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HEART FAILURE (F PEACOCK AND L ZHANG, SECTION EDITORS)

Stethoscope as a Vector for Infectious Disease

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Abstract
Purpose of Review To discuss the current status of the stethoscope as a vector for infection and possible interventions to promote stethoscope disinfection.
Recent Findings Anywhere from 70 to 100% of stethoscopes are contaminated after a physical examination with bacterial counts of stethoscopes comparable to those of the physician's dominant hand. Disinfection with alcohol agents can reduce the number of pathogens and risk of transmission, which is recommended by guidelines. However, only 0–11% of healthcare providers disinfected their stethoscope before patient contact and 0–24% disinfected after the contact. The effectiveness of educational programs with visual reminders and supplying disinfectants is uncertain.
Summary Stethoscopes commonly harbor bacteria and can serve as a vector for transmission of infectious diseases. Only a minority of healthcare providers actually disinfect their stethoscope. There is a clear need for strategies to alter physicians' recognition and behavior for stethoscope disinfection.

Keywords Stethoscope · Healthcare-associated infection · Infection control · Disinfection

Introduction

The stethoscope has been the center of patient care and universally used by healthcare providers and is a bond between the patient and a doctor. Although newer imaging technologies and novel biomarkers have been implemented [1], auscultation is an essential part of patient care, providing diagnostic and prognostic information with a repeatable and non-invasive manner. Detecting a heart murmur with auscultation is the easiest way to screen for valvular heart disease. An S3 heart sound is one of the most diagnostic signs of heart failure and has a significant impact on prognosis [2]. Additionally, the stethoscope is not merely a tool for physical examination but also serves as an icon of the medical profession, symbolizing professional and empathetic patient care. Auscultation, as well as other physical exam maneuvers, promotes communication and interaction between physicians and patients.

However, hidden in this ubiquitous healing tool is the potential for patient harm with inappropriate use, specifically as a means to transmit infectious disease. Every other vector of transmission is addressed including gown, gloves, and masks, but the stethoscope has been completely neglected. The following review will discuss the stethoscope's role as a harbor of infection, current practices of disinfection, and possible educational interventions.

The Impact of Healthcare-Associated Infections

Healthcare providers' hands have been considered one of the main routes of cross-transmission of healthcare-associated infections (HAIs), and the importance of adequate hand washing is widely accepted. This was recognized as early as 1846 by Dr. Ignaz Semmelweis leading to the widespread use of hand hygiene [3]. In the mid-nineteenth-century, puerperal fever was a common and fatal disease. Dr. Semmelweis hypothesized doctors' hands transmitted puerperal fever and demonstrated the incidence of puerperal fever was drastically decreased by hand hygiene with chlorinated lime solutions.

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Even in the current era, the risk of HAIs is substantial and is an important cause of morbidity and mortality for patients. A survey of HAI prevalence conducted in 2011 reported that about one in 25 hospitalized patients will have at least one HAI [4]. There were estimated 722,000 HAIs in US hospitals resulting in estimated 75,000 deaths from HAIs during their hospitalizations. The most common pathogens of HAIs are *Clostridium difficile* (*C. difficile*), *Staphylococcus aureus* (*S. aureus*), *Klebsiella pneumoniae*, *Klebsiella oxytoca*, *Escherichia coli*, *Enterococcus* species, and *Pseudomonas aeruginosa* (*P. aeruginosa*).

Pneumonia, surgical site infection, gastrointestinal infection, urinary tract infection, and bloodstream infection are the major types of HAIs. Hospital-acquired and ventilator-associated pneumonia, which are mainly caused by multidrug-resistant gram-negative bacilli, is the leading cause of death among HAIs [5, 6]. The majority of gastrointestinal infections are secondary to *C. difficile* infections, which are also major contributors to the burden of HAIs in acute care hospitals [7, 8]. Urinary tract infections can be caused by prolonged catheter placement with inappropriate care [9, 10].

Beyond the providers' hands, patients can also get these infections from medical equipment and can lead to HAIs. However, the stethoscope, the "physicians' third hand," is less recognized as an infectious vector and the importance of disinfecting stethoscopes has been under-recognized compared to hand hygiene.

The Stethoscope as a Vector of Healthcare-Associated Infections

Several studies have documented that stethoscopes are frequently colonized by pathogenic bacteria. In 1972, Gerken et al. investigated the cultures of 100 stethoscopes used in a teaching hospital and reported 21% carried coagulase-positive staphylococci, many of which were resistant to multiple antibiotics [11]. In 1996, Smith et al. examined 200 stethoscopes from hospitals and outpatient clinics and showed 80% were contaminated with bacteria, the majority of which were *Staphylococcus* species including methicillin-resistant *S. aureus* (MRSA) [12]. Another study evaluated 40 stethoscopes from physicians, nurses, medical students, and house staff in an intensive care unit and general medical ward at a university hospital. Coagulase-negative *Staphylococcus* (CNS) was present on 100% of stethoscopes and *S. aureus* on 38% [13].

Similar findings have been reported in more recent literatures. Gupta et al. investigated the degree of contamination of stethoscopes in different hospital wards and intensive care units of a tertiary care teaching hospital. They evaluated 50 stethoscopes of which all were culture positive. CNS was predominantly isolated (77%) [14•]. Earpieces, as well as the diaphragm, can be infected. Of 74 stethoscopes studied for the colonization of diaphragms and earpieces, 66% of ward stethoscopes and 69% of doctors' stethoscopes were colonized at either the bell/diaphragm or the earpiece, or both. High levels of CNS colonized both the diaphragm and earpieces [15]. The majority of isolated bacteria were CNS [13, 14•, 16, 17]. *S. aureus* was also frequently observed [16–21]. Other possible pathogens were *C. difficile*, *P. aeruginosa*, and vancomycin-resistant enterococci [22–25].

Longtin et al. compared the contamination level of physicians' hands and stethoscopes. They evaluated four regions of the physician's gloved or ungloved dominant hand and two sections of the stethoscopes after the completion of a physical examination. The study included 83 inpatients at a university teaching hospital and 489 samples were collected. The total aerobic colony counts (ACCs) for fingertips, thenar eminence, hypothenar eminence, dorsum of the hand, stethoscope diaphragm, and stethoscope tube were 467, 37, 34, 8, 89, and 18, respectively. The diaphragm was the second most highly contaminated site behind the fingertips and more so than the thenar and hypothenar eminences and dorsum of the hand. The contamination level of the diaphragm was highly correlated with the fingertips [26••].

The stethoscope harbors a number of pathogenic bacteria and can spread them through a multistep process similar to the physicians' hand. Stethoscopes are used repeatedly throughout a day, directly touch the patients' skin and collect pathogens during a physicians' examination. One study reported stethoscopes disinfected at the beginning of the day harbored > l000 colony-forming units (cfu) per membrane after an 8-h use, representing the daily loading of the bacteria on a stethoscope. These bacteria could survive 6 to 18 h on the membrane and are waiting to be transmitted to the next patient [27–29]. Therefore, the stethoscope should be recognized as a vector of infectious disease and dealt with appropriately, as well as physicians' hands.

Stethoscope Disinfection

To cope with substantial contamination of the stethoscope, several types of disinfectants have been investigated and have demonstrated the effectiveness of alcohol-based agents [13, 19, 30, 31]. Nunez et al. investigated the effectiveness of ethyl alcohol, propyl alcohol, and antiseptic soap. Before cleaning, the mean number of colonies was 132 cfu per stethoscope. Disinfecting the stethoscope diaphragm reduced the bacterial count to 0 cfu per stethoscope with propyl alcohol, 2 cfu per stethoscope with ethyl alcohol, and 11 cfu per stethoscope with antiseptic soap. The cleaning with three different antiseptics was effective in reducing the contamination of the membranes, while the propyl alcohol-based disinfectant was the most effective and the antiseptic soap was the least effective

[30]. Another study evaluated isopropyl alcohol, sodium hypochlorite (bleach), benzalkonium chloride swabs, and soap for disinfection of stethoscope diaphragm and rim. The most effective cleaning agent was isopropyl alcohol. Cleaning decreased the cfu of the diaphragm surface from 158 cfu to 0.2 cfu and of the rims from 289 cfu to 2.2 cfu [13]. Jones et al. investigated 150 stethoscopes for the effectiveness of an alcohol swab, nonionic detergent, and antiseptic soap. Before disinfection, 133 stethoscopes (89%) grew staphylococci, including *S. aureus*. Disinfecting the stethoscope reduced the bacterial count by 94% with alcohol swabs, 88% with nonionic detergent, and 75% with antiseptic soap, suggesting the effectiveness of alcohol swabs [19].

One study showed the usefulness of alcohol-based hand soap. Schroeder et al. investigated 92 stethoscopes for the simultaneous rubbing of hands and the stethoscope head with alcohol-based hand foam. This method of disinfection significantly reduced bacterial count and eliminated MRSA colonies identified before the disinfection [32]. Another study reported single cleaning with an alcohol wipe was more effective than the alcohol-based hand rub, possibly because of the mechanical effect of the cotton pledget [33].

Several studies showed the meaningful relationship between stethoscope contamination and cleaning practices [21, 34, 35]. Zuliani et al. investigated 80 stethoscopes and found frequent cleaning practices of stethoscopes correlated with low contamination on the stethoscope [21]. Mitchell et al. reported stethoscopes cleaned daily or more frequently harbored a bacteria count approximately half compared to that of those cleaned less frequently [36]. Another study reported a longer length of time since the last stethoscope cleaning and increased risk of MRSA colonization [35].

In total, the literature shows disinfection of stethoscopes, especially with alcohol agents, can reduce the number of bacteria harbored on stethoscopes and potentially ameliorate the risk for transmission. According to CDC guidelines, surfaces of stethoscopes should be disinfected with a disinfectant to minimize the antimicrobial activity and prevent the spread of HAIs [37]. It is also recommended to disassemble a stethoscope, remove diaphragms from the chest piece, wipe their surfaces with a 70% isopropyl alcohol solution, and dry all parts before reassembly.

Special attention is needed for the prevention of *C. difficile* transmission because it forms spores that are resistant to alcohol-based agents [38]. Dedicated stethoscopes or contact precautions need to be considered.

Stethoscopes Are Rarely Disinfected

Despite the evidence for the effectiveness of disinfecting stethoscopes, only a minority of healthcare providers routinely disinfect their stethoscope. Jones et al. investigated the stethoscope cleaning measures of 150 healthcare providers in the emergency department of a university-affiliated community hospital. Overall, 48% of healthcare providers cleaned their stethoscopes daily or weekly, 37% monthly, and 7% yearly; and 7% had never cleaned their stethoscopes [19]. Another study investigated 44 healthcare providers reported 2% disinfected their stethoscope once daily, 13% disinfected after every patient contact, 11% disinfected before every patient contact, and 2% reported they disinfected before and after every patient contact [39]. Boulee et al. investigated the stethoscope cleaning methodology used by healthcare providers before and after the evaluation in the emergency center, surgical ICU, and labor and delivery rooms of a fast-paced trauma center. They investigated 400 interactions and stethoscope disinfection was observed in 2% of patient encounters before the patient exam and 16.3% after the patient exam. Cleaning duration lasted < 15 s in 90.4% of cases [40].

What is the reason for this low rate of stethoscope disinfection in our daily clinical practice? To answer this question, Muniz et al. investigated determinants of frequent disinfection [41]. An anonymous online survey was conducted with 1401 nurses, nurse practitioners, and physicians at an academic children's hospital. Of these, 76% believed that infection transmission occurs via stethoscopes, but only 24% reported disinfecting after every use. The belief that infection transmission occurs via stethoscopes was significantly associated with disinfection after every use. Major barriers for disinfection were lack of time, lack of access to disinfection materials, and lack of visual reminders to disinfect. Most healthcare providers believed that the stethoscope is contaminated and can contribute to the transmission of infections. Nevertheless, only a minority of them reported disinfecting their stethoscopes.

Another study investigated medical students for the stethoscope disinfection habits. Of 308 medical students investigated, 22.4% had never cleaned their stethoscope and only 3.9% cleaned their stethoscope after every patient. Cleaning frequency was significantly associated with others acting as role models, students having confidence in how to clean stethoscopes, and students thinking cleaning was important [42]. Other possible barriers were a lack of time and forgetfulness [16].

Interventions for Stethoscope Disinfection

Considering barriers for stethoscope disinfection, there are possible means to facilitate compliance. Educational campaigns can inform the risk of infection transmitted via stethoscopes. Materials showing stethoscope disinfection methods can serve as a reminder and promote appropriate disinfection procedure. Improved accessibility to alcohol wipes can reduce the effort to obtain disinfectants. Performance feedback with patients' participation may also promote disinfection. Single-

use disposable stethoscope diaphragm covers may allow clean auscultation and contribute to reduce transmission of pathogens.

Hill et al. investigated the effectiveness of an intervention with a poster campaign and placing alcohol-based wipes in acute elderly care wards. After these promotions, a mean total colony count per stethoscope fell from 70 at baseline to 41 at 3 months. MRSA colonies fell from 0.42 per stethoscope to 0.08 per stethoscope at 1 month. There were no MRSA colonies detected at 3 months. This small study showed simple interventions could lead to changes in physicians' practice and reduce the cross-infection risks [43].

However, another study reported a different result. Holleck et al. conducted educational programs at the start of clinical rotations for house staff, medical students, and attending physicians in a tertiary care department of a Veterans Affairs hospital [44]. They implemented an interactive presentation about stethoscope disinfection at intern report, resident report with attending physicians, and nursing staff meetings on the wards. Reminder flyers were placed inhouse staff workspaces and at the entrance to each nursing unit along with alcohol swabs. However, of 128 and 41 encounters before and after the intervention, no stethoscope disinfection was observed. The authors reported interactive presentations were well accepted, generating discussion among interns, residents, and attending physicians. The monitoring of stethoscope disinfection was announced before the survey, which could make the physician be more cognizant about disinfection. Despite these interventions, follow-up observation showed no stethoscope hygiene.

Gastmeier et al. reported evidence for stethoscope involvement in outbreaks of infection [45]. After bloodstream infections with *K. pneumoniae* in a neonatal intensive care department, intervention measures were immediately introduced. The importance of a dedicated stethoscope use and of disinfection was stressed. Strict adherence to standard infection control procedures was also recommended. The department conducted demonstrations using fluorescent light to show whether the whole hand had been disinfected. However, further cases occurred in the following week. Even after the additional intervention activities, the strain which caused the outbreak was discovered on a stethoscope. Even with a heightened awareness of an outbreak and heightened infection control, the stethoscope was neglected as a vector of infection.

Despite the recognition or reminder of the stethoscope as a vector for infectious disease, healthcare providers may not be allowed to spend enough the time between patient examinations to diligently clean their stethoscopes. The lack of time can be remarkable in busy high-acuity care units where contaminated auscultation can transfer bacteria to immune-compromised patients or to postoperative patients, resulting in surgical site infections. There is a clear need for a strategy, other than educational efforts, to actually alter physicians' behavior.

Conclusion

The stethoscope commonly harbors pathogens and can serve as a vector of infectious disease. Guidelines recommend disinfecting stethoscopes routinely to reduce the pathogens and possible risk for transmission. However, only a minority of healthcare providers actually disinfects their stethoscope and the effectiveness of educational programs was uncertain. Another strategy to alter physicians' recognition and behavior is strongly warranted.

Compliance with Ethical Standards

Conflict of Interest Yu Horiuchi, Nicholas Wettersten, Rajiv S. Vasudevan, Olga Barnett, and Alan S. Maisel declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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- • Of importance
- •• Of major importance

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