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Infection Control in Limited Resources Countries: Challenges and Priorities

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Abstract
Purpose of Review The purpose of this article is to review the current status of health care-related infections (HCRI) in low- and middle-income countries (LMIC).
Recent Findings HCRI in LMIC are being recognized as an important health problem globally. Despite important efforts, complex medical and non-medical problems prevail.
Summary The HCRI burden in LMIC is bigger than in developed countries, with prevalence between 5.7 and 19.1%. The impact on patients, their families, and the hospital systems is high, but has been largely underestimated. During the last 30 years, some progress has been made, with an increased awareness from the medical community and some very successful programs; however, there is a huge gap for improvement and success. In many health care facilities, there is a need of functional surveillance programs, continuous supply of antiseptics, safe water supply, personal protective equipment, essential antibiotics to treat infections, appropriate number of health care personnel trained in infection control, and appropriate health care infrastructure and political commitment.

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Introduction

Health care-related infections (HCRI) remain as the most frequent adverse event related to health care worldwide, despite the growing body of evidence on its increasing burden and the strategies necessary for its reduction. Millions of patients are affected by these infections each year, posing a major threat to patients' safety. They increase morbidity and mortality and may lead to disability, reducing patients' health-related quality of life [1]. HCRIs also lead to significant financial losses for health systems [2].

HCRIs affects on average 7% of the hospitalized patients in developed countries; however, the rate of HCRIs in low- and middle-income countries (LMICs), which represents 68% of the countries of the world and more than 75% of the world's population, is higher [3]. According to the 2011 World Health Organization (WHO) report, the prevalence of HCRIs in these countries is estimated to be between 5.7 and 19.1% [4••], but may even be higher [1]. Under reporting and lack of functioning national surveillance systems are major drawbacks to accurate data. Since the problem is bigger than in developed countries, its impact on morbidity and already insufficient budgets is out of proportion.

The purpose of this manuscript is to review the burden of HCRIs, the challenges faced in infection control, and the progress and success of different strategies during the last 30 years in LMICs. We also review how to build a strong and an effective infection control program in limited resources conditions.

Infection Rates and Burden of Health Care-Related Infections in Limited Resources Countries

In Europe, HCRIs affects more than 4.2 million patients each year [5] and 722,000 in the USA [6•]. In LMICs, the global picture on the burden of these infections is only partially known, as there are important variations in resources allocated to infection control and surveillance, and the use of different definitions and methodologies makes it difficult to have reliable data. In a review on the burden of HCRIs in 2011 from developing countries, the rate of HCRIs varied from high-quality to low-quality studies, ranging from 15.5% from the former and 8.5% in the latter [7••].

A survey done by WHO in 2010 showed that only 16% (23 of 147 countries included) of developing countries were reporting a functioning national surveillance system with some differences between low- and middle-income countries [4••]. In low-income countries, very few countries had a national surveillance program for HCRIs; on the contrary, many middle-income countries had surveillance and infection control programs despite the existence of multiple barriers. Shortage of trained personnel, supplies, diagnostic tools, and adequate organizational infrastructure is a constant, making infection prevention and control a challenge [7••, 8, 9••, 10].

Most studies on HCRIs from LMIC come from Eastern Mediterranean countries, Latin America, and some regions in Asia; these studies usually provide data from individual centers or specific wards such as intensive care units in hospitals with high standards. In the review by Allegranzi et al, few publications were multicenter country-specific, or included information at a national level. Surgical site infections (SSI) were the most reported and most frequent type of hospital acquired infection (29.1%), followed by urinary tract infections (UTI) (23.9%), bloodstream infections (19.1%), and health care-associated pneumonia (14.8%), including ventilator-associated pneumonia (VAP) [7].

More recent reports on device-associated HCRI are also higher compared to those from developed countries. Overall, central line bloodstream infections (CLABSI), VAP, and catheter-associated urinary tract infections (CAUTI) rates were 4.86, 5.5, and 1.9 times higher than the US Centers for Disease Control and Prevention (CDC) National Healthcare Safety Networks rates [11, 12•, 13]. In Table 1 a summary of device associated HCRI from four studies in LMICs is shown.

In these countries, not only the risk of HCRIs is significantly higher but also other associated factors such as prolonged hospital stay; disability; increased antimicrobial resistance; increased costs for health care institutions, patients, and their families; and excess deaths. Most of these effects are severe and underestimated [7••, 12•, 14, 15]. Information is usually scattered, and mortality and cost-estimations are frequently biased.

In Mexico, the annual cost of HCRI approaches US $1.5 billion US dollars; in Mexican ICUs, the average cost of a single episode of a blood stream bacteremia in intensive care units was US $11,591, with six extra days of hospital stay [16]. In an 800-bed, tertiary care, university hospital in Malaysia with a HCRI prevalence of 13.9%, the cost of antibiotics to treat a single case of a hospital-acquired infection was US $521,000 per year [17]. With the emerging multi-drug resistant infections, increasing costs are expected. In another report, also from Thailand, it was estimated that 43% of deaths in patients with hospital-acquired infections were due to MDR bacteria [18•].

HCRIs mortality is difficult to estimate in most studies, due to bias and confounding factors. Although little information has been published, VAP and central line blood stream infections (CLABSI) are a leading cause of death in LMIC [19, 20••], with rates higher than benchmarks from high-income countries. In a study that examined mortality of patients with VAP in different developing countries, incidence ranged from 10 to 41.7 per 1000 ventilator days [19], higher when compared to the CDC NHSN hospitals in the US, with a VAP rate between 3.6 and 10.2 per 1000 ventilator-days depending on the type of intensive care unit [14]. In a more recent report on device-associated infection rates in India, the crude extra mortality for VAP was 22.7 and 16.3% for CLABSI. Both of these HAIs have also showed the highest length of hospital stay (LOS) [20••].

A growing challenge in infection control is antimicrobial resistance (AMR), which has become a global health problem. In LMICs, AMR is of major concern, as it is amplified by many other factors that include increasing antibiotic use, poor antibiotic control over the counter sales, high prevalence of infections in hospitals, limitations in infection prevention strategies, weak surveillance programs, lack of a microbiology laboratory with rapid tests at the point of care, absence of stewardship programs in hospitals, shortage of trained health care personnel, and poor bioinformatics availability and support [12•, 18•]. According to the International Nosocomial Infection Control Consortium (INICC) report from 2014, the prevalence of AMR organisms causing HCRIs in LMIC is much higher than those from the USA. Mortality related to HCRIs with MDR pathogens is also higher [21••].

Reasons for the increased burden of AMR in LMIC need to be further evaluated, but strong surveillance and infection control programs, enhanced networks of high quality, functional microbiology laboratories in all hospitals, and strong stewardship antibiotic programs are of utmost importance.

A Historical Perspective of Infection Control in Low and Middle-Income Countries During the Last 30 years. Have We Made Some Progress?

Despite the current difficulties in infection control policies and prevention strategies in LMICs, there has been some progress

Table 1 Device-associated health care-related infections in adult intensive care units from low and middle countries

Country/study (author and reporting dates) (publication date)	CLABSI	CAUTI	VAP
Multiple countries (Rosenthal VD.) (2008) [12]	8.9	6.6	19.8
Multiple countries (Allegranzi B et al. 1995–2008) (2011) [7]	11.3	9.8	22.9
China (Hu B et al. 2008–2010) (2013) [41]	7.6	1.29	10.5
India (Metha Y et al. 2004–2013) (2016) [19]	5.1	2.13	9.4
NHSN (2012) (USA) [14]	(0.8–1.4)	(0.7–3.6)	(1.7–5.3)

Data are overall (pooled mean) infection episodes per 1000 device-days. *CLABSI* central line bloodstream infection, *CAUTI* catheter-associated urinary tract infection, *VAP* ventilator-associated pneumonia, *NHSN* National Healthcare Safety Network (USA). Lower and upper pooled means described for device-associated health care-related rates in intensive care units

and success during the last 30 years. Most of the countries (mostly, middle-income countries) have developed some sort of National Surveillance Program supported by the Ministry of Health in most cases, along with infection prevention strategies for their health care facilities. Some of these policies and interventions have been tremendously successful, but for the most part difficulties remain, as many of the medical facilities lack the adequate resources to properly implement those plans [22].

During the last three decades, many hospitals in LMICs adopted infection prevention and control strategies from International Organizations, such as PAHO (Pan American Health Organization) and CDC (Centers for Disease Control and Prevention). Some hospitals, mostly academic medical centers, also implemented infection control programs developed in North America and Europe that later served as a model to promote local guidelines and nationally recognized infection prevention programs in health care facilities. Since the 1990s, many medical institutions established Infection Prevention Committees to start the implementation of infection control programs, achieving different grades of success [23, 24].

Concomitant to the strategies mentioned before, national conferences and Infection Prevention Associations have been organized, increasing the awareness of HCRIs among healthcare workers. Education on patient safety and infection prevention has slowly gained importance among health care providers, since the rate of HCRIs are surrogate markers of the quality of health care delivery. In many cases, local and national health authorities have also increased their commitment [12•, 24].

Besides some successful local infection control policies and programs in LMICs, the emergence of global initiatives focused on prevention of HCRIs have also provided benefits in some of these countries, particularly with organizational engagement and coordination. Among the global initiatives that have been successfully adopted in different regions are the following:

World Health Organization "Clean Care is Safer" This approach was launched >10 years ago to improve practices and change behavior in healthcare delivery with the aim to achieve safer, high-quality patient care [4••]. The main component of this initiative, "Save Lives: Clean your Hands" advocates the need to improve and sustain hand hygiene in health care workers to help reduce the spread of infections in health care facilities. Since that year, many medical institutions and Ministries of Health across the globe have adopted this initiave, with the commitment to increase hand hygiene compliance and reduce the number of HCRIs. Despite having a different degree of success, this strategy has definitively increased the awareness of the hand hygiene importance.

International Nosocomial Infection Control Consortium (INICC) This is a non-profit, open, multicenter, international, collaborative program modeled on the US CDC-NNIS/NHSN system, founded in 1998 in Argentina. This consortium is a research network that includes prospective, targeted, outcome and process surveillance designated to identify and reduce HCRIs rates in the participating facilities, mostly, from LMICs. The participation in this network is voluntary and runs parallel to Institutional and/or country specific surveillance systems. For some participants, this network has allowed hospitals to establish their own HCRIs rates, even in situations with poorly developed Infection Prevention and Control Programs [15].

Registration and reporting data is a key element for any single Infection Prevention Program, but exclusive registration of HCRIs is not enough to change the health care delivery process. Due to the multiple barriers in infection control and prevention in LMICs, achieving changes on the process of health care delivery remains an important challenge. Process standardization and bundle prevention strategies for the main HCRIs are good approaches, and in order to achieve a greater success, better coordination between this global strategies and local authorities is needed.

A word of caution should be mentioned related to this global and simple proposals such as the "Save Lives: Clean your Hands", since the adoption of this strategy alone, should not be considered a complete infection control program by itself.

Other less-known initiatives, such as St. Jude Children's Research Hospital with their hospital affiliated partners in Latin America, have also made incredible change at individual Institutions and in some cases, at the country level.

Through this program, they have trained around 200 Latin American infection preventionists and increased patients' safety in several institutions.

Current Challenges in Infection Control in Low- and Middle-Income Countries

Infection control and preventive measures in resource-limited settings comprise a special situation since in many occasions personnel are not adequately trained and therefore, unable to identify key risk factors for infection acquisition. Basic prevention practices such as hand hygiene, contact precautions, use of facemask, and gloves are occasionally not achieved due the lack of these basic resources. Extraordinary efforts must be undertaken to strengthen and enhance the capability of infectious disease control programs in these health care settings. Equipment, facilities, supplies, and standards of operations need to be improved. More importantly, all personnel in healthcare settings, including physicians, nurses, administrative workers, and other staff, have to develop their own awareness, essential knowledge, and skills, in order to protect themselves against emerging infectious diseases.

National Surveillance Programs A challenge in the infection control field is having reliable and up to date information on trends in infection rates and antimicrobial resistance. Unfortunately, many LMICs have dysfunctional surveillance systems where the lack of standardization in reporting criteria and microbiology laboratory facilities give unreliable results. Furthermore, surveillance systems in LMIC do not provide clear and timely information influenced in part, by external factors, such as political and economic interests.

An ongoing challenge is to provide a useful surveillance system guided by international organizations such as WHO, with the aim of standardizing surveillance methods. Sentinel surveillance laboratories should be supported to provide prompt, reliable results, faster feedback to the healthcare facilities and timely identification and notification of outbreaks.

Reprocessing Medical Equipment A well-known fact is that many hospital from LMIC reuse medical equipment that is designed for single use given the costs implicated in constantly acquiring new products. Single use medical equipment such as vascular and electrophysiological catheters are often reprocessed, and even if sterilization is performed under optimal reprocessing protocols, these are frequently non-regulated and insufficient to guarantee device sterility [25]. The same can be true for intravenous catheters, three-way stopcocks and tracheostomy tubes [26].

Despite the fact that guidelines exist for reprocessing of medical devices [27], many hospitals from LMIC have unregulated reprocessing practices and many do not have a standardized protocol for such a purpose. Evaluating the impact of reprocessing medical equipment related to hospital acquired infections is complex. Finding strategies to reduce cost on non-reusable medical equipment, balancing it with an adequate reprocessing protocol in favor of the patient safety and quality is critical.

Available Resources Basic supplies that may be taken for granted in developed nations, such as functional handwashing facilities, constant and safe water supply, antiseptics for hand hygiene, sterile gowns, properly fitting gloves, waterproof aprons, and safety goggles, are irregularly available in many hospitals from LMICs. Not infrequently, many health care facilities rely on donations from other hospitals, other countries and from non-profit organizations. Basic supplies for infection prevention and control must always be available in order to have a positive impact on the reduction of hospital related infections. Only then, will a better safety culture in health care workers be developed. Availability of supplies should be a priority for policy makers and administrators.

Outbreaks in Low- and Middle-Income Countries Analyzing outbreaks and epidemics during the last three decades, such as influenza [28], Ebola [29], and MERS-Co [30], to name a few, these events have arose in LMIC. Delayed identification of emerging pathogens aids against proper measures for infection control and might increase the risk for horizontal spread of the disease and infection of medical personnel. One example of this is the first imported case of MERS to Korea [31], where the diagnosis of the index case was established 9 days after the onset of symptoms, with the consequence of an uncontrolled and spread of MERS to 30 secondary cases, 124 third generation and 24 fourth generation cases. Ebola containment is another example of the differences between LMIC and high income settings. The proportion of health care workers infected in Africa during patients' care was far superior compared to that in developed countries [32, 33].

Infection Control Professionals Many LMICs have not developed educational programs to adequately train professionals in the field of infection prevention. Preventionists are frequently trained in the field by necessity, not by a formal structured education program. In many countries, national regulations to authorize, train and manage such professionals are inexistent, both at the national and local level [34]. The few formally trained infection control professionals often receive training in other countries and return to their country of

origin to work on the field. This need has been addressed before, and despite some intiatives and training courses have helped [35], there is a clear need for more action [36].

Corruption and Inadequate Resources All levels of health care have to be coordinated in order to deliver good quality of care and provide a safe environment of health attention to patients. Unfortunately, corruption and embezzlement exist. Pharmaceutical companies and diverse medical suppliers compete for concession contracts and distribution of their merchandise to individual hospitals, hospital groups and to a larger scale, to whole healthcare systems; these contracts can be biased by bribes. In limited-resource countries, it is not uncommon that transparent data like infection rates are not openly available, or are manipulated to minimize negative repercussions. This overshadows the real problem and the efforts to achieve infection control are therefore misdirected. A high level of corruption has been associated with a higher antibiotic use [37] and much of this could be mirrored in other aspects of infection control. Smuggling of antimicrobials and the use of low-quality generic drugs that deliver suboptimal concentrations negatively impact antimicrobial resistance. Health care providers and administrators inflict additional damage to the already low resource system by pilfering and deviation of resources designated for infection control.

How to Build a Strong and an Effective Infection Control Program with Limited Resources

Healthcare systems all over the world spend most of their budgets on hospital care. This is why any intervention designed to improve how health care is delivered should be thoroughly considered [38]. HCRIs rates are inversely related to the quality of health care [9••], but most infections can be prevented with good hygiene and standardization of the health care delivery process. In most settings, these strategies have been cost-effective.

With the increasing interest in HCRIs from different perspectives, including the society, medical and non-medical institutions, national health authorities and the safety matters of healthcare delivery in individual hospitals across the planet, prevention of HCRIs and non-infectious adverse events have become a priority worldwide; however, as health care systems vary so widely, preventive strategies must be designated accordingly. Despite these variations and the economic and organizational difficulties faced in LMICs, we encourage health care authorities, government and the public work to advocate decisions to improve health care delivery.

Most HCRIs can be prevented with readily available and relative inexpensive strategies. Care components to prevent and reduce HCRIs and assure safe and good quality of healthcare delivery include (a) appropriate number of health care personnel trained in infection control; (b) presence of an infection prevention and control program for care practices and infection surveillance; (c) appropriate health care infrastructure; (d) continuous supply of antiseptics and desinfectants; (e) promotion of hand hygiene; (f) regulated sterilization procedures; (g) vascular supplies and safe intravascular access practices; (h) essential antimicrobials for treating infections; (i) assurance of appropriate chlorinated water in the entire healthcare facility; and (j) political commitment, support of institutional policies and organizational structure from the hospital authorities [9••, 39].

The aforementioned policies should be available in all health care institutions, not only in public, academic medical centers in big cities, as frequently occur in many developing countries. Prevention and infection control programs go far beyond a white paper or a government recommendation and authorities; health care workers and the society itself need to ensure an optimal and safe delivery of health care at all levels. Optimal infrastructure, enough human and non-human resources such as access to hospitalization, ancillary services with a functional microbiology laboratory, trained personnel in infection control and prevention, and implementation and monitoring of HCRIs and risk factors are key to success [9••, 39, 40].

Infection prevention and control activities should also include continuing education and research. Education of all health care personnel in the basic prevention strategies of the most frequent HCRIs needs to be done in regular basis. It is recommended that basic training on insertion and care of vascular lines, urinary catheters, ventilation support, wound care, and appropriate use of antibiotics and antiseptics, along with hand hygiene promotion is continuously conducted. Establishing reliable goals and feedback is also recommended.

For any infection prevention and control team, researching processes, barriers and outcomes on infection prevention strategies is highly recommended, as each health care facility is unique. With a greater knowledge of problems and tailored interventions, program impact will be enhanced. Last, a comparison of data across other LMIC infection control programs will serve to widen, adapt and adopt best practices in infection control.

Conclusions The rate of HCRI in LMICs is between 5.7 and 19.1%, higher to the rates from developed countries. The impact of these infections is significant for patients, their families and the hospital systems. The burden of HCRI and their negative impact have largely been underestimated.

Despite some progress on the prevention and control of HCRIs in LMICs, multiple barriers exist. Shortage of trained personnel, supplies, diagnostic tools and inadequate organizational infrastructure is a constant, making the prevention a challenge.

Adequate health care infrastructure, including functional microbiology laboratories at the point of care, infection control basic training for all health care personnel, constant availability of non-reusable supplies, standardized disinfection practices, bioinformatics availability and support, along with political and administrative commitment are essential to achieve sustainable and successful infection control programs in LMICs.

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Compliance with Ethical Standards

Conflict of Interest Drs Diana Vilar-Compte, Adrián Camacho-Ortiz and Samuel Ponce-de-León declare having 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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