Quarantine, Isolation, and Cohorting: From Cholera to *Klebsiella*

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Abstract

Background: Isolation is defined as the separation of persons with communicable diseases from those who are healthy. This public health practice, along with quarantine, is used to limit the transmission of infectious diseases and provides the foundation of current-day cohorting.

Methods: Review of the pertinent English-language literature.

Results: Mass isolation developed during the medieval Black Death outbreaks in order to protect ports from the transmission of epidemics. In the mid-1800s, infectious disease hospitals were opened. It now is clear that isolation and cohorting of patients and staff interrupts the transmission of disease. Over the next century, with the discovery of penicillin and vaccines against many infectious agents, the contagious disease hospitals began to close. Today, we find smaller outbreaks of microorganisms that have acquired substantial resistance to antimicrobial agents. In the resource-limited hospital, a dedicated area or region of a unit may suffice to separate affected from unaffected patients.

Conclusion: Quarantine, or cohorting when patients are infected with the same pathogen, interrupts the spread of infections, just as the contagious disease hospitals did during the epidemics of the 18th and 19th centuries.

THE CURRENT PRACTICE of cohorting can be linked to historic isolation practices reaching as far back as biblical times. The book of Leviticus first describes this method of infection control. It is written "If the shiny spot on the skin is white but does not appear to be more than skin deep and the hair in it has not turned white, the priest is to isolate the affected person for seven days" [1]. Isolation is defined by the U.S. Centers for Disease Control and Prevention (CDC) as the separation of persons with a communicable disease from those who are healthy and uninfected [2]. This public health practice, along with quarantine, is used to limit the transmission of infectious diseases and provides the foundation of cohorting as we know it today.

Historical Perspective

The origin of mass isolation can be traced to the mid-14th century and the medieval epidemics of Black Death (bubonic plague), which is caused by the bacterium *Yersinia pestis*, that killed nearly a one-third of Western Europeans [3]. The practice of quarantine was started in order to protect coastal ports from the transmission of these infectious epidemics.

Derived from the Venetian dialect of the Italian words "quaranta giorni," the term quarantine means "forty days" [4]. This practice originated in 1374, when all ships were required to lay anchor for 40 days prior to reception of the crew on land [5]. Italy was affected to a great extent by the Black Death because of its multiple ports on the Mediterranean and its position as a major gateway to Europe. In 1403, in Venice, the concept of a lazaretto, or quarantine station, was born as travelers arriving by sea were quarantined on an island for 40 days. (The word "lazaretto" is derived from Lazarus, the patron saint of lepers, and originally meant a leper house, a place of confinement for persons with leprosy, which was, incorrectly, believed to be highly contagious.) This first recognized lazaret is known today as "Lazzaretto Vecchio" and can be found just south of Venice in the Venetian Lagoon [5]. The island Santa Maria di Nazareth was instrumental in curbing the plague in Italy, although as many as 500 people died per day on the island, and mass graves entombed thousands of men, women, and children who had succumbed to the Black Death [6]. The practice of quarantine and isolation allowed the determination of whether persons would recover or perish from a communicable disease prior to embarking for shore.

As commerce and human travel extended westward to the Americas, so did the communicable diseases plaguing Europe. Following the expeditions of Columbus in the late 15th century, European colonists settled along the coast of North America, predominately in the regions of what are now Boston, New York, and Philadelphia. With these settlements came livestock, horses, agriculture, and new diseases. Immigration also outpaced infrastructure, resulting in the foulness of New York City in the 17th and 18th centuries. John Duffy portrayed the conditions by noting that “overflowing privies emptied into the streets where hogs consumed the filth and wallowed in it.” Streets filled with the foul odors of rotting carcasses, piles of rubbish, and tubs of “night soil” that emptied directly into the alleyways and canals. During this time, smallpox swept through the city repeatedly, consuming 5%–10% of the population with each outbreak [7].

In 1738, New York City commandeered Bedloe’s Island, the present-day Liberty Island, from private ownership and by necessity began its own quarantine practices. This maritime quarantine station was established to protect New York from smallpox and other malignant fevers [7]. A pesthouse was constructed on the site, not to facilitate treatment, but to interrupt the transmission of disease. These almshouses were not classified as hospitals because minimal medical care was provided other than meager custodial and nursing services.

In 1751, “Pennsylvania Hospital” was established in Philadelphia as the first formal general hospital in the United States. A subsequent hospital was not established until New York City founded The New York Hospital in 1791 [8]. As epidemics of smallpox and yellow fever continued to cycle, additional pesthouses and almshouses opened to care for the indigent and destitute. The Philadelphia lazaretto, opened in 1799, housed the first quarantine-specific hospital in the United States along with administration buildings and a burial ground. During this same time, all fever victims in New York were relocated promptly to isolation within Bellevue Hospital, and a Smallpox Hospital was constructed on Blackwell’s Island (now Roosevelt Island) in the East River to isolate infected persons from the remainder of the population [7].

The 1800s were marked by an “ever-widening stream of immigrants pouring into the Port of New York,” predominately from Ireland and Germany, and more than two million travelers were received from 1840 to 1860 [7]. During this time, infectious diseases continued to be the leading cause of death and included cholera, diphtheria, scarlet fever, measles, typhoid, tuberculosis, and smallpox (despite Edward Jenner’s creation of its vaccine in 1796) [9,10]. It was during this era that an understanding of infection transmission began, and cohorting patients for a specific disease (rather than a general quarantine of all travelers) really took hold. The Health Care Infection Control Practices Advisory Committee (HICPAC) currently defines cohorting as “the practice of grouping together patients who are colonized or infected with the *same* organism to confine their care to a single area and prevent contact with other patients” [11]. Prior to this understanding, patients with all types of infectious diseases were permitted to interact within an infectious disease hospital.

The practice of cohorting for specific infections began in 1864 with the opening of the Boston City Hospital. As it opened its doors, a “pavilion system” allowed each ward to be physically isolated from the others where “sunlight and air could freely circulate” [9]. Three years later, a free-standing

smallpox building was constructed to cohort all infected patients together. Subsequently, in the 1880s, two new buildings were erected, one specifically for diphtheria and the other for scarlet fever. This cohorting extended to the staff, comprised of a “Contagious Service” of physicians and nurses who were required to wear designated gowns and were forbidden to visit the regular wards after the contagious wards rounds [9].

Beyond isolated wards and buildings, the South Department was constructed in 1895 at the Boston City Hospital as a completely separate institution for those with contagious diseases. The South Department had its own distinct administration, medical and nursing staff, laundry services, morgue, and even private ambulance service. This contagious disease hospital, complete with a “high wall to prevent germs from escaping into the neighborhood,” was the first of its kind in the United States and served as an example for many others to come [9].

The following century brought remarkable advancements in the fields of virology and microbiology, allowing Louis Pasteur and Emil von Behring to establish the rabies and diphtheria vaccines, respectively, in 1895, nearly a century after Edward Jenner’s smallpox vaccine. Shortly thereafter, vaccines were developed for cholera, typhoid, and the plague [10]. In 1928, Sir Alexander Fleming discovered penicillin, revolutionizing medical care for decades to come. Over the following three decades, vaccines were developed against yellow fever (1937), polio (1955), measles (1963), mumps (1967), and rubella (1969) [12]. Around the 1950s, the contagious disease hospitals began to close, as did the South Department of the Boston City Hospital, in 1960 [9,13]. The days of vast epidemics purging large percentages of the population were drawing to a close.

Contemporary Era

Today, we rarely suffer epidemics resulting in hundreds of thousands of deaths from the plethora of microorganisms from the previous eras. A single non-healthcare-associated infection of the current era worth noting is the human immunodeficiency virus (HIV). Over the past few decades, HIV has reached pandemic status, plaguing millions of people worldwide. Public health practices including cohorting, isolation, and quarantine, utilized for other infectious diseases, have not been widely implemented for HIV, as this is a blood-borne infection not transmissible by routine contact [14].

We currently find smaller outbreaks of microorganisms that have acquired significance because of antimicrobial resistance, frequently referred to as multi-drug-resistant organisms (MDROs). Currently, we encounter outbreaks of predominately healthcare-associated microorganisms carrying genetically advanced means of resistance to our most powerful antimicrobial agents. Because of the potential for healthcare-associated outbreaks, hospitals have developed policies to prevent the spread of MDROs, often returning to the methods of isolation and cohorting. The practices of quarantine and isolation therefore are not confined to historic medical texts but are reported sporadically throughout our current literature. Over time, we continue to interrupt these outbreaks by isolation and cohorting.

In 1961, only two years after the introduction of methicillin, the first cases of methicillin-resistant staphylococci were reported out of England [15–18]. The first large outbreak in the

United States ensued at the Boston City Hospital in 1968, where methicillin-resistant *Staphylococcus aureus* (MRSA) was isolated from 18 patients. Doctor Barrett predicted that “methicillin-resistant staphylococci will become more widespread in the United States and may present some clinical and epidemiologic problems in the future” [19]. This forecast was correct: The following four decades were replete with instances of MRSA outbreaks in the community, hospital wards, nursing facilities, and, ubiquitously, medical, surgical, and neonatal intensive care units (ICUs) [15,20–27].

The 1980s saw the arrival of MDROs expressing resistance to progressively newer antibiotics. In 1983, the first reports of antibiotic-resistant *Klebsiella pneumoniae* and *Serratia marcescens* were published in Germany [28]. Since that time, MDROs have acquired increasingly broader resistance and have been associated with worse patient outcomes. These organisms include extended-spectrum beta-lactamase (ESBL)-producing *Klebsiella*, *Enterobacter*, *Citrobacter*, *Serratia*, and *Pseudomonas* species, as well as carbapenemase-producing *Klebsiella pneumoniae* [29–35].

Vancomycin resistance emerged in 1988, perhaps because of the greater use of empiric vancomycin against MRSA, its first indication for use, and other severe gram-positive infections. The first reported cases were of *Enterococcus faecium*, less likely to cause an infection than *Enterococcus faecalis*, yet more likely to gain resistance through plasmid transfer [36,37]. Throughout the 1990s and thereafter, vancomycin-resistant enterococci (VRE) outbreaks became more frequent and paralleled the universal spread seen with MRSA [38–43].

Cohorting and Outbreak Control

It is likely our current infectious outbreaks occur by person-to-person transmission. Spread can occur from a healthcare worker to patients, such as an epidemic of *Pseudomonas aeruginosa* among neonates cared for by the same nurse during intermittent otitis externa infections, proving “we are the fomites of disease—the vectors of transmission of nosocomial pathogens” [48,49]. Direct transmission also occurs with widespread movement of patients and staff between wards, overcrowding, close proximity of patients, and larger numbers of patients per room, such as when four patients are housed together, as was seen in two MRSA outbreaks [15,22]. Numerous studies have determined the clonal relatedness of isolated pathogens by pulsed-field gel electrophoresis (PFGE). The majority of outbreaks reviewed were monoclonal, the organisms carrying the same electrokaryotype, supporting the concept of patient-to-patient transmission [23,30–33,39,42,44,46].

In nearly every healthcare-associated MDRO outbreak, a principal mode of infection control is cohorting of patients and staff. This has proved effective for disrupting outbreaks of MRSA [21,22,26,27], VRE [38,39,41–43], ESBL-producing *K. pneumoniae* [30,32–34], *S. marcescens* [44], *Acinetobacter baumannii* [31,45–47], and *P. aeruginosa* [48].

Ideally, all affected patients should be cohorted into a single dedicated hospital ward or ICU. However, as discussed previously, hospitals constantly at capacity or with limited ICU availability may not have the ability to do this [50]. In 1973, a 1,000-bed hospital converted a standard ward into an isolation unit, complete with individual washroom facilities and a central exhaust system to control ventilation [21]. Ten

years later, a large Veterans Affairs medical center controlled a large MRSA outbreak with an isolated ward staffed with a dedicated medical team [22]. This same single-unit isolation cohorting has been successful in other settings, including outbreaks of neonatal ICU-acquired *A. baumannii* with the establishment of a separate cohort nursery; VRE by implementing a hospital ward capable of providing various levels of care, including intensive care to rehabilitation for infected patients; and finally for carbapenem-resistant *K. pneumoniae* by cohorting patients infected or colonized into a single unit with a dedicated nursing staff [34,41,47].

Frequently, a private ward or ICU is not available for a cohort unit, and a region within a unit is designated for this purpose, a method that also has proved successful in controlling numerous outbreaks [31,33,38,44,46,50]. A cardiothoracic ICU experienced a VRE outbreak in which a section of the ICU was restricted for those infected or colonized with VRE, where the nursing ratio was one-to-one and scrub exchange was required before returning to the operating rooms [38]. After failure to control a carbapenem-resistant *A. baumannii* outbreak, all patients in another ICU who were infected or colonized were cohorted into one region of the unit, and a special entrance was used to provide access to these patients. A separate team of healthcare workers was assigned to this area to minimize transmission to non-affected patients [46]. In much the same fashion, we previously reported the success of a high-risk region of our own ICU with “super-isolation” for multiple non-clonal MDROs that required admission through a separate entrance, limited personnel in the region, and performance of procedures at the bedside whenever possible to reduce transportation out of the unit [50].

Nearly ubiquitous to all outbreaks is the initial failure of standard isolation precautions, universal screening of new admissions, and the cohorting of nursing, ancillary staff, and patient care equipment [21,26,30,31,33,34,41,45–47,50]. Other methods of outbreak control are unit closure [21,30,42–44,48], hiring of additional staff or an infectious disease consultant [22,44], encouraging use of disposable equipment [42], and screening of staff and subsequent reassignment of those colonized to non-clinical duties [15,30,48]. Most of these reports attribute their successful interruption of the outbreak to the practice of cohorting patients and staff.

Interestingly, enhanced barrier precautions and increased surveillance do not always prove successful. This was seen in a recent large unmasked, cluster-randomized, clinical trial of more than 9,000 patient admissions to 18 ICUs. The STAR*-ICU trial implemented surveillance culture reporting of MRSA and VRE status only in the intervention ICUs, allowing immediate utilization of expanded barrier precautions [51]. The control ICUs continued their standard surveillance and contact precaution practices. As expected, patients colonized or infected with MRSA or VRE were placed on barrier precautions more often in the intervention ICUs. Unexpectedly, however, the incidence of new colonization or infection within the ICUs did not differ significantly in the intervention and control ICUs. This study is noteworthy, as it found no reduction in the incidence of MRSA or VRE colonization or infection within the intervention ICUs despite closer surveillance and expanded barrier precautions [51].

Although no formal organization has provided specific guidance regarding cohorting, we believe that under the proper circumstances, it remains one of many effective means

to achieve infection control. Strict contact precautions, reinforced hand hygiene, closer surveillance, and dedicated staff and patient care equipment are other best practices needed to help prevent the nosocomial transmission of MDROs. After implementation of standard isolation guidelines, we recommend the establishment of an isolation ward or distinct ICU for all infected or colonized patients to control significant infectious outbreaks. At this time, we do not recommend the isolation of patients without positive cultures. In the rare instance of a particularly severe ICU outbreak, we may provide "protective isolation" for all non-infected patients as an additional measure of infection control. In the resource-limited hospital, a dedicated area or region of a unit may suffice to cohort affected patients away from the unaffected patients. This form of quarantine, cohorting, interrupts the spread of infections, just as the lazarettos did during the epidemics of the 15th century.

Author Disclosure Statement

LHR, LMR, KTC, and ADP have no conflicts of interest to disclose. RGS is a consultant for Merck, Pfizer, Astellas, and Johnson and Johnson.

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