<0.001$, and they had similar diagnostic sensitivity and specificity; however, the absolute values by GC-MS were lower. The correlation between the Immulite’ 2000 and the TobacAlert™ was $R=0.997$, $p<0.001$. Even though the different methods have different criteria to distinguish smokers and non-smokers, cotinine measurements do predict exposure to environmental tobacco smoke and/or the smoking status of individuals.

The findings and conclusions in this abstract have not been formally disseminated by the National Institute for Occupational Safety and Health and should not be construed to represent any agency determination or policy.

Curriculum Strengthening for Kenya Medical Training College

Cathy Robinson, MSA, MT(ASCP), CLS-G, Kaitlin Sandhaus, Senior Project Manager, American Society for Clinical Pathology, Chicago, IL

This research details how the Kenya Medical Training College system (KMTC), CDC-Kenya, and the ASCP identified curriculum and training deficiencies at KTMC schools of medical technology and then developed a plan to correct them. The first phase of collaboration between ASCP and CDC-Kenya focused on improving training for laboratory professionals with emphasis on better quality assurance/quality control (QA/QC) and stressed the importance of implementing such standards countrywide. For example, based on observations and interviews with both incumbent professionals and laboratory students it was evident QA/QC implementation and instruction were, at best, woefully insufficient – and in many cases simply nonexistent. Given this deficiency, the second phase of collaboration, requested by KMTC leaders, focused on standardizing the curriculum for medical technology training at KTMC’s eleven campuses. Through a series of workshops with senior KTMC faculty members, courses, lab training, and standards were reviewed. ASCP consultants presented information on writing learning objectives and various methods for teaching. Workshop participants agreed on content revision needs and placement of courses. Requested content, including lesson plans developed by ASCP consultants, was delivered at the Curriculum Finalization Workshop which also provided an opportunity for
KMTC faculty to practice new teaching methodologies. The resulting unification and clarity of materials is expected to improve teaching and learning outcomes. Based on the new standardized content and decisions made at the Finalization Workshop, new syllabi were developed which KMTC implemented countrywide in September 2008. Looking forward, KMTC hopes to gain ASCP International Certification for graduates of its revamped medical technology programs.

Does VAMP-8 Play A Role in the Development of Atherosclerosis?
Rania Al Hawas, Sidney Whiteheart, Departments of Molecular and Cellular Biochemistry, University of Kentucky Medical Center, Lexington, KY; Deborah Howatt, Alan Daughtery, Gill Heart Institute, Division of Cardiovascular Medicine, University of Kentucky, Lexington, KY

Atherosclerosis is a leading cause of death in western countries and the major cause of cardiovascular diseases. A plethora of cells are involved in atherosclerosis such as, endothelial cells, leukocytes, and platelets. Beyond their vital role in hemostasis and occlusive thrombosis, platelets appear to play a role in the initiation of atherosclerosis through the secretion of various pro-inflammatory and pro-thrombotic substances. Platelet secretion is mediated by the integral membrane proteins called SNAREs. Our laboratory has previously shown that vesicle-associated membrane protein 8 (VAMP-8/endobrevin) is the primary vesicle SNARE required for all platelet secretion events. Given the known role of platelets in hemostasis and the proposed role of platelets in atherosclerosis, we sought to determine whether the deletion of VAMP-8 affects the development of atherosclerosis. For these studies, ApoE-/- mice, which are susceptible to atherosclerosis, were crossed with VAMP-8-/- mice to obtain VAMP-8-/-/ApoE-/- animals. Consistent with our hypothesis, the 50 weeks old VAMP-8-/-/ApoE-/- mice showed a reduction in lesion size compared to the control. This was measured by the Oil Red-O staining of the plaques in the aortic sinus and the en face analysis of the plaque size seen in the aortic arch.

Conclusion: These data show that the loss of VAMP-8 reduces development of atherosclerotic plaques and suggests that platelet secretion may play a role not only in thrombosis but also in the initiation of atherosclerosis.

Duration of Loxosceles reclusa (Brown Recluse Spider) Venom Detection by ELISA from Swabs
David L. McGlasson, MS, CLS(NCA), Wilford Hall Medical Center, Lackland AFB, TX; Jonathan A. Green, PhD, University of Missouri-Columbia, Columbia, MO; William V. Stoecker, MD, Stoecker & Associates, Rolla, MO; David A. Calcara, MD, Stoecker & Associates, Rolla, MO

Diagnosis of Loxosceles reclusa envenomations is currently based upon clinical presentation. It is difficult to distinguish a spider bite from other disorders without finding the spider for identification. An enzyme-linked immunosorbent assay (ELISA) can detect surface Loxosceles venom at the envenomation site, allowing diagnostic confirmation. The earlier the diagnosis of a spider bite, the better the clinical outcome. To investigate duration of recoverable venom antigen, whole venom and fractionated sphingomyelinase D venoms were injected subcutaneously in New Zealand White rabbits. Cotton swabs were compared for venom recovery over a 21-day period using a surface swab technique. Significant amounts of Loxosceles reclusa antigen were found on the surface of the individual rabbits skin. The sensitivity of the ELISA for the whole venom with the cotton swabs for 7, 10, 14, and 21 days were 67%, 65%, 62%, and 60%, respectively. For the sphingomyelinase D, the sensitivity of the ELISA was 95%, 90%, 83%, and 77%. The overall specificity remained high through out the tests, at 95%, 96%, 93%, and 92% on days 7, 10, 14, and 21, respectively. The duration of recoverable antigen using this experimental model appears to be at least two weeks and as long as 21 days. Because the duration of the recoverable antigen is at least two weeks, the ELISA venom test appears capable of detecting venom on patients presenting with Loxosceles envenomations. We now have the ability of being able to definitely say that an area of necrosis is caused by a brown recluse spider bite.

Effect of a Blood Center Tour on Student Recruitment: Case Study on Austin Peay State University
Eleanor K Jator, PhD, MT(ASCP), Austin Peay State University, Clarksville, TN

Clinical laboratory science is one profession that is not known to many college students because the visibility of the profession is not as obvious when compared to other health professions. As recently observed by Austin Peay State University, student excursions to a laboratory can be an effective avenue in educating students about the clinical laboratory profession. As an educational and recruitment endeavor, fifteen Medical Technology (MT/CLS) senior students and five students currently enrolled in biology courses with undeclared majors participated in a tour of the Red Cross facility in Nashville, TN. The tour involved observing the following areas: blood donation, component preparations, storage, distribution and quarantine of blood.
After the tour, the five students with undeclared majors inquired more about the profession and picked up the MT/CLS program brochures. Thereafter, three of the five students declared Medical Technology as their field of study. Learning about the profession while watching laboratory professionals perform their jobs as well as interaction with senior MT/CLS students had a positive effect on these students. Students with undeclared majors and those taking science courses can potentially be attracted into the clinical laboratory science profession through planned clinical laboratory visits.

Novel Diagnostic Applications of an Available Technology
Keely Pierzchalski, MT(ASCP), CLS(NCA), Dalal Tonb, PhD, Tracey Nadal, BS, Laura Bolling, BS, AI DuPont Hospital for Children, Wilmington, DE

Thermocyclers are typically used for PCR reactions to control temperature and enzymatic reaction time. In this study, the thermocycler was adapted to perform an enzymatic assay of disaccharidases, normally carried out in 1.5 ml micro-tubes using a water-bath and heating block to meet temperature requirements. The objective was to increase assay efficiency by utilizing a 96-well PCR plate format. The thermocycler method was validated by assaying twenty-four samples, in four runs, in parallel with the standard manual method. Briefly, in the manual method, 20 or 40 μl of sample and 100 ul of substrate were placed in micro-tubes and incubated in a 37°C water-bath for 15 or 60 minutes, and transferred to a 100°C heating block to stop the reaction. For the thermocycler method, 5 or 10 μl of sample and 25 ul of substrate were directly placed in the well of the PCR plate. The thermocycler was programmed for the appropriate time and temperature for reaction incubation and termination. Validation results showed the correlation coefficients of the disaccharidases to be 0.98(lactase), 0.93(maltase), 0.95(sucrase), 0.86(Palatinase), and 0.88(Glucosaminase). No statistical or clinically diagnostic differences were observed between the two methods, confirming that the thermocycler method was reliable. From start to finish, personnel were reduced from two to one and time from four to two hours. In addition, less sample volume and materials are required. Due to the efficiency and accuracy we consider the thermocycler method a success. We hope to apply this novel application of PCR technology to other enzymatic assays.

Phospholipase D1 Analysis During Biofilm Formation of Candida albicans
April L Harkins, PhD, MT(ASCP), Nathan Wagner, Danielle Miskulin, Erik Munson, PhD, Marquette University, Milwaukee, WI

In this study, we examined the change in phospholipase D1 (PLD1) activity during hyphal induction and biofilm formation of Candida albicans strains that were isolated from multiple human host sites. Previous studies have shown the involvement of PLD1 during hyphae production and disseminated candidiasis in mouse models. The clinical isolates used were maintained in standard growth media and induced to form hyphae in the presence of fetal bovine serum and a shift in incubation temperature. Biofilm formation was performed by the inoculation of Candida strains into polystyrene wells. The metabolic activity of the biofilm was measured using a colorimetric XTT [2,3-bis(2-methoxy-4-nitro-5-sulphophenyl)-2H-tetrazolium-5-carboxanilide] reduction assay. The results showed that strains of Candida isolated from disseminated infections were able to form hyphae and biofilms more rapidly. PLD1 activity increased with both hyphae formation and biofilm formation, showing the involvement of this lipid mediator during these virulent processes. Revealing the proteins and lipids involved in hyphae and biofilm formation will help in identifying novel therapeutic targets for improved antifungal action against C. albicans biofilms that are 1,000-fold more resistant to many major classes of antifungals.

The Status of Michigan’s Physician Office Laboratory Workforce
Sharon Bobryk, MSA, CLS(NCA), MT(ASCP), Beaumont Laboratory Services, Royal Oak, MI; Linda Goossen, Ph.D, MT(ASCP), Grand Valley State University, Grand Rapids, MI

Physician’s offices comprise the largest portion of the clinical laboratory personnel sector (The Lewin Group, 2008; Cherry, Hing, Woodwell, & Rechtsteiner, 2008); however, literature describing the testing personnel in these laboratories is scarce. The purpose of this study was to describe the workforce status in Michigan’s physician office laboratories (POL) by quantifying the number of professionals performing laboratory testing, establishing a baseline description of their educational level and credentials, and exploring current vacancy trends. Both a telephone and written survey were employed to elicit responses from 127 CLIA-licensed physician office laboratories throughout the state of Michigan. The major findings conclude that there are approximately 15,837 full-time employees performing laboratory testing in the POLs in Michigan. Eleven percent of testing personnel hold certifications in MLT/CLT or MT/CLS; eighty-nine
percent of testing personnel lack any laboratory-related credentials. Vacancies in which CLT/MLT degrees were desired remained unfilled longer than any other types of vacancies. A trend to note is that in this study medical assistant schooling is the most prevalent form of specific training for testing personnel. These findings indicate that many POL workers lack formal education in laboratory science. As a result, the educational needs of these groups should be explored by laboratory accreditation agencies, educational programs, and state personnel licensing requirements.

Transforming Laboratory Medicine with the College of American Pathologists Electronic Cancer Checklists

Andrea R. Pitkus, MT(ASCP), CLS(NCA), College of American Pathologists, Deerfield, IL

Standards are lacking for the collection and structuring of laboratory reporting elements for use by downstream entities. Although HL-7 messaging standards are utilized for laboratory data transmission, the structure of laboratory data varies among information systems. Interoperability of laboratory data from disparate information systems is a barrier to Health Information Exchange (HIE), especially with cancer or public health reporting.

Standardization of both the collection and communication of laboratory information in a checklist format has been shown to increase the completeness of information collected and reported, reduce costs, improve patient care and safety, and allow for quality assurance. The College of American Pathologists Electronic Cancer Checklists (CAP eCC), which ensure the collection of necessary data elements for cancer reporting, is one example of this.

The CAP eCC utilizes two strategies to resolve interoperability barriers. One is the creation of cancer checklists by pathology experts designed to collect the essential data elements necessary for cancer reporting. The checklists integrate laboratory information such as serum tumor and molecular markers, and elements utilized by cancer registrars downstream. Secondly, the checklists have been transformed into XML file format, an international data exchange standard endorsed by standards organizations like HL-7.

The resulting checklist facilitates the electronic collection and interoperability of laboratory data among various information systems. XML fosters worldwide adoption and utilization of a structured pathology reporting format. Future uses of this format include standardized lab order sets, requisitions, and laboratory data integration, interpretation, and reporting for improving patient care.

Using a Phlebotomy Audit to Ensure Compliance in your Hospital

Khadee Lindsey Davenport-Landry, MT(ASCP), Veterans Affairs Medical Center, Iowa City, IA

The purpose of this audit is to pinpoint areas of the pre-analytical phase of care that may have adverse effect on patients care. Proper patient identification is a Joint Commission patient safety concern that needs to be monitored. This audit evaluates processes that may have an impact on possible misidentification issues as well as serving as a learning tool for ways to improve and continue quality care at your facility. The audit is performed using predetermined criteria focusing on patient identification, proper phlebotomy, ensuring privacy, hand hygiene and proper labeling. Phlebotomies are observed and processes are documented as acceptable, not acceptable, and non-applicable. Circumstances are noted since each situation may be slightly different. Compiling and reviewing data gives a better understanding to where phlebotomists may need additional training to meet compliance standards. This audit also provides a feedback opportunity for the phlebotomists, also allowing time to reinforce their importance in the pre-analytical process. Results from the audit performed at the Veterans Affairs Medical Center in Iowa City, IA showed that employees with a routine to their phlebotomy process were more likely to follow procedure, whereas those who did not have a consistent routine did not always comply with procedure. The results have been presented to our hospital Performance Improvement Committee and notice sent to the departments in which additional follow-up is needed. The findings of the phlebotomy audit suggest that basic re-observation and training should be added to annual competencies of all phlebotomy staff. This audit could be modified to fit the processes of most institutions.

Why Technologists in Illinois Do Not Join ASCLS

Jeanne M. Isabel, MSEd, CLSpH(NCA), Northern Illinois University, DeKalb, IL; Lillian Mundt, EdD, CLS(NCA)SpH, Kristy Shanahan, MS, CLS(NCA), Rosalind Franklin University of Medicine and Science, North Chicago, IL

Clinical laboratory educators routinely introduce students to professionalism and the importance of membership in one’s professional society. In the clinical setting, technologists and laboratory personnel are so busy that they may not feel
like volunteering for the professional society after work. The process of increasing membership in ASCLS for the State of Illinois seems to be ever challenging. ASCLS-IL leadership engaged students on rotation from several CLT/CLS programs to anonymously survey laboratory personnel to discover aspects of ASCLS membership. The actual response rate is not known but of the 59 surveys returned, 52 were from individuals not members of ASCLS. Reasons given for not joining ASCLS include the following responses; 46% -lack of information about ASCLS, 10% -ASCLS does not meet their needs, 12% -unnecessary to join any professional society, and 32% -other. Responses to additional survey questions revealed that not all benefits offered through membership in a professional society are important to potential members. It is difficult to identify which “perks” are deemed valuable by current and future organization members. Although the number responding to the survey was small, their responses may reflect the cause for Illinois’ low membership numbers. Because of the rather large percent indicating lack of information about ASCLS, a campaign to improve marketing and visibility of ASCLS at the grassroots level may be the answer. Certainly there are many initiatives to engage laboratory personnel in the profession, such as Labs are Vital. We need to find a way to bring our “excitement” about what ASCLS means to all professionals.
The peer-reviewed Research and Reports Section seeks to publish reports of original research related to the clinical laboratory or one or more subspecialties, as well as information on important clinical laboratory-related topics such as technological, clinical, and experimental advances and innovations. Literature reviews are also included. Direct all inquiries to David L McGlasson MS CLS(NCA), 59th Clinical Research Division/SGRL, 2200 Berquist Dr., Bldg. 4430, Lackland AFB TX 78236-9908, david.mcglasson@lackland.af.mil
not many manuscripts are submitted to Clinical Laboratory Science for review and publication. In 2006, 43 articles were published in Clinical Laboratory Science (CLS) by 62 authors. Several articles had multiple authors. Seven authors each had published two articles in CLS, two had three, and one had four. In 2007, 40 articles were written by 63 authors. Six authors each had published two articles in CLS, four had three, and one had five. Seven authors published at least one article in both 2006 and 2007.

A professional society exists in part to encourage members to conduct research. The American Society for Clinical Laboratory Science (ASCLS) fulfills this purpose by providing grants and scholarships to researchers. ASCLS also accepts submissions of research and other articles for publication in Clinical Laboratory Science and ASCLS Today. In spite of having these opportunities to fund and publish research, few members actually do apply for grants or contribute articles to ASCLS publications (personal communication ASCLS annual meeting).

The problem this study addresses is that the leadership of ASCLS does not know how members perceive the importance of conducting research or their duty to the profession to do so. The purpose of this study was to assess the perceived importance of research among ASCLS members and to create awareness in members of research opportunities in their daily work.

METHODO
An online survey was developed and housed on the website Survey Monkey. The survey consisted of seven demographic questions and three Likert-type questions that assessed participants’ views on 1) the importance of and opportunity for conducting research in the clinical laboratory setting, 2) what activities in the clinical laboratory constitute research, and 3) how likely they were to conduct and publish research. These questions appear in individual tables included in the results section of this article. All ASCLS members with current email addresses (approximately 7,000) were invited to participate in the survey. The survey remained available online for one month.

RESULTS
Of the 7,000 members invited, 762 members (about 10%) accessed the survey, and 758 completed it. A few participants chose to skip some demographic questions. Table 1 displays demographic questions and data. Question six, which asked participants to identify the State in which they practice, was not included for analysis. Bench technologists comprised the highest number of survey participants (38.2%). Most (81.4%) of participants hold CLS or MT certification. The bachelor degree is the highest degree held by 50.6% of participants. Female participants (83%) outnumbered male participants (17%). Most of the participants in this survey (39.7%) range in age from 50 to 59 years old. Most participants (70.6%) hold membership in states without licensure.

Table 2 shows data for responses to question eight that asked participants to rate their level of agreement with statements about research. Nearly all participants agree or strongly agree that 1) there is important information to be gathered from research on clinical laboratory specimen results, 2) research contributes valuable information to the body of knowledge of CLS knowledge, 3) conducting research is one of the benchmarks of a profession. A lesser number, but still a majority, of participants agree or strongly agree that 1) opportunities exist to conduct research in the clinical laboratory setting, 2) research in the clinical laboratory setting contributes to improved patient care, and 3) laboratory professionals have a responsibility to conduct research as well as publish and present findings.

The majority of participants disagree or strongly disagrees that 1) there are adequate resources available to conduct research in the clinical laboratory setting, and 2) there is adequate time available to conduct research in the clinical laboratory setting.

A high number of participants (75%-97.1%) agreed or strongly agreed that the following are clinical laboratory activities constitute research: determination of turn-around times, patient/client satisfaction survey, method validation, investigation into the effects of pre-analytical variables, laboratory test development, correlation of laboratory data with patient outcomes, influence of different leadership styles on performance, institution / client needs assessment, assessment of patient outcomes, assessment of instructional methods, and case study synthesis. Table 3 shows data for these responses to question nine.

Table 4 shows data for responses to question 10 that asked participants how likely they were to publish and present research findings and assist other with publication. A high number (70.8%) of participants indicated that they are unlikely to publish research findings on their own, and 53.6% are unlikely to present findings at a national meeting. Over half responded that they were likely to publish research findings with the assistance of university faculty (51.9%).
and would be willing to assist others with writing. Responses were compared between male and female participants. Males were more likely to publish research findings on their own (44.8%) than were females (26.3%). A chi square of 7.5 revealed that this is a significant finding (p=0.006) at an alpha of 0.05.

Responses were also compared between university-based and hospital-based educators. University-based educators were more likely to publish research findings on their own (53.5%) than were hospital-based educators (27.7%). A chi square of 13.6 revealed that this is a significant finding (p=<0.001) at an alpha of 0.005. Although not statistically significant, over three fourths (75.2%) of university faculty are willing to assist clinical laboratory professionals with scholarly writing.

Responses to question 10 were compared to various age groups. No significant differences were found, although the greater than 60-year-old age group was more likely to publish research on their own than other groups.

**DISCUSSION**

The results of this study are not highly generalizable, because only approximately 10% of ASCLS members who were invited actually participated in this study. In addition, not all laboratory professionals are members of ASCLS, and therefore did not have the opportunity to participate in this study. Those laboratory professionals who self-selected to respond to the survey may have more positive perceptions regarding research than those who chose not to participate.

The results of this study seem to confirm that most laboratory professionals are female with many nearing retirement age. In addition, the results of this study demonstrate that many bench technologists recognize the importance of conducting research and that many laboratory activities constitute research.

<table>
<thead>
<tr>
<th>Questions</th>
<th>Number responding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question 1: What is your role in the clinical laboratory?</td>
<td></td>
</tr>
<tr>
<td>Regional Manager</td>
<td>0.7% (5)</td>
</tr>
<tr>
<td>Laboratory Administrator</td>
<td>9.1% (69)</td>
</tr>
<tr>
<td>Section Supervisor</td>
<td>10.7% (81)</td>
</tr>
<tr>
<td>Bench Technologist/Technician</td>
<td>38.2% (289)</td>
</tr>
<tr>
<td>Educator hospital –based</td>
<td>6.2% (47)</td>
</tr>
<tr>
<td>Educator university-based</td>
<td>20.6% (156)</td>
</tr>
<tr>
<td>Other</td>
<td>18.6% (141)</td>
</tr>
<tr>
<td>Question 2: What are your credentials?</td>
<td></td>
</tr>
<tr>
<td>CLS/MT</td>
<td>81.4% (614)</td>
</tr>
<tr>
<td>CLT/MLT</td>
<td>9.9% (75)</td>
</tr>
<tr>
<td>Diplomate</td>
<td>1.1% (8)</td>
</tr>
<tr>
<td>Specialist</td>
<td>10.3% (78)</td>
</tr>
<tr>
<td>Categorical</td>
<td>0.9% (7)</td>
</tr>
<tr>
<td>Other</td>
<td>7.8% (59)</td>
</tr>
<tr>
<td>Question 3: What is your highest earned degree?</td>
<td></td>
</tr>
<tr>
<td>Associate</td>
<td>9.5% (71)</td>
</tr>
<tr>
<td>Bachelors</td>
<td>50.6% (380)</td>
</tr>
<tr>
<td>Masters</td>
<td>30.8% (231)</td>
</tr>
<tr>
<td>Doctorate</td>
<td>9.2% (69)</td>
</tr>
<tr>
<td>Question 4: What is your gender?</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>83.3% (620)</td>
</tr>
<tr>
<td>Male</td>
<td>17% (127)</td>
</tr>
<tr>
<td>Question 5: What is your age range?</td>
<td></td>
</tr>
<tr>
<td>20-29</td>
<td>16.4% (124)</td>
</tr>
<tr>
<td>30-39</td>
<td>11.9% (90)</td>
</tr>
<tr>
<td>40-49</td>
<td>17.4% (131)</td>
</tr>
<tr>
<td>50-59</td>
<td>39.7% (300)</td>
</tr>
<tr>
<td>&gt;60</td>
<td>14.6% (110)</td>
</tr>
<tr>
<td>Question 7: Does your State require licensure?</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>25.8% (195)</td>
</tr>
<tr>
<td>No</td>
<td>70.6% (534)</td>
</tr>
<tr>
<td>I don't know</td>
<td>3.6% (27)</td>
</tr>
</tbody>
</table>

Table 1. Responses to demographic questions
However, only a few are willing to publish research findings on their own unless they receive help. Men are significantly more likely than women to publish research findings on their own. University-based faculty are significantly more likely than hospital-based faculty to publish research findings on their own, and are willing to assist others with scholarly writing.

Table 2. Responses to question 8

<table>
<thead>
<tr>
<th>Question 8</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>There is important information to be gathered from research on clinical laboratory specimen results.</td>
<td>64.0% (484)</td>
<td>35.6% (269)</td>
<td>0.3% (2)</td>
<td>0.1% (1)</td>
</tr>
<tr>
<td>Research contributes valuable information to the body of knowledge of Clinical Laboratory Science.</td>
<td>66.3% (500)</td>
<td>32.9% (248)</td>
<td>0.8% (6)</td>
<td>0.0% (0)</td>
</tr>
<tr>
<td>Conducting research is one of the benchmarks of a profession.</td>
<td>45.4% (342)</td>
<td>47.0% (354)</td>
<td>7.2% (54)</td>
<td>0.4% (3)</td>
</tr>
<tr>
<td>Opportunities exist to conduct research in the clinical laboratory setting.</td>
<td>28.4% (213)</td>
<td>46.3% (348)</td>
<td>22.1% (166)</td>
<td>3.2% (24)</td>
</tr>
<tr>
<td>There are adequate resources available to conduct research in the clinical laboratory setting</td>
<td>6.9% (52)</td>
<td>24.3% (182)</td>
<td>55.3% (414)</td>
<td>13.5%</td>
</tr>
<tr>
<td>There is adequate time available to conduct research in the clinical laboratory setting.</td>
<td>2.7% (20)</td>
<td>14.3% (107)</td>
<td>57.9% (434)</td>
<td>25.1%</td>
</tr>
<tr>
<td>Research in the clinical laboratory setting contributes to improved patient care.</td>
<td>45.0% (338)</td>
<td>50.5% (379)</td>
<td>4.1% (31)</td>
<td>0.4% (3)</td>
</tr>
<tr>
<td>As a laboratory professional, I have responsibility to conduct research.</td>
<td>16.7% (125)</td>
<td>49.0% (366)</td>
<td>29.9% (223)</td>
<td>4.4% (33)</td>
</tr>
<tr>
<td>As a laboratory professional, I have a responsibility to publish my research findings.</td>
<td>20.1% (150)</td>
<td>54.0% (404)</td>
<td>21.9% (164)</td>
<td>4.0% (30)</td>
</tr>
<tr>
<td>As a laboratory professional, I have a responsibility to present my research findings at professional society meetings.</td>
<td>19.4% (145)</td>
<td>53.1% (396)</td>
<td>24.1% (180)</td>
<td>3.4% (25)</td>
</tr>
</tbody>
</table>
### Table 3. Responses to question 9

**Question 9**  
The following laboratory activities constitute research:  

<table>
<thead>
<tr>
<th>Activity</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Determination of Turn-Around-Times</td>
<td>25.7% (194)</td>
<td>49.3% (372)</td>
<td>23.6% (178)</td>
<td>1.5% (11)</td>
</tr>
<tr>
<td>Patient/Client satisfaction surveys</td>
<td>25.5% (191)</td>
<td>50.1% (376)</td>
<td>22.7% (170)</td>
<td>1.7% (13)</td>
</tr>
<tr>
<td>Method validation</td>
<td>39.1% (291)</td>
<td>47.2% (351)</td>
<td>12.4% (92)</td>
<td>1.3% (10)</td>
</tr>
<tr>
<td>Investigation into the effects of pre-analytical variables</td>
<td>48.4% (364)</td>
<td>48.7% (366)</td>
<td>2.4% (18)</td>
<td>0.5% (4)</td>
</tr>
<tr>
<td>Laboratory test development</td>
<td>52.4% (395)</td>
<td>44.3% (334)</td>
<td>3.3% (25)</td>
<td>0.0% (0)</td>
</tr>
<tr>
<td>Correlation of laboratory data with patient outcomes (data mining)</td>
<td>52.5% (396)</td>
<td>44.5% (336)</td>
<td>3.0% (23)</td>
<td>0.0% (0)</td>
</tr>
<tr>
<td>Assessing the influence of different leadership styles on performance</td>
<td>20.7% (155)</td>
<td>55.4% (415)</td>
<td>22.7% (170)</td>
<td>1.2% (9)</td>
</tr>
<tr>
<td>Institution/client needs assessment</td>
<td>19.4% (145)</td>
<td>58.1% (434)</td>
<td>21.2% (158)</td>
<td>1.3% (10)</td>
</tr>
<tr>
<td>Assessment of patient outcomes</td>
<td>40.7% (303)</td>
<td>50.1% (406)</td>
<td>9.0% (67)</td>
<td>0.3% (2)</td>
</tr>
<tr>
<td>Assessment of instructional methods (training outcomes)</td>
<td>32.1% (241)</td>
<td>54.1% (406)</td>
<td>13.2% (99)</td>
<td>0.5% (4)</td>
</tr>
<tr>
<td>Case study analysis/synthesis</td>
<td>37.3% (281)</td>
<td>53.0% (399)</td>
<td>9.4% (71)</td>
<td>0.3% (2)</td>
</tr>
</tbody>
</table>

### Table 4. Responses to Question 10.

**Question 10**  
Recognizing that laboratory professionals, in the clinical setting, engage in activities that constitute research: How likely are you to:  

<table>
<thead>
<tr>
<th>Activity</th>
<th>Likely</th>
<th>Unlikely</th>
</tr>
</thead>
<tbody>
<tr>
<td>Publish your research findings on your own</td>
<td>29.2% (219)</td>
<td>70.8% (531)</td>
</tr>
<tr>
<td>Publish your research findings with help from university faculty</td>
<td>51.9% (388)</td>
<td>48.1% (360)</td>
</tr>
<tr>
<td>Assist clinical laboratory professionals with scholarly writing</td>
<td>52.3% (393)</td>
<td>47.7% (359)</td>
</tr>
<tr>
<td>Present research findings at a state or national meeting</td>
<td>46.4% (347)</td>
<td>53.6% (401)</td>
</tr>
</tbody>
</table>
In addition, those 60 years old or older (perhaps retired) are more likely to publish research findings on their own (33.3%) than members in other age groups (<30%).

CONCLUSION
Clinical laboratory professionals recognize the importance of conducting, publishing, and presenting research, although not all survey participants agreed that it was their responsibility to do so. Many participants feel that they lack resource and time to conduct research, even though many activities in the clinical laboratory constitute research. Many participants would publish the findings of their research if they had assistance with the publication process.

IMPLICATIONS
The establishment of collaborations between CLSs who have research data and those with the skills to write articles and create poster presentations would help to generate manuscripts that could be published. The results of this study suggest that collaborations between university faculty and bench technologists or hospital-based faculty may result in increased opportunities for publications. In addition, retired members may be able to mentor younger members in collaborative publication efforts. Fostering these collaborations is one way that ASCLS could begin again to fill its journal.

Clin Lab Sci encourages readers to respond with thoughts, questions, or comments regarding this article. Email responses to westminsterpublishers@comcast.net. In the subject line, please type “CLIN LAB SCI 22(3) RE MUNDT”. Selected responses will appear in the Dialogue and Discussion section in a future issue. Responses may be edited for length and clarity. We look forward to hearing from you.

REFERENCES
Methicillin Resistant *Staphylococcus aureus*: Carriage Rates and Characterization of Students in a Texas University

RODNEY E. ROHDE, REBECCA DENHAM, AARON BRANNON

OBJECTIVE: To evaluate the carriage rates of *Staphylococcus aureus* and methicillin resistant *Staphylococcus aureus* (MRSA) in a university student population and describe risk factors associated with the carriage of each.

DESIGN: Cross-sectional study (N = 203). Institutional Review Board approval was obtained from Texas State University-San Marcos.

SETTING: Texas State University-San Marcos, San Marcos, TX.

PARTICIPANTS: Two-hundred and three university student samples were collected from December 2007 to July 2008.

INTERVENTIONS: None indicated.

MAIN OUTCOME MEASURES: The sample set was screened for *S. aureus* and MRSA identification by standard microbiological techniques and confirmed by use of a Vitek 2 per manufacturer recommendation. Antibiotic susceptibility testing was conducted on each MRSA isolate by Vitek 2. A questionnaire was conducted with each student to acquire demographic and risk factor information. Demographic data is shown by raw numbers, percentages, mean, and median where applicable. The compiled data was screened and analyzed by chi square (p values) and odds ratio (OR) with confidence interval (CI) to determine significance.

RESULTS: Of the 203 participants who were screened, 60 (29.6%) carried *S. aureus*. Univariate analysis found that only hospitalization in the past 12 months was significantly associated with the risk of being a *S. aureus* carrier (OR=3.0, 95% CI 1.28-7.03). Of the 60 participants that carried *S. aureus*, 15 were identified as MRSA. This relates to a 7.4% MRSA carriage rate among generally healthy university students. Univariate analysis found that hospitalization in the past 12 months (OR = 4.2, 95% CI 1.29-13.36) and recent skin infection (OR = 4.4, 95% CI 1.07-18.24) were significantly associated with the risk of being a MRSA carrier. No unique antibiotic susceptibility patterns were identified with the MRSA isolates.

CONCLUSIONS: The carriage rate of *S. aureus* is consistent with similar studies. MRSA carriage in this university study appears high as compared to the general population. Although this study did not confirm a variety of risk factors for carriage of MRSA previously identified by others, university healthcare personnel should be aware of the changing epidemiology of MRSA and preventive measures needed to avoid outbreaks.

ABBREVIATIONS: MRSA= Methicillin resistant *Staphylococcus aureus*; CA-MRSA=Community-associated methicillin resistant *Staphylococcus aureus*; HA-MRSA=Healthcare-associated methicillin resistant *Staphylococcus aureus*; CLS = Clinical Laboratory Science; OR = Odds Ration; CI = Confidence Interval.

INDEX TERMS: Methicillin resistant *Staphylococcus aureus*, MRSA, Community-associated methicillin resistant *Staphylococcus aureus*, College healthcare.


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INTRODUCTION

Since the introduction and widespread use of antibiotics, resistant strains of bacteria have become a major healthcare problem1. Isolates of Staphylococcus aureus with resistance to beta-lactam antibiotics were first reported in the United States in 1961, and have since continued to evolve.1,2 Methicillin resistant Staphylococcus aureus (MRSA) has become one of the major antibiotic-resistant pathogens in recent years, and is capable of causing a wide range of skin and invasive infections including endocarditis, pneumonia, osteomyelitis, gastroenteritis, septic arthritis, deep abscess formation, and rarely, necrotizing fasciitis.3-8 For the past several decades, MRSA has become a serious problem in patients with exposure to the healthcare system, and is responsible for substantial morbidity and mortality in hospitals around the world.9 Today, healthcare-associated methicillin resistant Staphylococcus aureus (HA-MRSA) accounts for approximately 85% of all invasive MRSA infections.10 Unfortunately, the epidemiology of MRSA seems to be changing.

MRSA has evolved in the community and is unrelated to the evolution of HA-MRSA in hospitals and other settings. These community associated strains, known as community-associated methicillin resistant Staphylococcus aureus (CA-MRSA) have begun to appear outside of the healthcare setting, and the rise of serious infections have been seen in non-hospitalized, previous healthy young people.11 CA-MRSA is easily transmissible, not only between families, but also in larger close-contact communal settings such as prisons, schools, and sports teams.5,11 Environmental sources, such as the sharing of clothing, sports equipment, towels, razors, and soaps; improper care of skin trauma; crowded living conditions, along with lack of cleanliness and personal hygiene, are identified as possible risk factors for CA-MRSA infections.1,5,12

Because nasal carriage (colonization) of S. aureus has been identified as a major risk factor for subsequent infections, an understanding of the risk factors for carriage of S. aureus and MRSA is crucial to understanding the potential for invasive infections and transmission of such diseases.3 A variety of studies have examined community prevalence of nasal carriage in subpopulations including hospitals, outpatient settings, jails, and injection drug users.3,9,13-16 Several studies have been conducted with medical students17-19 but few studies have examined the characteristics of CA-MRSA in a general student population.20-22

The purpose of this study was (1) to measure the nasal carriage rate of S. aureus and MRSA, (2) to examine the antibiotic sensitivity of MRSA isolates by microbiological susceptibility testing, and (3) to conduct an univariate analysis in order to identify risk factors significantly associated with nasal carriage of S. aureus and MRSA in a population of dormitory and non-dormitory students at a four year public university in Texas. It is anticipated that the findings of this study will be utilized in (1) the development of specific health education and/or promotion activities for those who are at greater risk for acquiring MRSA or who are currently colonized in this university population via a campus-wide program on MRSA awareness, (2) the identification of antibiotic resistance trends occurring in this university population, and (3) to assist university healthcare officials in the control and prevention of transmission of MRSA with respect to risk factors identified in this study.

MATERIALS AND METHODS

Sample and Data Acquisition

A cross-sectional design was applied to determine the rate of S. aureus and MRSA carriage in university students and to describe exposures (risk factors) associated with carriage. Clinical Laboratory Science (CLS) personnel at the university recruited college students by notification during dorm hall meetings, classroom lectures, and random encounters for participation. Investigators incorporated a purposeful sampling strategy with the final sample consisting of dormitory and non-dormitory students over the age of 18 who had been previously enrolled.
for at least one long semester. A long semester at this institution is approximately three and a half months. Previous enrollment for at least one long semester aided the research design by serving as a criterion to standardize the students’ exposure to university risk factors. All student participation was voluntary, and participants first authorized informed consent documents. The institutional review board of Texas State University–San Marcos approved all procedures and protocols. Only students who understood English were asked to participate. CLS personnel obtained questionnaire information (Figure 1) and nasal swabs from students who elected to participate. Data collection (i.e., nasal swabs and questionnaires) occurred from December 2007 to July 2008. The questionnaire was administered to collect general demographic information including age, ethnicity, and gender. Additionally, risk factor information about possible MRSA exposure, knowledge of MRSA, hospital admission and work, intravenous drug use, dorm living status, and athletic involvement was collected. BactiSwabs (Remel Inc., Lenexa, KS) were used (both anterior nares) for demonstration to participants by CLS personnel and subsequently self-administered by each participant. No identifying information was collected from the informed consent, questionnaire, or swab. Specimens were then transported to the Texas State University CLS laboratory for specimen processing.

Laboratory Analysis
Nasal swab specimens were screened for *S. aureus* and MRSA using the standard media mannitol salt agar (MSA) and oxacillin-resistant screening agar (Becton Dickinson BBL, Franklin Lakes, NJ), Dry Spot Staphytec Plus test kits (Oxoid Limited, Lenexa, KS), and Dropit catalase reagent (Key Scientific Products, Round Rock, TX). Positive colony growth on oxacillin agar was confirmed as MRSA by Vitek 2 (bioMérieux, Hazelwood, MO) susceptibility testing at CTMC (CTMC, San Marcos, TX) using Vitek GN19 susceptibility cards. Cards were inoculated and incubated in the Vitek 2 per manufacturer recommendations and results were analyzed by the advanced expert system, software version R04.03. All tests were performed according to the manufacturer’s instructions. All growth on MSA or Oxacillin Agar not consistent with *S. aureus* or MRSA was discarded.

*S. aureus*, MRSA, and *S. epidermidis* specimens were provided by CTMC as confirmed by Vitek 2 analysis and were used as positive and negative controls during inoculation of all microbiological testing. Because no medical intervention is indicated for MRSA carriage, laboratory results were not reported to students.

Data Screening
CLS personnel entered questionnaire and laboratory results into an Excel database (Microsoft, Redmond, WA) for initial data collection. Prior to conducting our analyses, the total data set (N = 203) was screened for missing and/or out of range values, sparse cell frequency counts, and the sample size to number of cells ratio using SPSS (version 15.0, SPSS Inc., Chicago, IL). There were no missing data points, or empty cells and the sample size was greater than five times the number of cells for all analyses except ethnicity. A chi square and odds ratio (OR) analysis with 95% confidence intervals (CI) was conducted on the total sample (N=203) and subsequently on the MRSA isolates (N = 15). To account for sparse cell frequencies with certain categories, the variable, ethnicity, was coded for Caucasian versus non-Caucasian (African American, Asian, Hispanic, and other) and age was coded as 18-23 years versus 24 years and above.

Data Analysis
A cross-sectional design was utilized to determine the carriage rates of *S. aureus* and MRSA in university students and to describe any risk factors associated with each, respectively. The questionnaire was designed to ascertain student demographics (age, gender, and ethnicity), health care exposures (kidney dialysis, surgery, hospitalization, occupation, IV drug use, antibiotic use, or catheter), living condition (campus dormitory, non-dormitory, athletic participation, or jail history), and history of skin infection (skin infection, boil or sore with pus, been told by a doctor that they had MRSA, or heard of MRSA or antibiotic resistant staphylococcus). The students together as a university sample were analyzed using SPSS by univariate analysis on each variable listed in the questionnaire with *S. aureus* carriage being the outcome (dependent) variable. The analysis of each independent variable was then subsequently examined with MRSA being the outcome variable. Odds ratios with associated 95% confidence intervals were calculated and reported. The statistical significance of factors was evaluated using an alpha level of 0.05. A Multivariate analysis for significant variable associations using logistic regression (Enter method) did not identify a valid multivariable model for explanation.

Each MRSA isolate was tested for susceptibility, intermediate resistance, or resistance to a panel of antibiotics. The analysis was conducted by the Vitek 2 and data was examined for any unique trends or outliers as identified by standardized results.
Figure 1. Questionnaire for risk factors to *Staphylococcus aureus* and Methicillin Resistant *Staphylococcus aureus* (MRSA)

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>Don’t know/Prefer not to answer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ethnicity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>African-American</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asian</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Infections</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 In the past 12 months, have you had a skin infection, boil, or sore?</td>
<td>Yes</td>
<td>No</td>
<td>Don’t know/Prefer not to answer</td>
</tr>
<tr>
<td>2 In the past 12 months, has a doctor told you that you have a skin infection called MRSA, “mersa,” or antibiotic resistant Staph?</td>
<td>Yes</td>
<td>No</td>
<td>Don’t know/Prefer not to answer</td>
</tr>
<tr>
<td>3 Have you ever heard of MRSA, “mersa,” or antibiotic resistant Staph?</td>
<td>Yes</td>
<td>No</td>
<td>Don’t know/Prefer not to answer</td>
</tr>
<tr>
<td><strong>Healthcare</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 In the past 12 months, have you been a patient in the hospital?</td>
<td>Yes</td>
<td>No</td>
<td>Don’t know/Prefer not to answer</td>
</tr>
<tr>
<td>5 In the past 12 months, have you had surgery?</td>
<td>Yes</td>
<td>No</td>
<td>Don’t know/Prefer not to answer</td>
</tr>
<tr>
<td>6 In the past 12 months, have you worked in a healthcare facility?</td>
<td>Yes</td>
<td>No</td>
<td>Don’t know/Prefer not to answer</td>
</tr>
<tr>
<td>7 In the past 3 months, have you taken any antibiotics?</td>
<td>Yes</td>
<td>No</td>
<td>Don’t know/Prefer not to answer</td>
</tr>
<tr>
<td>8 In the past 12 months, have you used intravenous drugs?</td>
<td>Yes</td>
<td>No</td>
<td>Don’t know/Prefer not to answer</td>
</tr>
<tr>
<td><strong>Living Conditions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 Are you currently living in a dorm?</td>
<td>Yes</td>
<td>No</td>
<td>Don’t know/Prefer not to answer</td>
</tr>
<tr>
<td>10 In the last 6 months, have you lived in a dorm?</td>
<td>Yes</td>
<td>No</td>
<td>Don’t know/Prefer not to answer</td>
</tr>
<tr>
<td>11 In the past 12 months, have you been in jail?</td>
<td>Yes</td>
<td>No</td>
<td>Don’t know/Prefer not to answer</td>
</tr>
<tr>
<td>12 In the past 12 months, have you participated in athletics?</td>
<td>Yes</td>
<td>No</td>
<td>Don’t know/Prefer not to answer</td>
</tr>
</tbody>
</table>
RESULTS

Study Population
A total of 203 participants volunteered to participate in this study. The subject’s ages ranged from 18 to 52 years old (mean = 22, median = 21). The age group of 18-23 (158, 78%) was greater than the 24+ age group (45, 22%). The male to female ratio was 81 (40%) to 122 (60%), respectively. Ethnically, Caucasians (136, 67%) and Hispanics (41, 20.2%) made up the majority of the population (87.2%). African Americans (10, 5%), Asians (7, 3.4%) and others (9, 4.4%) made up the remainder of the ethnicity of our population sample. There were 108 (53.2%) dorm students that participated in this study. Of those, 34 (31.5%) were positive for S. aureus colonization, and seven (6.5%) were positive for MRSA colonization.

S. aureus and MRSA Colonization, Risk Factor Analysis, and Susceptibility
Of the 203 participants who were screened, 60 (29.6%) carried S. aureus. Univariate analysis found that only hospitalization in the past 12 months (p = .009) was significantly associated with the risk of being a S. aureus carrier (OR = 3.0, 95% CI 1.277-7.029). All other risk factors were not statistically significant. Although not significant, there was a moderate association with surgery in the past 12 months and risk of S. aureus colonization (OR = 1.9, 95% CI 0.62-5.66).

Of the 60 participants that carried S. aureus, 15 were identified as MRSA. This relates to a 7.4% MRSA colonization rate among generally healthy, university students. Univariate analysis found that hospitalization in the past 12 months (OR = 4.2, 95% CI 1.29-13.36) and recent skin infection (OR = 4.4, 95% CI 1.07-18.24) were significantly associated with the risk of being a MRSA carrier (p = .026 and .011, respectively). All other risk factors were not statistically significant. There was a moderate elevation of odds ratio (OR = 4.0) and significant chi-square value (p = .038) for surgery in the past 12 months and risk of MRSA colonization. However, this result was deemed not significant due to confidence intervals including one (95% CI = 0.982-16.288). Results of univariate analysis for S. aureus and MRSA are listed in Tables 1 and 2, respectively.

Antibiotic susceptibility characteristics of MRSA isolates are shown in Table 3. Only 14 MRSA isolates were analyzed for antibiotic susceptibility; one sample could not be cultured due to contamination. No unique patterns were observed with the antibiotic susceptibility testing. All isolates were 100% resistant to beta lactam antibiotics. Vancomycin, linezolid, gentamicin, moxifloxacin, quinupristin/dalfopristin, and rifampicin were 100% effective (susceptible). Interestingly, erythromycin was 86% resistant to all isolates.

### Table 1. Univariate analysis of S. aureus colonization risk factors

<table>
<thead>
<tr>
<th>Risk Factors</th>
<th>Raw Data⁴</th>
<th>p Value</th>
<th>Odds Ratio</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGE</td>
<td>in text</td>
<td>.630</td>
<td>1.2</td>
<td>.571 2.522</td>
</tr>
<tr>
<td>GENDER</td>
<td>in text</td>
<td>.337</td>
<td>1.3</td>
<td>.732 2.484</td>
</tr>
<tr>
<td>ETHNICITY</td>
<td>in text</td>
<td>.214</td>
<td>1.5</td>
<td>.783 2.969</td>
</tr>
<tr>
<td>SKIN INFECTION⁵</td>
<td>4</td>
<td>.921</td>
<td>1.1</td>
<td>.314 3.596</td>
</tr>
<tr>
<td>HOSPITAL PT</td>
<td>13</td>
<td>.009</td>
<td>3.0</td>
<td>1.277 7.029*</td>
</tr>
<tr>
<td>SURGERY</td>
<td>6</td>
<td>.258</td>
<td>1.9</td>
<td>.621 5.658</td>
</tr>
<tr>
<td>WORK HEALTHCARE</td>
<td>24</td>
<td>.769</td>
<td>1.1</td>
<td>.591 2.038</td>
</tr>
<tr>
<td>ANTIBIOTIC USE</td>
<td>18</td>
<td>.754</td>
<td>0.9</td>
<td>.465 1.740</td>
</tr>
<tr>
<td>IV DRUGS</td>
<td>1</td>
<td>.628</td>
<td>0.6</td>
<td>.064 5.319</td>
</tr>
<tr>
<td>DORM</td>
<td>36</td>
<td>.243</td>
<td>1.4</td>
<td>.780 2.652</td>
</tr>
<tr>
<td>JAIL</td>
<td>1</td>
<td>.874</td>
<td>1.2</td>
<td>.108 13.667</td>
</tr>
<tr>
<td>ATHLETICS</td>
<td>26</td>
<td>.854</td>
<td>1.1</td>
<td>.575 1.952</td>
</tr>
</tbody>
</table>

A. Age categorized into traditional (18-23 years old) and nontraditional (24+ years old).
B. Ethnicity categorized into Caucasian and non-Caucasian (Hispanic, African American, Asian, Other).
C. Skin infection includes recent skin infection and skin infection with MRSA.
D. Raw number of participants who admitted to the risk factor and who were colonized with S. aureus. (Demographic raw numbers are broken down in the results section.)
DISCUSSION
According to the National Health and Nutrition Examination Survey (NHANES) conducted from 2003-2004, the prevalence of colonization with S. aureus and MRSA in the civilian non-institutionalized population of the United States was 28.6% and 1.5% respectively. The present Texas study identified a carriage rate of 29.6% S. aureus in a university student population which is consistent with the NHANES data. However, the 7.4% MRSA carriage rate among the student population is much higher than the 1.5% carriage rate of the NHANES population. Several different subpopulations have been assessed for CA-MRSA colonization rates including homeless and runaway youths, 6.2%; an American Indian clinic population, 1.9%; Texas county jail inmates, 4.5%; children at well-child checkups, 9.2%, and a college football team with outbreak history, 8.0%. The Texas university MRSA carriage rate in this study population compares most closely with the 8.0% carriage rate found in a college football team. Since people are generally unaware of their MRSA carriage status and because the S. aureus carriage rate mirrored that of the general population, the authors feel confident that the overall MRSA carriage rate was not unduly biased.

The commonly known risk factors of MRSA are well recognized, typically being healthcare-associated, including hospital admission, recent surgery, intravenous drug use, and working in a healthcare environment. Univariate analysis in the Texas university study revealed hospitalization to be strongly associated with S. aureus and MRSA nasal carriage. Recent skin infection was also significantly associated with the risk of being a MRSA carrier. The Texas university findings echo previous studies and the known risk factors associated with a healthcare environment. Additionally, the MRSA isolates in this study did not reveal any unusual resistance patterns; all isolates were resistant to beta lactam antibiotics and susceptible to non-beta lactam drugs. Interestingly, erythromycin exhibited 86% resistance to the isolates.

This study did not confirm a variety of other risk factors for nasal carriage of S. aureus previously identified. The authors believe this may be due to the fact that most of the previous studies were in medical students and not a healthy, general college population. Like this study, a study in a Hawaiian community college found no significant association with S. aureus carriage and ethnicity, gender, recent antibiotic use, or prior S. aureus infections. A student community study of preclinical medical students and undergraduate students conducted from 2000-2002 reported significant associations with S. aureus carriers and males as well as older age. This study found no significant associations with these risk factors.

Table 2. Univariate analysis of MRSA colonization risk factors

<table>
<thead>
<tr>
<th>Risk Factors</th>
<th>Raw Data</th>
<th>p Value</th>
<th>Odds Ratio</th>
<th>95% Confidence Interval</th>
</tr>
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<td>AGE</td>
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</table>

A. Age categorized into traditional (18-23 years old) and nontraditional (24+ years old).
B. Ethnicity categorized into Caucasian and non-Caucasian (Hispanic, African American, Asian, Other).
C. Skin infection includes recent skin infection and skin infection with MRSA.
D. Raw number of participants who admitted to the risk factor and who were colonized with MRSA. (Demographic raw numbers are broken down in the results section.)
The investigators of this project initially intended to examine the crowded and perhaps unsanitary conditions of university residence halls and their association with \textit{S. aureus} and MRSA carriers. It could be anticipated that these types of close-quarter living conditions would increase the risk of \textit{S. aureus} and MRSA colonization. However, this study found no significant differences between the colonization rates of dorm students and the colonization rates of non-dorm students. A study on Nigerian students found similar results stating that the number of people with whom the subjects shared a room did not seem to affect the rate of nasal carriage.\textsuperscript{22}

There were several limitations to this study. Samples were collected from one university and not all dorms on the campus were sampled. It is also important to note that the investigators conducted a small pilot study (\textit{N} = 203) and thus results should not be generalized to the entire student population. This may not be representative of other universities or other shared campus living quarters. The self-administered questionnaire and self-administered nose swab could have led to inaccuracies in the risk factor data collected and the colonization rates of MRSA. Students completing the questionnaire may have been lacking the knowledge to accurately complete and answer the risk assessment questions. For instance, several students questioned whether oral contraceptives and aspirin were considered antibiotics, and other students might not have considered insulin or other IV therapy as recent IV drug use.

Because this study was cross-sectional and anonymous, the authors weren’t able to examine intermittent versus persistent carriage of \textit{S. aureus} and MRSA. Participants who may have been intermittently colonized may not have been detected in this study. Additionally, positively identified MRSA samples could not be further studied and detailed histories of past colonization risk factors could not be investigated. Finally, the investigators were not able to conduct genetic analysis (e.g. PFGE) of MRSA isolates to characterize strains that may be significant. Regrettably, the MRSA isolates became contaminated or perished at a secondary laboratory. It is anticipated that a future study will be conducted to include a larger sample size with genetic analysis included.

### Table 3. Antibiotic susceptibility of MRSA isolates

<table>
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<tr>
<th>Isolates\textsuperscript{B}</th>
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<th>CFS</th>
<th>CIP</th>
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<th>ERY</th>
<th>GEN</th>
<th>LF</th>
<th>LZ</th>
<th>MXF</th>
<th>NF</th>
<th>Q/DF</th>
<th>R</th>
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</table>

A. Abbreviated antibiotics: BP = benzylpenicillin; CFS = cefoxitin screen; CIP = ciprofloxacin; CLIN = clindamycin; ERY = erythromycin; GEN = gentamicin; LF = levofloxacin; LZ = linezolid; MXF = moxifloxacin; NF = nitrofurantoin; Q/DF = quinupristin/dalfopristin; R = rifampicin; TET = tetracycline; TMP = trimethoprim; V = vancomycin; OX = oxacillin

B. Isolate numbers (14 total MRSA isolates; 1 isolate unable to grow due to contamination); R = resistant, S = susceptible, I = intermediate

C. RXN = Total percentage of MRSA isolates identified as S, R or I
Due to convenience, some of our participants were selected from other health profession majors. A majority of these students have worked in healthcare facilities, and this may have created a bias towards S. aureus and MRSA carriage rates. Further studies should look at randomly selected healthy members of a university to expand upon the knowledge of various carriage rates among schools and should examine other risk factors to help understand how MRSA and S. aureus are transmitted in the community along with risk assessment. Additionally, surveillance studies should be conducted to examine the community in the dorms alone to better assess the risk factors of living in close contact quarters over a period of time. This may augment the evaluation of how S. aureus and MRSA are transmitted through the community.

CONCLUSION
The purpose of this study was to identify the more commonly associated risk factors associated with S. aureus and MRSA carriage in a general university population. The investigators identified a strong association with past hospitalization for S. aureus colonization; past hospitalization and recent skin infection with MRSA colonization. No significance for MRSA carriage was identified between dormitory and non-dormitory students. CA-MRSA, along with HA-MRSA, has emerged as a growing world-wide problem in the past decade(s). Common-sense approaches to prevention, along with intelligent use of the laboratory (culture of wounds, antibiotic susceptibility testing, etc.) and available antimicrobials, can protect individuals from this new threat. University officials should be aware of the potential transmission risk and outbreak scenario that could develop in the rich environment of student living and recreation. Finally, research is desperately needed in the area of knowledge, awareness, and the learning needs (gaps in knowledge) of the general public with respect for MRSA and other antibiotic resistant organisms.

Clin Lab Sci encourages readers to respond with thoughts, questions, or comments regarding this article. Email responses to westminsterpublishers@comcast.net. In the subject line, please type “CLIN LAB SCI 22(2) RE ROHDE”. Selected responses will appear in the Dialogue and Discussion section in a future issue. Responses may be edited for length and clarity. We look forward to hearing from you.

REFERENCES


OBJECTIVES: To document the career paths of women clinical laboratory scientists who have transitioned from employment in a full service clinical laboratory to the higher education arena and who have administrative positions at the dean’s level, including assistant and associate dean positions.

METHODS: A multi-site case study design was selected for this qualitative research involving a purposive sample of eight research participants. Data collection was guided by ten open-ended questions in seven face-to-face and one telephone semi-formal interviews.

SETTING AND PARTICIPANTS: The purposive sample included women who held a current higher education administrative position at the dean’s level, including associate and assistant dean positions, in a university setting. These women also possessed a background in clinical laboratory science. The participants were located in eight higher education institutions in Nebraska, Illinois, Ohio, Tennessee, Missouri, and Texas.

MAIN OUTCOMES MEASURES: Experience as a clinical laboratory scientist, experience as faculty, experience as a higher education administrator, description of career path.

RESULTS: The participants of this qualitative study selected clinical laboratory science as their area of formal education through various means. Through no intentional action on their part, all of these women became faculty members in clinical laboratory education programs. By exhibiting the necessary knowledge and skills, these faculty members were selected to move into higher education administrator positions. The participants indicated their career paths were determined by “being in the right place at the right time” versus pre-determined career goals.

CONCLUSION: Participants in this study indicated having a background in clinical laboratory science enhanced their ability to obtain a position as a higher education administrator.

ABBREVIATIONS: CLS=Clinical laboratory science; CLS/MT=Clinical laboratory scientist/medical technologist; CLT/MLT=Clinical laboratory technician/medical laboratory technician; CLE=Clinical laboratory education.

INDEX TERMS: career paths of women clinical laboratory scientists; women higher education administrators; women’s leadership skills.

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Acknowledgements: The authors would like to thank the women participants of this case study for sharing the experiences of their career paths as they transitioned from clinical laboratory scientists to higher education administrators.
INTRODUCTION

Women, in increasing numbers, are joining their male colleagues as higher education administrators. However, only a small percentage of these women possess an academic background as clinical laboratory scientists. This qualitative case study sought to document the career paths of women clinical laboratory scientists who have transitioned from the clinical setting to the higher education arena and held an administrative position at the dean’s level, including assistant and associate dean positions. The findings indicated that even though these women possessed an academic background in clinical laboratory science, their experiences paralleled those of women higher education administrators with degrees in other academic areas.

BACKGROUND

In the 21st century, an increasing number of women are seeking and obtaining leadership positions in higher education. Women have progressed from being unable to attend college to holding leadership positions that guide the vision and mission of these institutions. A significant number of women are earning doctoral degrees and applying this knowledge as higher education administrators. As leaders in higher education, these women bring their own set of characteristics and skills to the table. Their collaborative leadership style, knowledge, skills, and commitment are valuable to the success of the institutions they serve.

The career paths that women follow to obtain positions as higher education administrators are varied. The traditional path includes experiences as faculty, program director, division chair, and dean. At critical points in their careers, women have participated in various professional development opportunities. These experiences have fostered new skills, added knowledge, and enhanced the skills identified as those of a competent leader. However, it is not mandatory that women follow this traditional path.

Women clinical laboratory scientists add an additional component to their career paths. Their first career is as a clinical laboratory scientist (CLS) in the hospital setting. As CLSs, they perform a variety of laboratory tests that provide the physician with the necessary data to make a diagnosis and to determine treatment for the patient. A small number of these women move from the clinical setting to the educational setting where they fill the higher education roles as faculty members in CLS and clinical laboratory technician (CLT) programs. Additional opportunities to move up the career ladder are offered to those that display the necessary traits and operant skills. The career paths of this unique group of women clinical laboratory scientists who have successfully transitioned to higher education administration are the focus of this study.

LITERATURE REVIEW

In the early days of laboratory testing, pathologists trained personnel on-the-job. As advancements in the testing and correlation of results with disease processes and patient conditions increased in complexity, formal education programs were established. The first of these programs was located in a hospital setting. Clinical laboratory education (CLE) programs were later developed in two-year and four-year academic settings. In both settings, there existed a need for a program director and didactic faculty. Since the majority of the laboratory workforce consisted of women, it made sense that the largest percentage of CLE program directors and didactic faculty also were women. When women moved to the education arena, new and different skills were required to conduct administrative tasks. These tasks included recruitment of students, curriculum development and revision, budget preparation, maintaining national program accreditation, program evaluation and assessment, and ensuring program stability and viability through strategic planning.

Successful CLE program directors must demonstrate a solid skill set that includes written and oral communication, budget planning, student assessment strategies and analysis, the ability to work with advisory board members and clinical affiliate representatives, program promotion, student recruitment, purchasing and inventory management, grant writing, curriculum and policy development, program accreditation, and strategic planning. As program directors develop an understanding of higher education and demonstrate success within their CLE programs, the natural step up the career ladder is to seek and obtain positions as higher education administrators.

In 1920, women constituted 47% of the undergraduate enrollment in higher education. Thirty-two percent of college presidents, professors, and instructors were women in 1930. During the period from 1930 to 1960, the proportion of women receiving bachelor degrees and their first professional degrees fell to 24%. During this same time, only 9% of doctoral degree recipients were women. In 1965, the Higher Education Act helped to increase the number of women undergraduates. Legislative actions such as Affirmative Action and Title IX also opened the doors of opportunity for women in higher education. During the 1970s, women...
faculty and administrators strived to find ways to improve their status within their professions.\(^1\)

In 1978, women made up 52\% of students at the masters level and 40\% of students at the doctorate level.\(^7\) Women constituted 51\% of the total student enrollment in higher education in 1980. During this same period, women made up 25\% of full-time faculty in higher education: 8\% were full professors, 16\% were associate professors, 28\% were assistant professors, 29\% were instructors, and 18\% held deanships.\(^1\) During the mid 1990s, 39\% of newly employed faculty were women and represented almost five times the number of veteran women faculty. Furthermore, research institutions hired women at twice the rate of comprehensive institutions.\(^2\) In the mid 1970s, the ratio of male presidents to female presidents was 20:1. By 1992, the ratio was 10:1.\(^3\) During the 21\(^{st}\) century, women continue to break through the “glass ceiling” of educational leadership.

Since the beginning of higher education in America, women have struggled to be considered equal to men.\(^1\) Even though women made up the majority of educators, few were encouraged to move their careers beyond the classroom. However, during the last fifty years, educational leadership roles for women have changed. Women have demonstrated they possess the characteristics and competencies to be leaders in the academic arena. Increasing numbers of women have moved into administration and researchers interested in this phenomenon have identified requirements that assist women in gaining these positions. These requirements included: pursuit of advanced degrees such as a doctorate, participation in leadership development activities, formation of a relationship with male and female mentors, demonstration of high levels of competence, and the development of problem solving and team-building skills.\(^4\)

Most of the earlier leadership studies looked at men as leaders; more recent studies focused on women as leaders.\(^1,3\)\(^-\)\(^14\) Some studies indicated that women are effective leaders yet have different styles than men. The leadership styles of women clinical laboratory scientists who have become higher education administrators were a component of this study.

**METHODOLOGY**

**Case Study Design**

Case study research design offered the best opportunity to explore and document the career paths of women clinical laboratory scientists who held higher education administra-

A multi-site case study was selected as the design for this qualitative research. Participants were located at eight higher education institutions at the university level that were located in Nebraska, Illinois, Ohio, Tennessee, Missouri, and Texas. Data collection was guided by ten open-ended questions in seven face-to-face and one telephone semi-formal interviews.

**Purposive Sample**

Three sources were used to identify probable participants: a clinical laboratory educators’ electronic list of participating members, the National Network for Healthcare Programs for Two-Year Colleges, and program directors of NAACLS accredited CLS/MT and CLT/MLT programs in the predetermined geographic region. Each source was asked to identify women who held a current higher education administrative position and possessed a background in clinical laboratory science. The initial contact was via an email that included a request for each source to submit contact information for an identified individual. Eight women in higher education administrative positions that possessed a background in clinical laboratory science and met the study criteria were contacted and asked to participate in the study.

**Participant Demographics**

The eight participants involved in this study had a previous history of employment in the clinical laboratory. These women had experience in clinical chemistry, hematology, coagulation, blood bank, and/or microbiology in a hospital clinical laboratory setting. Seven of the participants were clinical laboratory scientists with a formal degree in the field. The eighth participant held a degree in chemistry with employment in a clinical laboratory setting. Seven of the women held the title of dean, assistant dean or associate dean. The eighth held the title of assistant vice president. Regardless of differences in the position titles, job functions were similar and thus the researchers determined that the participant met the criteria of the study.
The participants were asked to complete a demographic information form. Five of the professionals were between 50 and 59 years of age, one was younger, and two participants were over the age of 60. Three of the participants held doctorates in philosophy, one completed the doctoral coursework but did not complete a dissertation, one held a doctorate of arts, one held an educational doctorate, and two possessed masters degrees. The number of years as a faculty member for these participants ranged from 10 to 39 years; three women were in the 20 to 39 year range. Five women were full professors, two were associate professors, and one was an assistant professor. Five of the eight participants were married. Seven of the eight participants were mothers.

Each of the eight participants was assigned a pseudonym and a university name that corresponded with a Greek letter. The selected pseudonyms included: Ann at Alpha University, Brianna at Beta University, Debra at Delta University, Gwen at Gamma University, Kelly at Kappa University, Lynn at Lambda University, Olive at Omega University, and Teresa at Theta University.

Interview Process
The informed consent and demographic information were reviewed and collected prior to beginning the interview process. The interviews were conducted in the natural settings of the participants between November 2005 and December 2005. Seven of the interviews were conducted in a face-to-face method. The eighth interview was conducted via telephone. Each participant was encouraged to ask questions related to the study prior to the start of the interview.

Each interview was guided by a semi-formal interview format that consisted of ten open-ended questions that provided opportunity for the researchers to ask “how” and “what” types of questions such that the interviewees would be more likely to share their experiences and knowledge. The interview questions may be found in Figure 1. The interview format allowed for complete, accurate, and reliable oral documentation. The oral interviews provided the mechanism to gain rich data from the interviewees in short periods of time. Participant curriculum vitae also were requested and subsequently provided to the researcher. The information in the curriculum vitae was used to verify the information provided by the participants on the demographic information form.

Data Analysis
As indicated by Bogden and Bilken, analysis involves working with the data, organizing them, breaking them into manageable units, coding them, synthesizing them, and searching for patterns (p. 146). The coding process involved the grouping of similar topics in categories such as major topics, unique topics, and leftovers. The data analysis phase consisted of reading and rereading the transcripts and reflecting on the meaning of the statements. Data reduction involved the chunking of data into manageable pieces. Taylor and Bogdan suggested keeping track of hunches, interpretations, and ideas when looking for emerging themes. This theme was supported by three categories that were developed from 45 data codes.

Data Validation
Although qualitative research does not lend itself to reliability and generalizability as does quantitative research, validity can be confirmed. Creswell and Merriam identified various strategies that include: triangulation, member checks, rich-thick description, clarification of researcher bias, evaluation of negative/discrepant information, a prolonged time in the research environment, peer debriefing, and use of an external auditor. For this study, member checks, rich-thick descriptions, and an external audit were used to validate the data.

RESULTS
The Getting to the Right Place at the Right Time theme was based on the three different careers experienced by each of these women. They experienced shared phenomena in the clinical laboratory, as a higher education faculty member, and as a higher education administrator. Participants related their high school academic strengths, college experiences, clinical laboratory science training, and clinical experiences. During their time as faculty, their teaching experiences were presented. And finally, they described their experiences as women higher education administrators.

Getting to the Right Place at the Right Time
This major theme supported the first research question, which was, “What are the lived experiences of women higher education administrators with a background in clinical laboratory science during their career path?” A major commonality of this group of women was the fact they had three different careers. The majority of the participants followed a traditional career path with experiences as a clinical laboratory scientist, a university faculty member and related experiences, and finally as a higher education administrator. One participant transitioned from a position as a part-time procedure writer to an associate dean position. Each of these participants experienced three career stops in their journey.
The Clinical Laboratory
The first stop was the clinical laboratory. Since clinical laboratory science is an often over-looked career choice, it was interesting to discover how this group of women obtained entry into the field. Five of the participants indicated a love for math and science when in high school. Ann at Alpha University stated, “I liked chemistry…and I thought working in a laboratory sounded like a fun thing to do. I decided to go into chemistry and I never regretted it. I think it has been a fun career for me.” Kelly at Kappa University indicated that the clinical setting “…just seemed to be a perfect mesh for me. I loved the science.” One participant discovered the clinical laboratory science profession after talking to her high school counselor. Indicating that a

Figure 1. Interview protocol

1. Please describe your career path upon obtaining your bachelor’s degree in medical technology.

2. What event or individual motivated you to move into an administrative position?

3. Leaders are often described as individuals with notable skills and characteristics, what leadership skills and/or characteristics do you possess?

4. What training or professional development opportunities have you participated in that attributed to your career success?

5. Mentoring is often something that happens along one's career path, what experiences have you have in a mentoring relationship?
   a) Describe your mentor, ie position, gender, special events, type of relationship.
   b) Have you mentored others, especially women, as they move through their careers?

6. The literature often cites barriers or obstacles for women administrators in higher education. Have you experienced barriers or obstacles during your career path? If so, please describe your experiences.

7. As a woman, what opportunities have you experienced in moving up the career ladder?
   a) Have you accepted all of the opportunities presented to you?
   b) Have you turned down advancement opportunities? If so, why?

8. Some research studies indicate that women are breaking the ‘glass ceiling’ of administration in higher education. Do you agree or disagree with this statement?
   a) What events in your career would indicate your agreement?
   b) What events in your career would indicate your disagreement?

9. It is often stated that women have ‘paid a price’ for success in administrative positions. What experiences have you had that either support or refute this statement?
   a) Identify the experiences that support this statement.
   b) Identify the experiences that refute this statement.

10. Women often balance career goals with marital and/or family commitments. Have you faced conflicts between these commitments?
    a) If so, how did you resolve these conflicts?
    b) What advice would you give women pursuing administrative positions in higher education?
    c) If you could redo your career choices, would you make the same choices? If so, why? If not, why?
career day at the local hospital piqued her interest in the clinical laboratory, Olive at Omega University said,

“You could visit the various areas of the hospital and – you’re going to laugh – but I signed up for physical therapy and maybe pharmacy. One of the two couldn’t accommodate me so they sent me to the lab. I really had never even thought about the lab… didn’t know it existed, but fell in love with it.”

Additional opportunities to learn about a career as a clinical laboratory scientist occurred during Girl Scout activities, volunteering as a candy striper in the hospital, and during college experiences. Debra from Delta University earned a degree in liberal arts with the intention of attending medical school. She stated,

“I couldn’t get a job because I had this liberal arts education and I could do nothing. I kind of fell into medical technology as a fluke. I called around and found a couple of hospitals that had medical technology schools so I applied to the ones that paid a stipend.”

The path by which seven of the participants earned their degree in CLS varied. For some, their training was university-based; others gained their education via a hospital-based program. The eighth participant earned a degree in chemistry. However, she was employed as a clinical chemist in a hospital laboratory. Upon earning their degrees, all had experience in a clinical laboratory for varying lengths of time.

The participants began their careers as laboratory professionals working in a full-service hospital laboratory. Most participants had experience in clinical chemistry. Ann, employed as a clinical chemist in the lab, described her time in clinical chemistry as “…a very, very exciting time to be in the lab, because it was just going from manual to automation. I participated in that whole process, because I would be the one who would set up the new method.” Additionally, hematology and coagulation, blood bank, and microbiology were other areas that provided clinical experiences. In this setting, they honed their skills as detail-oriented professionals who were highly organized and guided by strict policy and procedures. Their critical thinking and communication skills enabled them to carry out their responsibilities with accuracy and precision. As a vital member of the healthcare team, these women clinical laboratory scientists played an important role in quality patient care.

During their tenure in the clinical laboratory, these women assumed the role of clinical instructors and became involved in the training of CLT/CLS students from local colleges and universities. By working as clinical instructors for an academic program, their professional skills and abilities to teach and to relate to students were evaluated by the CLE program directors. When a CLT or CLS faculty position became available, several of these women were hand-picked for the position. Kelly at Kappa University stated,

“The director of the program here called me. They were changing [the program format] and moving some basic courses throughout the curriculum and they were adding faculty. They called me and asked if I was interested in teaching. I said, ‘Sure, why not?’ ”

Olive at Omega University shared,

“I’d really like to go into education. They were opening a new position in the laboratory and the [laboratory manager] said if I would agree to stay he’d promise it to me. I became the first education coordinator who was a medical technologist at the hospital-based program.”

However, a few of the participants actively sought opportunities in higher education.

Professors in Higher Education Departments
After obtaining experience in the clinical setting, these clinical laboratory scientists had opportunities to transition into education. Becoming a faculty member at the university level represented the second career stop for these participants. Lynn at Lambda University stated,

“A position came open at this university at the instructor level. I had finished my masters so I decided to switch to the university. [Just when I arrived] the program director position came open. [I] immediately knew this was what I wanted to do for the rest of my life – was the university work. I had no idea I wanted to be an administrator at that point in time, but I knew I wanted to teach and to do research…”
Two of the participants moved from the role of clinical instructor to program faculty after being contacted by the CLE program director. Although some of the participants progressed from the clinical area to higher education because they were identified as candidates for the faculty position, other participants actively sought positions as faculty at higher education institutions. Participants of the study also earned positions as clinical laboratory education program directors.

As they progressed in their careers, these women demonstrated the necessary skills to serve as the department chair position. This position afforded them experience in management, leadership, budget development, curriculum development, recruitment, grant writing, professional development, assessment, faculty evaluation, and mentoring.

**Higher Education Administration**

Program directors, department chairpersons, and division chairpersons are often viewed as administrators; however, for the purposes of this study, the researchers determined positions at the associate and assistant dean and dean were administrative positions. A distinguishing characteristic of the dean’s position is the interaction with multiple university-wide personnel and subordinates. Thus, becoming a higher education administrator represented the third career stop for these participants. The opportunities to transition from faculty status to administrator differed among the participants. Seven of the participants moved up the administrative ranks within one institution. These individuals were sought by a university dean or president and asked to consider administration. Ann at Alpha University was considering another employment opportunity and was traveling to complete the second interview when the dean of the college of pharmacy called her and said, “Ann, are you interested in the associate dean’s job because I would like to nominate you?” Ann replied, “Well yes I am.” The remaining participant actively sought a position at the administrative level. The majority of the participants were in the position of department chairperson prior to advancing to the assistant dean position. Brianna at Beta University stated,

“I was interim department head and then assistant director for the school. I had been in charge of budget and finance… I came on as half-time department head, half-time associate dean with the idea they were grooming me so when [the dean] retired… I could step in.”

Debra at Delta University indicated,

“I was the director of the medical laboratory technician and medical assistant program. [After] the college re-organized, the president asked me if I was willing to move to another campus as division head of mathematics and technology and I said yes. The position as associate dean of instruction opened up and I applied for that and got it.”

Previous experience with faculty, budget and finance, assessment, grant writing, and administrative responsibilities were noted as skills that enabled the participants to be considered for a position in higher education administration.

When further queried about whether they would repeat their career choices, the participants overwhelmingly indicated they would not change their career paths. They were adamant that being laboratory professionals had served them well. This position served as a springboard into higher education - first as a faculty member and then as an administrator. They reported their CLS skills, such as being detail-oriented, being able to organize and prioritize, and possessing a strong work ethic with no fear of commitment, served them well in their administrative roles. Although these women did admit to a desire to have made different choices, as a whole they appeared happy with their career choices. Brianna at Beta University summed up the sentiments of the group when she stated,

“I feel like I am on my third career. I was a medical technologist, a research scientist, and now I am an administrator. Each one fit my life at the time. I would probably say I would make the same choices because they fit my life as it was. Everything colors things and everything changes things.”

She further added, “… the choices you make influence where you go. I’ve been lucky that I’ve been happy with each career path.”

**CONCLUSION**

Through the use of a qualitative case study research design, eight women clinical laboratory scientists who held positions at the dean’s level or equivalent in higher education administration were interviewed. The interview questions were formulated to retrieve information about their career paths as it related to their experiences; skills, training, and profes-
sional development activities; identification of any barriers or obstacles; and how being a woman has influenced their careers as administrators in higher education institutions.

This group of women willingly shared the experiences as they related to their three career opportunities and how each of these professions served them well at that point and time along their career paths. Upon completion of their CLS training, they were all employed in the clinical laboratory setting. From there, they accepted a faculty position in a university system. By demonstrating various skills attributed to quality leadership, they were provided with opportunities to transition to higher education administration.

The experiences of this group of CLSs turned higher education administrators mirrored those of women in other studies with regard to mechanisms to successfully attain and maintain that position. Although some of the personality characteristics of CLSs, i.e. detail-oriented, highly organized, and procedure-oriented, may have attributed to their ability to move to an administrative position, these skills were enhanced by other competencies attained along the way.

Author’s Note:
The results of this qualitative research study identified three major themes: 1) Getting to the Right Place at the Right Time, 2) The Right Navigational Skills are Required, and 3) The Right Place Comes with a Price. The participant experiences that support the first theme are presented here.

A Note about Qualitative Research
The researcher that selects a qualitative research method “collects open-ended, emerging data with the primary intent of developing themes from the data” (Creswell, 2003, p. 18). This method of data collection allows for a study of an exploratory nature. The exploration and discovery of data via a qualitative research method often indicates that there is not much written about the participants or topic of study. The data from the participants are used by the researcher to formulate ideas (Creswell, 2003). The ideas then become data codes that are grouped into categories. The major theme development is then based on the identified categories.

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