ECONOMIST IMPACT

Tackling antimicrobial resistance in healthcare:

the significance of robust health and economic data

Supported by Pfizer

Contents

©Economist Impact 2023

About the report

Tackling antimicrobial resistance in healthcare: the significance of robust health and economic data is a report produced by Economist Impact and supported by Pfizer. Focusing on six countries—Brazil, Mexico, Egypt, Saudi Arabia, India and China—the report sheds light on the sparsity of economic burden estimates for antimicrobial resistance (AMR). The issue is explored quantitatively and qualitatively—this report presents the findings of an extensive literature review, bespoke economic modelling and an expert panel. We would like to express our gratitude to the Triangulate Health team for their invaluable contributions to the modelling methodology and framework, as well as for conducting the economic modelling. The editorial team at Economist Impact conducted a series of interviews with experts to validate the economic model framework and methodology. We extend our sincere appreciation to the following for their time and contributions to this work:

Nicholas Graves, Professor of Health Economics, Deputy Director of Health Services & Systems Research, Duke-NUS Medical School

Nasreen Hassoun-Kheir, Infectious diseases and infection control specialist, research fellow at Geneva University Hospitals and faculty of medicine, WHO collaborating centre, Geneva, Switzerland.

Marlieke de Kraker, Senior infectious diseases epidemiologist at Geneva University Hospitals, Switzerland

Laurence Roope, Senior Researcher at the Health Economics Research Centre (HERC), Nuffield Department of Population Health at the University of Oxford

We are also immensely thankful to the country experts who are key opinion leaders in this field; we could not have developed this research paper without the input and support of:

Sarang Deo, Professor and Area Leader, Operations Management; Deputy Dean, Faculty & Research; Executive Director, Max Institute of Healthcare Management, Indian School of Business (ISB)

Amani El-Kholy, Professor Emeritus of Clinical Pathology (Clinical Microbiology), Faculty of Medicine Cairo University, Egypt and National Expert in Clinical Microbiology

Ana Gales, Director of the Laboratory Alerta and Professor of the Division of Infectious Diseases, Escola Paulista de Medicina, Universidade Federal de São Paulo

Ziad A Memish, Senior Consultant in Infectious Diseases and Director of the Research & Innovation Centre at King Saud Medical City, Ministry of Health

©Economist Impact 2023

Mary Millard, retired nurse, AMR patient advocate, international patient speaker

Samuel Ponce de León Rosales, Head of the Microbiome Laboratory, School of Medicine, UNAM, and Programme Coordinator for Research on Epidemiological and Emerging Risks

Xiao Yonghong, Professor, Zhejiang University

Economist Impact bears sole responsibility for the content of this report. The findings and views expressed in the report do not necessarily reflect the views of Pfizer (the sponsor) or the consulted experts, and the report is not necessarily endorsed by either party. The sponsor played no role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript. While every effort has been taken to verify the accuracy of this information, Economist Impact cannot accept any responsibility or liability for reliance by any person on this report or any of the information, opinions or conclusions contained within it.

The Economist Impact research team was led by Neeladri Verma. The research team consisted of Gerard Dunleavy, Jocelyn Ho, Cassandra Cheung, and Radha Raghupathy, with support from Amanda Stucke and Nuriesya Saleha. The report was written by Radha Raghupathy and edited by Paul Tucker and Neeladri Verma.

©Economist Impact 2023

Executive summary

Antimicrobial resistance (AMR) is one of the top ten global public health challenges.[1] AMR results from microbes accumulating genetic changes that help them escape drugs meant to kill them.[1] Fuelled partly by inappropriate and injudicious use of antimicrobial agents, AMR is a looming threat—almost 5m global deaths were associated with AMR, and 1.3m were directly attributable to AMR in 2019.[2] AMR could cause a projected 10m annual deaths globally by 2050.[3] If the trend continues, the economic ramifications will also be huge. In a low-impact scenario, global GDP would decrease by over US$1trn per year after 2030; in a high-impact scenario, this decrease could be as high as US$3.4trn. Low-income countries are expected to face the greatest impacts, further widening disparities.[4]

Estimates of AMR burden have come under the lens owing to concerns that projections may be inaccurate. Despite the immense importance of AMR, lack of faith in estimates threatens to impair the response of policymakers, the public and healthcare providers. The multidimensionality of the problem and a lack of adequate national-level surveillance data are key factors impacting the accuracy of estimates. To address this problem, the World Health Organisation (WHO) launched the Global Antimicrobial Resistance and Use Surveillance System (GLASS), which aims to build surveillance capacity, improve data collection and provide technical support to participating countries.[5] However, there is still a lack of high-quality, patient-level resistance data linked to clinical outcomes. Furthermore, despite the WHO Global Action Plan on AMR emphasising the need for economic models, limited progress has been made.[6]

Our research is specifically centred around AMR in hospital acquired infections (HAIs). While AMR in humans occurs in both community and healthcare settings, HAIs contribute the maximum burden.[7] We study the burden of HAIs in emerging economies as defined by the International Monetary Fund (IMF). These countries undergo economic transition while maintaining sustained strong growth and stability.[8] It is not uncommon for countries in such transitions to perceive efforts to address AMR as an additional financial burden.[9] However, it is crucial to consider the long-term consequences of neglecting AMR. Failure to address it can result in even greater economic and societal costs while investing in hospital-based infection prevention and control (IPC) interventions can significantly reduce HAI rates by 35-70%, regardless of a country's income level, supporting efforts to combat AMR.[10]

We have focused on six emerging countries: Brazil, Mexico, Egypt, Saudi Arabia, India and China. Given the greater burden of AMR in the

©Economist Impact 2023

hospital setting, the gaps in national-level data in these countries that need to be addressed and the scope for larger health and economic gains from hospital-based interventions that reduce AMR, we focus on HAIs, measuring their disease burden and direct costs to the healthcare system.

Measuring the burden of AMR

Through a bespoke economic model and a series of model validation interviews, this study explores the estimated direct costs to health systems due to HAIs caused by selected resistant bacteria in 2019. The selected resistant bacteria include carbapenem-resistant *Enterobacterales (Escherichia coli, Citrobacter, Enterobacter, Klebsiella, Proteus, Providencia and Serratia species), Pseudomonas aeruginosa and Acinetobacter baumannii, and methicillin-resistant Staphylococcus aureus* (MRSA). The WHO Global Priority Pathogens List classifies these bacteria as critical or high priority targets for the discovery and development of new antibiotics.[11]

Using our model, Economist Impact estimates 0.5m-1m deaths and 11.7m-23.8m disability-adjusted life years (DALYs) attributable to the selected resistant bacteria across the six countries in 2019. Furthermore, the estimated direct costs to health systems due to the resistant HAIs vary from US$386.7m to US$1.5bn, depending on the excess length of hospital stay (ranging from one to four days). Our research also captures the unique challenges and successes in tackling this issue in our countries of interest.

Key findings

While significant efforts have been made to estimate and tackle the burden of AMR, gaps remain in developing and implementing effective initiatives and policies. Our research focuses on how to improve estimates of the economic burden and use these to strengthen AMR response.

Improving economic estimates requires:

1. Stronger surveillance: Key to improving estimates of the economic burden of AMR is strengthening active surveillance of drug-resistant infections and generating high-quality data. Harnessing digital technologies will improve surveillance by overcoming the challenges inherent in fragmented health systems and workforce constraints. The WHO GLASS programme provides an IT tool, WHONET, to facilitate the collection of laboratory data.[5] Many countries included in our research are also developing in-house tools for electronic surveillance.[12,13] Ensuring compatibility between local, national and international IT systems will improve reporting and transparency.[14]

2. Simplified case definitions for HAIs: Collection of HAI data can be onerous in low-resource settings owing to complex definitions needing detailed clinical documentation and laboratory support.[15] The National AMR Surveillance Network of the Indian Council of Medical Research has explored the usage of modified definitions of HAIs more appropriate to the country and resource setting. Efforts to standardise such definitions across emerging countries, especially those with resource limitations, can improve HAI reporting and the reliability of estimates.[16]

3. Better cost tracking: Quantifying the economic burden of AMR is a huge undertaking. Various direct and indirect costs need to be considered given the multidimensionality of the problem. Important direct costs include those relating to hospitalisation, testing and treatment. A simple starting point would be to improve estimates of the cost of antimicrobials used in resistant HAIs. Better documentation and tracking of antimicrobial consumption is vital. The WHO's GLASS is collecting antimicrobial consumption data, but national efforts should be escalated.

©Economist Impact 2023

More accurate economic burden estimates can be leveraged to:

1. Create awareness: Reliable estimates of the cost of the problem, both to individuals and society, can be a powerful tool in creating AMR awareness among the public, hospital administrators and policymakers. A message of how resources wasted via misuse of antibiotics can be redirected to improved healthcare provision can be powerful in galvanising action. Understanding cost implications will encourage hospitals to establish better AMR-control training for healthcare professionals.

2. Assess cost-effectiveness of AMR interventions: With improved estimates of the financial implications, cost savings of interventions used to control AMR, including stewardship programmes, can be measured more accurately. These savings can be used for ring-fenced budgets in a milieu where resources are stretched.

3. Use of ring-fenced budgets to tackle AMR: Additional resources secured through ring-fenced budgets can be used to roll out financial incentives to hospitals for ensuring rational antimicrobial usage, establishing better surveillance systems, improving laboratory and IT infrastructure, and ensuring good sanitation. These measures will ensure that patients have access to the right antibiotics at the right time, improving health outcomes.

The AMR epidemic in emerging countries needs to be tackled head-on; crucial to this endeavour are better estimations of the magnitude of the problem. Concerted efforts can improve our understanding and catalase action. Support from the global community in knowledge transfer and capacity building is needed to bridge the gap between nations and unite against a common enemy.

Strategies to improve AMR responses in HAIs

Improve surveillance by partnering with other quality-improvement programmes: Resource constraints, workforce shortages, and fragmented health systems compound the challenge of HAIs and AMR. Collaborating with hospital programmes can reduce resource demands, improve AMR visibility, enhance infection control measures, and ultimately improve patient outcomes.

Enhance reporting transparency: To raise awareness and promote research, it is essential to enhance the transparency of HAI and AMR reporting, making information more accessible to the public. All stakeholders should collaborate to prioritise transparency, while governments should invest in improving data integration and availability.

Develop better cost-tracking systems for hospital care and antimicrobials: Accurate cost tracking in inpatient care is crucial for estimating the economic burden of resistant HAIs. To track antimicrobial costs accurately, more precise consumption estimates are needed, with digital platforms proving useful. Building robust IT infrastructure and upskilling the workforce are essential for accurate cost tracking and antimicrobial consumption monitoring.

Establish cost-effectiveness of AMR interventions to obtain ring-fenced national budgets: Accurate estimates of the economic burden of AMR in HAIs, along with assessments before and after interventions have been implemented, allows for a thorough evaluation of the cost-effectiveness of AMR control measures and provides insights into the potential cost savings. It is recommended to reinvest these savings towards further efforts to control the burden of AMR.

©Economist Impact 2023

Introduction

Antimicrobials have yielded great advances in modern medicine. When used responsibly, they are life-saving tools that provide considerable benefits to patient care. Unfortunately, injudicious use of antimicrobials in human, animal, and agriculture sectors is challenging their effectiveness and impact.

AMR results from microbes such as bacteria, viruses, fungi and parasites developing genetic changes over time that render certain antimicrobials ineffective in controlling them.[1] The deadliest manifestation of AMR is the emergence of "superbugs" that are unresponsive to most or all available antimicrobials. As "last-resort" antimicrobials become ineffective, morbidity, premature mortality, healthcare utilisation and costs associated with AMR are predicted to further increase.[17]

Existing estimates project that AMR would cause about 10m annual deaths globally by 2050.[3] However, recent data suggest that the reality could be far worse and further compounded by indiscriminate antimicrobial use during the pandemic. A systematic analysis estimated that almost 5m global deaths were associated with bacterial AMR in 2019, of which 1.3m were directly attributable to AMR. Yet, significant data gaps exist for low-and middle-income countries (LMICs): 19 countries and territories had no data for the modelling parameters.[2]

Estimating the economic burden of AMR is another important decision-making tool. However, suboptimal data pose challenges in obtaining accurate estimates. A World Bank model that projects the global economic impact of AMR between 2017 and 2050 highlights that weak surveillance data from LMICs limits the accuracy of projections. The model suggests that AMR could cause an annual global GDP decline of 1.1% in a low-impact scenario and 3.8% in a high-impact scenario by 2050. This impact would be greater on low-income countries, further widening inequality. Moreover, healthcare expenditures are expected to increase steeply. By 2050, the World Bank estimates that AMR could drive annual healthcare costs to increase by approximately 25% in low-income countries, 15% in middle-income countries and 6% in high-income countries.[4]

Limited data and uncertain estimates of the AMR burden can mislead policy approaches.[18] The WHO Global Action Plan on AMR emphasises the need to strengthen surveillance to better understand the incidence, prevalence, range of microbes and geographical patterns of AMR. In addition, it recommends prioritising the development of economic models to assess the costs of AMR and the cost-effectiveness of implementing national plans.[6] To support

©Economist Impact 2023

surveillance, WHO launched the GLASS in 2015, which aims to build the capacity of national surveillance systems while providing a standardised approach to the collection, analysis, interpretation and sharing of AMR data. Comprehensive epidemiological, clinical and population-level data are collected through routine and focused surveillance. GLASS provides IT tools such as WHONET, which facilitates management and analysis of microbiological data and lends technical support to participating countries to build laboratory capacity.[5] As of December 2022, 127 countries and territories had enrolled in GLASS; the 2022 GLASS report includes AMR data from 87 countries.[19] However, GLASS does not yet offer models or platforms for economic burden estimation.

To understand the challenges in estimating the AMR burden—as well as opportunities for progress—in countries which are currently undergoing economic transition alongside sustained strong growth and stability, we have focused our research on six countries: Brazil, Mexico, Egypt, Saudi Arabia, India and China. These countries, identified as emerging economies by the IMF, belong to different income groups and vary in terms of their respective health-system set up and administration.[8] Four out of these six countries are currently enrolled in GLASS.

Infections in the healthcare settings contribute the maximum burden of AMR. Data from Europe shows that over 60% of resistant infections occur in the healthcare setting.[7] Investing in hospital-based IPC interventions can significantly reduce HAI rates by 35-70%, irrespective of a country's income level, leading to reduction in the health and economic burden of AMR.[10] Given that infections occurring in healthcare facilities contribute the maximum burden of AMR alongside huge scope for IPC interventions to reduce this burden, we have studied HAIs.[20] We focus on bacteria that are identified by the WHO as critical and high-priority pathogens and cause HAIs.[11,21]

This report captures the HAI-driven AMR challenge in these countries in two ways. In quantitative terms, an economic model estimating the direct costs of HAIs to the healthcare system is presented. Qualitatively, existing AMR policies and practices are explored through discussions with local experts. Through these efforts, we identify avenues to improve AMR burden estimates in HAIs and implement targeted responses.

©Economist Impact 2023

The economic burden of AMR in hospital acquired infections: a plethora of unknowns

The economic burden of AMR in HAIs is difficult to quantify, given its multidimensionality. Experts we interviewed attributed the lack of national-level estimates to fragmented health systems, poor reporting and difficulty in accurately quantifying costs. Estimating the direct, patient-level cost of AMR should consider the exact microbe, resistance type and all treatment costs, but this is challenging, especially in the public sector.

"It is very difficult to assess the costs of AMR in public hospitals where the government gets everything through the total purchasing and supply chain," says Amani El-Kholy, professor emeritus of clinical pathology (clinical microbiology) at Cairo University. "It is somewhat easier in the private system, where the patient or insurance company pays."

Indirect costs such as productivity losses due to illness, work absenteeism and premature death are also hard to quantify.[22] The costs of AMR are not limited to the patient with the infection but have a broader impact on the welfare of other patients in the healthcare system. Longer hospital stays due to AMR reduce inpatient capacity. Antimicrobial selection by treating physicians is usually dictated by the hospital resistance data. With the rise in AMR, hospital guidelines often recommend a broad spectrum or last-resort antimicrobials as the first-line therapy for patients suspected of having severe infections, even before resistance testing results are available. This approach, while intended to provide prompt treatment to save lives, may not always be the most appropriate choice for a patient's specific infection. Moreover, it can contribute to the development of further resistance, potentially diminishing the future effectiveness of these drugs and subjecting patients to unnecessary risks.[23]

Data regarding the economic burden of AMR in HAIs in our countries of interest are limited. A review of studies evaluating the attributable cost of AMR in 2016-21 showed significantly higher costs due to AMR in tertiary care settings, ranging approximately from US$2,300-29,000. Yet high-income countries contributed 20 of the studies, and the remaining nine came from upper middle-income countries. The US, China, and Japan together contributed 20 of the 29 studies. There were none from low-income countries. A lack of studies regarding productivity losses of patients and caregivers was also noted.[24]

A national-level estimate of the economic burden of AMR due to certain critical or high-priority bacteria among inpatients in China was performed in 2015. This showed that hospital costs for patients with multidrug-resistant infections were around US$3,400 more than hospital costs for those with infections treatable with antibiotics. The societal economic burden of AMR was estimated at US$77bn (about 0.4% of China's GDP) in 2017,

©Economist Impact 2023

with US$57bn attributed to multidrug-resistant organisms.[25] According to the experts we interviewed, the other countries in our study have hospital-level or regional data regarding the economic burden of AMR in HAIs. However, there are challenges in acquiring national-level estimates owing to a lack of coordinated systems and data collection.

Taking into consideration the high economic burden of AMR in the hospital setting, gaps in national-level data in our countries of interest and the scope for better hospital-based interventions to reduce AMR, we utilised a static economic model to estimate the health burden and direct costs of AMR in HAIs.

Economic modelling approach

To estimate the direct health-system costs of AMR, we focused on HAIs caused by selected bacteria in six emerging economies. We conducted a literature review, created an economic model and validated our research approach through expert interviews. Appendix 1 contains a detailed description of our modelling methodology.

Our model adopts a patient-based framework and focuses on HAIs caused by the following resistant bacteria classified as critical or high priority by the WHO:[11]

- Carbapenem-resistant *Enterobacterales* (Includes *Escherichia coli, Citrobacter, Enterobacter, Klebsiella, Proteus, Providencia and Serratia species*)
- Carbapenem-resistant *Pseudomonas aeruginosa*
- Carbapenem-resistant *Acinetobacter baumannii*
- Methicillin-resistant *Staphylococcus aureus* (MRSA)

Country-specific indicators such as total population and discharge rates were used to estimate the number of patients hospitalised with HAIs caused by the resistant bacteria in 2019. Where data were unavailable, suitable sources were used for extrapolation. Table 1 shows the indicators used and the framework for the estimation of HAIs caused by the resistant bacteria.

Table 1: Indicators used for estimation of AMR burden

Calculations	Indicators
Total hospitalised patients	• Total population size • National discharge rate
Hospitalised patient with an HAI	• Prevalence of HAIs • HAIs disaggregated by infection type
Hospitalised patients with an HAI caused by bacteria of interest	• HAIs disaggregated by infection type and bacteria type
Hospitalised patients with an HAI caused by the resistant bacteria of interest	• Resistance rate by bacteria type
Direct healthcare system costs of HAIs by the resistant bacteria of interest	• Excess length of stay • Generalised cost per inpatient hospital day
Disease burden of HAIs by the resistant bacteria of interest	• Mortality rate for each resistant bacteria of interest (%) • Disability Adjusted Life Years (DALYs) for each resistant bacteria of interest

©Economist Impact 2023

The attributable mortality rates for the selected resistant bacteria were used to estimate total deaths due to resistant HAIs in each country.[26-30] Global Burden of Disease data were used to derive the average DALYs per resistance-related death.[2] The direct health-system cost due to resistant infections was defined as the cost associated with excess inpatient stay due to the resistant infection. The cost was calculated by multiplying three parameters: the number of patients with a resistant HAI, the average excess length of stay and the cost of an inpatient bed day.[31,32]

The model framework and approach were validated through a series of expert interviews and their input was incorporated into the model or model limitations.

Findings

Overall health burden and direct costs of selected resistant HAIs

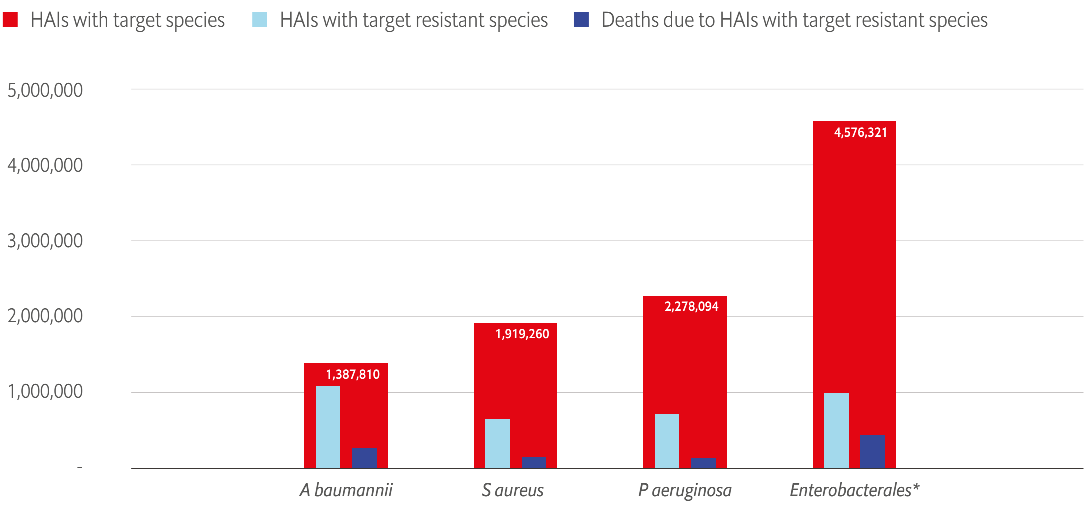
Our model estimated that 16.4m HAIs occurred across the six countries in 2019. Of these, 3.5m were due to resistant bacteria of interest to us. Carbapenem-resistant *Acinetobacter baumannii* contributed the greatest number of resistant infections, followed by carbapenem-resistant *Enterobacterales*, as shown in Figure 1. The highest number of AMR-linked deaths was attributed to *Enterobacterales*.

Mortality attributed to resistant infections of interest across all six countries was estimated to be 0.5m-1m deaths in 2019. The estimated DALYs were 11.7m-23.8m. Direct costs to the health system varied from US$386.7m to US$1.5bn, depending on the excess length of stay (ranging from one to four days). Country-specific results are highlighted in Figures 2 to 7.

Challenges and opportunities in AMR burden estimation

The best available data were chosen to estimate the health and economic burden of AMR in our countries of interest. These estimates are helpful in improving our understanding of the challenge at hand—but there is scope for improvement. The lack of robust, nationwide, patient-level, active surveillance systems is a major challenge to these estimates.

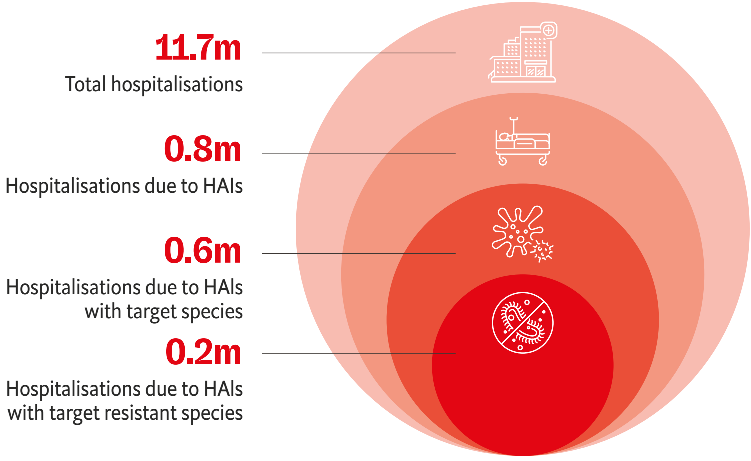
Figure 1. HAIs classified by causative bacteria, stratified by resistance and deaths in 2019



*include *Escherichia coli, Citrobacter, Enterobacter, Klebsiella, Proteus, Providencia* and *Serratia* species

©Economist Impact 2023

Figure 2. Snapshot of the health burden and direct costs of selected resistant bacteria causing HAIs in Brazil in 2019



Direct cost to health system

US$31m is the estimated average health system cost of HAIs with target resistant species

Attributable mortality

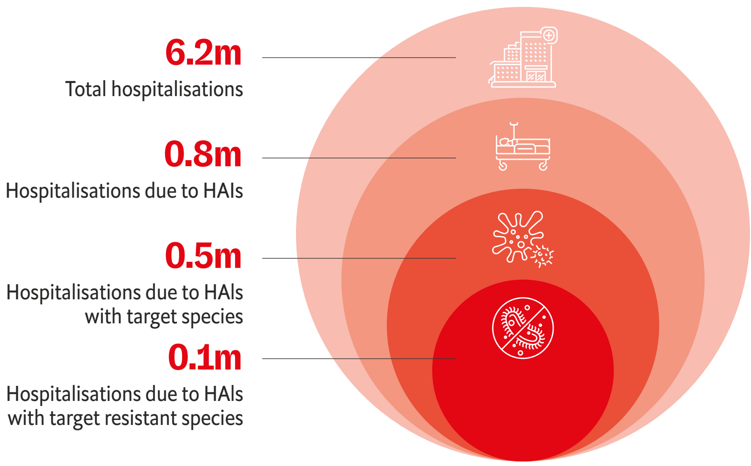
25,800-52,400 estimated attributable mortality in patients with HAIs with target resistant species

DALYs

0.6m-1.2m estimated DALYs due to HAIs with target resistant species

Note: Direct cost to health system is calculated as the direct cost of additional inpatient bed days associated with resistant infections. The estimates here are based on 4 day excess LOS

Figure 3. Snapshot of the health burden and direct costs of selected resistant bacteria causing HAIs in Mexico in 2019



Direct cost to health system

US$144m is the estimated average health system cost of HAIs with target resistant species

Attributable mortality

12,000-30,300 estimated attributable mortality in patients with HAIs with target resistant species

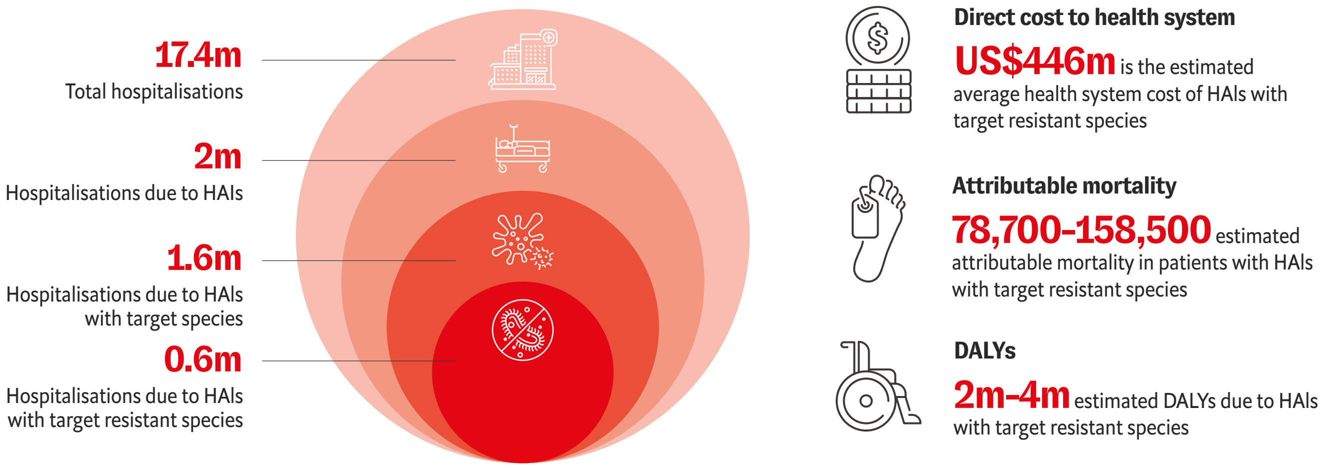
DALYs

0.3m-0.7m estimated DALYs due to HAIs with target resistant species

Note: Direct cost to health system is calculated as the direct cost of additional inpatient bed days associated with resistant infections. The estimates here are based on 4 day excess LOS

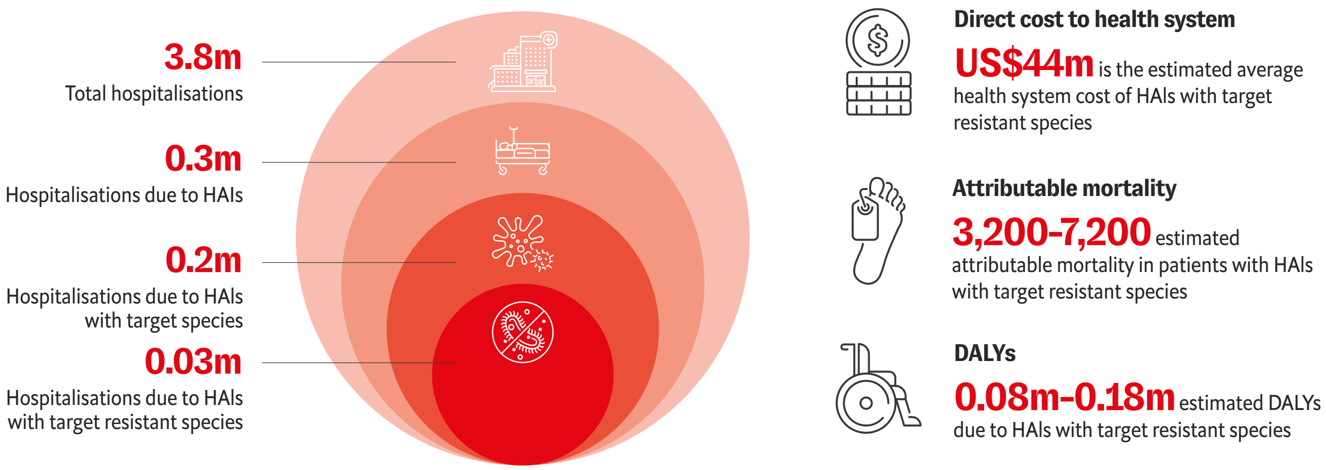
©Economist Impact 2023

Figure 4. Snapshot of the health burden and direct costs of selected resistant bacteria causing HAIs in Egypt in 2019



Note: Direct cost to health system is calculated as the direct cost of additional inpatient bed days associated with resistant infections. The estimates here are based on 4 day excess LOS

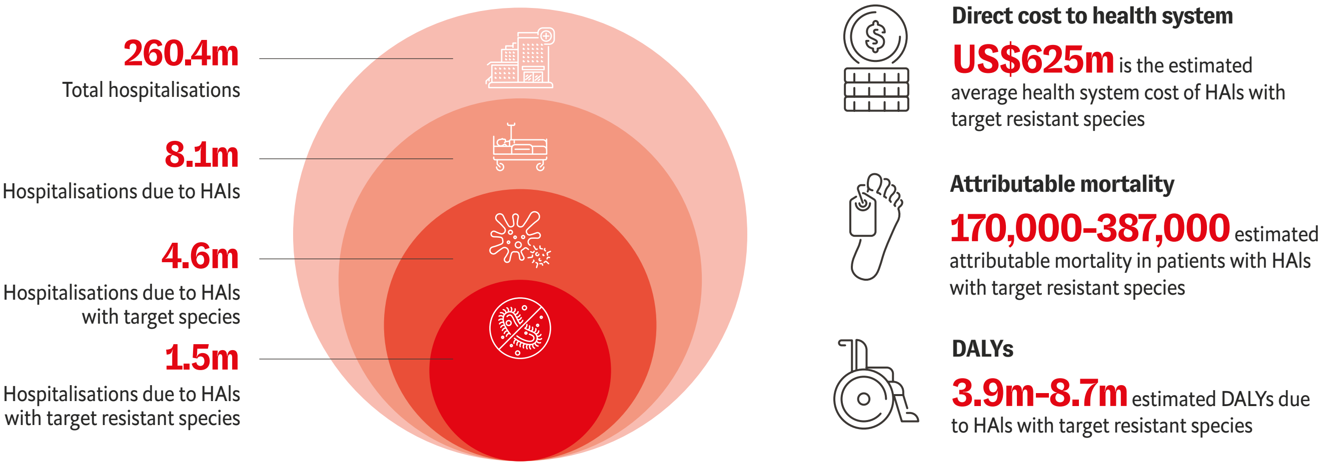
Figure 5. Snapshot of the health burden and direct costs of selected resistant bacteria causing HAIs in Saudi Arabia in 2019



Note: Direct cost to health system is calculated as the direct cost of additional inpatient bed days associated with resistant infections. The estimates here are based on 4 day excess LOS

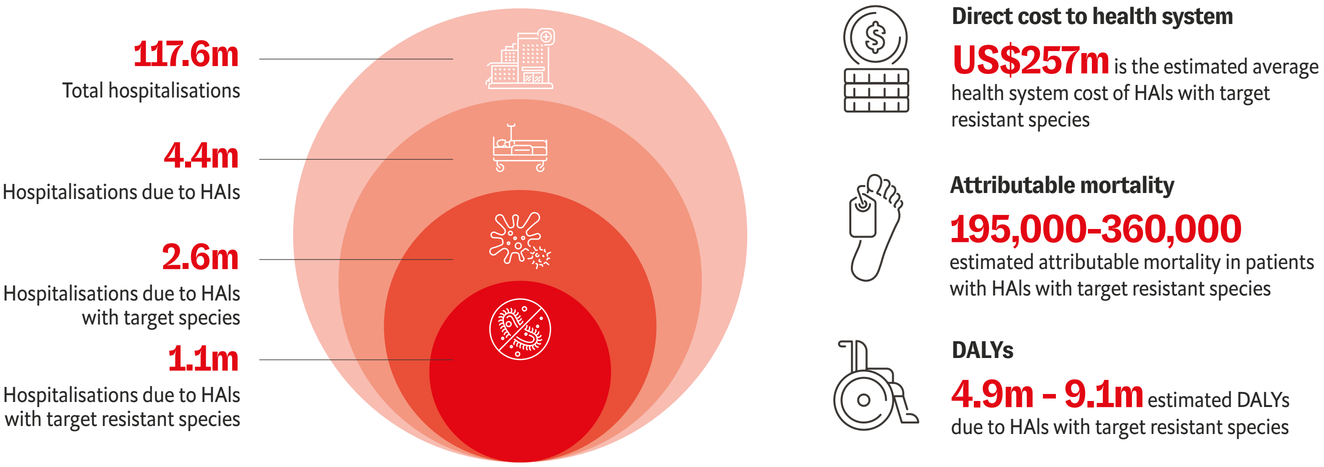
©Economist Impact 2023

Figure 6. Snapshot of the health burden and direct costs of selected resistant bacteria causing HAIs in China in 2019



Note: Direct cost to health system is calculated as the direct cost of additional inpatient bed days associated with resistant infections. The estimates here are based on 4 day excess LOS

Figure 7. Snapshot of the health burden and direct costs of selected resistant bacteria causing HAIs in India in 2019



Note: Direct cost to health system is calculated as the direct cost of additional inpatient bed days associated with resistant infections. The estimates here are based on 4 day excess LOS

©Economist Impact 2023

Estimation of HAIs

HAI estimation was limited by patchy data on discharge rates and a lack of information on incidence. Hospital discharge rates were not available for some countries—for India, Egypt and Saudi Arabia, extrapolations were used. The Organisation for Economic Development and Cooperation (OECD) discharge rate data were used for other countries. OECD data include all patients admitted for one night, including those that died, while we aim to study HAIs occurring two days after admission. Data on HAI incidence were not available, so point prevalence estimates were used. This can overestimate the incidence, as the length of stay is not accounted for.[33]

Estimation of resistance

Overestimation of resistance rates can result in falsely high estimates of health and economic burden. "In emerging economies, there is a risk of overestimation of resistant organisms," notes Laurence Roope, a senior researcher at the Health Economics Research Centre at the University of Oxford. "Often, due to limited resources, testing for resistance is only performed in patients who are very ill or have not responded to antibiotics, meaning that resistant strains are over-represented."

The GLASS 2022 report notes a discrepancy in resistance rates of E coli to third-generation cephalosporins, a widely used class of antibiotics. When all 87 countries and territories reporting resistance were included, resistance was around 42%. However, when countries with over 75% antimicrobial sensitivity testing per million population were considered, resistance dropped to 10.6%. Interestingly, high levels of resistance were seen in certain bacteria-causing HAIs, regardless of testing sensitivity. One example is carbapenem-resistant Acinetobacter baumannii, the prevalence of which was at least 56% regardless of testing rates.[34] In our model, carbapenem-resistant Acinetobacter baumannii contributed the greatest number of resistant infections across all countries (Figure 1). However, our model does not allow us to estimate the number of individuals behind the resistant pathogens. The same individual may have had more than one resistant infection, potentially resulting in overestimation of the burden.

Currently, most centres in our countries of study use phenotypic information to determine resistance. Phenotypic resistance relies on studying the growth of a bacteria in the presence of specific antibiotics, which can take several days to assess. Molecular diagnostics identify the gene or mutation in the microbe causing the resistance and can provide results in minutes to hours. But molecular diagnostics, while highly sensitive and quick to identify resistance

> "In emerging economies, there is a risk of overestimation of resistant organisms. Often, due to limited resources, testing for resistance is only performed in patients who are very ill or have not responded to antibiotics, meaning that resistant strains are over-represented."

Laurence Roope, Senior researcher at the Health Economics Research Centre at the University of Oxford

©Economist Impact 2023

"In Brazil, the Brazilian Health Regulatory Agency (ANVISA), only gets data based on phenotypic resistance of HAI. Not all Brazilian public hospitals are capable of affording the implementation of molecular tests but through the Central Public Health Laboratories (LACENS), we could have access to molecular tests, but they are swamped with samples and take too long to report. Besides, the LACENS is not accountable to ANVISA, but to the Ministry of Health."

Ana Gales, Professor at the Division of Infectious Diseases, Escola Paulista de Medicina, Universidade Federal de São Paulo

markers, may not fully correlate with phenotypic resistance. Therefore, both tests should be used to complement each other.[35]

The cost-effectiveness of using molecular tests in clinical management is being investigated; the techniques are currently recommended by the WHO for public health surveillance.[35] However, the complexity of governance, setup and costs are often deterrents to using a holistic approach. "In Brazil, the Brazilian Health Regulatory Agency (ANVISA), only gets data based on phenotypic resistance of HAI," says Ana Gales, Professor at the Division of Infectious Diseases, Escola Paulista de Medicina, Universidade Federal de São Paulo. "Not all Brazilian public hospitals are capable of affording the implementation of molecular tests but through the Central Public Health Laboratories (LACENS) we could have access to molecular tests, but they are swamped with samples and take too long to report. Besides, the LACENS is not accountable to ANVISA, but to the Ministry of Health."

Estimation of mortality

Data on attributable mortality rates for resistant HAIs are limited. Our model estimates that mortality attributed to resistant infections among HAIs of interest across all six countries could have reached as many as 0.5m-1m deaths in 2019. In comparison, analysis of the global burden of AMR in 2019 estimated the global attributable mortality of all resistant infections caused by 23 pathogens including the ones of our interest to be 1.3m.[2]

Our model estimates for mortality due to AMR among the selected pathogens are high. Various factors may explain this. Our model focused on six emerging countries with diverse income levels and health systems, including the two most populous countries of the world. Modelling for some variables required extrapolation. The case definitions of HAIs in data sources were not aligned and there was a lack of data for mortality rates from non-bloodstream infections. Hence, attributable mortality rates for bloodstream infections were applied to all the types of HAIs. Some data sources used for mortality assumptions were dated and novel antibiotics may not have been routinely used in that period. All these factors could have resulted in overestimation of the health burden.[26]

The PANORAMA study is a multinational study performed in LMICs that compared the difference in attributable mortality and length of stay among patients with treated carbapenem-resistant versus susceptible Enterobacteriaceae blood-stream infections.[36] Two of our countries of interest, India and Egypt, were among the ten LMICs included in this study. Similar collaborative prospective studies can help to better quantify the mortality and excess length of stay associated with critical or high priority organisms causing HAIs.

Estimation of costs

There is a dearth of costs data for the public hospital setting. For daily hospitalisation costs, a conservative choice was made to use primary hospital bed rates reported by the WHO. However, HAIs by critical and high priority pathogens more commonly occur in tertiary centres, and patients diagnosed in primary centres are likely to be transferred to a tertiary setting for management. The hospitalisation costs also exclude drugs and diagnostics, given a lack of data on these parameters. As drugs and diagnostics are major expenses in management of resistant infections, they should be better quantified.[37]

©Economist Impact 2023

Each country in the model had unique advantages and challenges in estimating the health-system direct costs of AMR in HAI. Our discussion with the experts unravelled these aspects further.

Brazil

The government is taking steps to combat AMR through its National Action Plan (PAN-BR: 2018-22).[38] Prof Gales notes that ANVISA and the health ministry have separate systems to collect information on HAI and AMR. ANVISA collects data regarding central line-associated bloodstream infections (CLABSI), ventilator-associated pneumonia (VAP), surgical site infections and hospital-acquired urinary tract infections (UTI) occurring in intensive care units from all hospitals with an infection control programme. Prof Gales describes that in 2021, 76% of hospitals submitted their data to the ANVISA surveillance system. The epidemiological data are collected and verified by a healthcare professional, improving the reliability of estimates, but ANVISA relies on laboratory results provided by each hospital's laboratory. On the other hand, the health ministry has a central lab that operates in each state—each receives samples from different hospitals that do not have in-house capability for resistance testing and genotyping, yet epidemiological data are not consistently available. ANVISA's data are published in an annual report, while the health ministry's laboratory data are not published or easy to access.

"The US Centre for Disease Control and Prevention is working with Oswaldo Cruz Foundation (Fiocruz), the Ministry of Health, and ANVISA to strengthen the Brazilian Antimicrobial Resistance Surveillance System. Efforts are also underway to unify the ANVISA and LACENS data towards improving national estimates of HAI and AMR," notes Prof Gales. The health ministry began AMR surveillance as part of the GLASS programme in 2018 and is now involved in capacity-building efforts.[39] "But we really do not have an idea of the economic burden of AMR in Brazil. There are very few studies, mainly coming from private hospitals."

Mexico

Mexico has a national plan for the surveillance, detection and reporting of priority AMR pathogens. In June 2018 the General Health Council issued regulations making Mexico's National Action Strategy against Antimicrobial Resistance obligatory for all actors (public and private) in the national health system.[40,41]

Despite these measures, Prof Samuel Ponce de León, head of the Microbiome Laboratory, UNAM School of Medicine, notes a false sense of security around HAIs in Mexico. "Every hospital needs to have an infection control programme and report HAIs in Mexico, but the passive surveillance system is very weak. Current reports suggest an HAI rate of 1.5-7%. People see this report, notice that the numbers sit around the global average and assume we do not have any

"Every hospital needs to have an infection control programme and report HAIs in Mexico, but the passive surveillance system is very weak. Current reports suggest an HAI rate of 1.5-7%. People see this report, notice that the numbers sit around the global average and assume we do not have any problems."

Samuel Ponce de León, Head of the Microbiome Laboratory, UNAM School of Medicine

©Economist Impact 2023

problems." Various factors contribute to the lack of proper surveillance, including workforce constraints, overcrowded hospitals and poor infrastructure. The National Hospital Network for Epidemiological Surveillance (RHOVE by its Spanish initials) is looking to improve estimates. The organisation tracks information on HAIs generated from secondary and tertiary units of 363 hospitals across the public and private sectors through active surveillance. Its 2022 report estimates HAIs at 7.3%. While this is a more accurate estimation than passive surveillance, only selected hospitals and units are included.[42] The point prevalence study we used in our model to estimate HAIs at 13.2% included acute care wards across four specialty or tertiary care centres.

Mexico is not a participant in GLASS.[43] The National Network of Public Health Laboratories, overseen by the health ministry and the RHOVE, carries out surveillance for priority AMR bacteria.[44] However, most of the reports of AMR come from larger teaching hospitals, thereby skewing the results. Various pharma-funded surveillance programmes exist, but they are often restricted to a small range of organisms and specific antibiotics. To improve AMR data collection, the Network for the Research and Surveillance of Drug Resistance was created in 2018.[45] Data obtained from the network's surveillance across 47 centres in 20 states of Mexico was used to inform resistance rates in our model. The centres included are diverse, including maternal and child health centres, paediatric hospitals, general hospitals, speciality centres, and university hospitals.

One of the objectives of Mexico's National Strategy for Action against Antimicrobial Resistance is to develop an economic assessment of AMR in the country for sustainable investment.[46,47] "There has been some effort from individual hospitals and networks to estimate the economic burden, but no formal economic evaluation of AMR has been performed by the federal government yet," notes Prof Ponce de León.

Egypt

In our modelling exercise, we made several extrapolations for Egypt owing to a lack of data in the public domain. Hospital discharge rates were extrapolated from Turkey. A point prevalence study from 2018, including two acute care hospitals from Egypt, was used to estimate the prevalence of HAIs. The distribution of pathogens and resistance rates were extrapolated from regional-level data from the same manuscript.[48] There is an urgent need to revisit these results with national sources of data.

The National Action Plan for Antimicrobial Resistance (2018-22) outlines the government's target to establish a nationwide AMR surveillance system by 2020.[49] Dr El-Kholy describes the situation in Egypt to be quite promising in terms of data collection for surveillance and the availability of this information to policymakers. However, data are

"The Ministry of Higher Education oversees all university hospitals and the Ministry of Health [oversees] all national public health laboratories; both organisations collect data on HAIs and AMR. Together, these institutions cover about 80% of hospitalised patients, with the rest being treated in the private sector. The data in GLASS come from the national public health laboratories, but data from the university hospitals is not included here."

Amani El-Kholy, Professor emeritus of clinical pathology (clinical microbiology) at Cairo University

©Economist Impact 2023

partially accessible to the public and frontline healthcare providers. The Tracking AMR Country Self-Assessment Survey 2022 country report for Egypt notes the existence of a national AMR surveillance system.[50] The government collaborates closely with the WHO, and Egypt has been a member of GLASS since 2016—as of 2019, nine surveillance sites in Egypt were providing information to GLASS.[39] "The Ministry of Higher Education oversees all university hospitals and the Ministry of Health [oversees] all national public health laboratories; both organisations collect data on HAIs and AMR," says Dr El-Kholy. "Together, these institutions cover about 80% of hospitalised patients, with the rest being treated in the private sector. The data in GLASS come from the national public health laboratories, but data from the university hospitals is not included here." Dr El-Kholy also says that technological limitations delayed analysis and release of AMR and HAI data collected by the Supreme Council of University Hospitals, from university hospitals.

Saudi Arabia

The National Action Plan for Combating AMR, released in 2017, describes the establishment of a national surveillance system for AMR as a priority objective. This process would include collecting AMR information from sentinel sites and developing reference laboratories for microbiological testing and a national coordination structure for surveillance.[51] The country has made significant progress towards these objectives but more remains to be achieved.

Saudi Arabia joined GLASS in 2017 and has around 30 laboratories conducting AMR detection and reporting.[52] The National Reference Laboratory for AMR surveillance was designated in 2017 and is operational, but data access is restricted.[53] Ziad Memish, a senior consultant in infectious diseases and director of the Research & Innovation Centre at King Saud Medical City, says that these data could be available to decision-makers in certain countries of our region, but states there is a need for more transparency. "The data on AMR [have been] collected for many years now, but I am yet to see these data being made available to the public. I continue to see multiple small reports from members of the AMR committees in different Gulf States, but these are usually single-institution data. I have not seen combined or compiled data that can be accessed by the practising physicians." He describes the UAE as a regional example in terms of expansion. "A document has recently been published by the UAE with national-level data regarding hospital acquired infections and AMR. These efforts should be expanded across the region."

China

China is addressing AMR through various measures, even though it has not yet joined GLASS. The China Antimicrobial Surveillance Network (CHINET), established in 2005, tracks the prevalence of bacteria and resistance patterns. As of 2018, over half of the population of China was covered by this system. An electronic interface is used for reporting by participating hospitals. Data can be retrieved at any time by participating physicians or researchers. External parties need express authorisation to access the information.[54] Resistance data in our model was obtained from journal publications based on CHINET. "Over 80% of the hospitals in China are public hospitals controlled by the government," says Xiao Yonghong, Professor, Zhejiang University. "Hence, the government can exercise administrative powers to ensure their participation in the surveillance programmes. However, active surveillance is still lacking, and larger budgets are needed for better execution."

The 2nd National Action Plan for AMR (2016-20) emphasises coordination between various ministries. The programme is administered by the National Health and Family Planning Commission, which oversees 14 ministries including education and finance. Budget is guaranteed by the participation of the finance ministry, while other participating ministries also have clearly defined roles.[55] Prof Xiao alludes to the success of such coordination in improving AMR response.

©Economist Impact 2023

> **"Over 80% of the hospitals in China are public hospitals controlled by the government. Hence, the government can exercise administrative powers to ensure their participation in the surveillance programmes. However, active surveillance is still lacking, and larger budgets are needed for better execution."**

Xiao Yonghong, Professor, Zhejiang University

That said, although HAI surveillance in China is mandatory, studies suggest that implementation has room for improvement. A review spanning 2012-17 noted that only 39.5% of 233 primary care hospitals and 67.2% of 201 secondary and tertiary care hospitals were set up to perform point prevalence surveys for HAIs. Active HAI surveillance in ICUs was established in just 38.7% of 406 secondary and tertiary centres.[56] Since 2018, hospital accreditation has been linked to the control and prevention of HAIs. Its effects remain to be seen.

"Limited data exists on the economic burden of AMR in China at a national level," says Prof Xiao. "There is an ongoing collaborative effort to quantify this burden, which is supported by the National Science Foundation. This project will have results in two to three years and will shed more light on this space."

India

India is a member of GLASS and has a national coordinating centre for AMR surveillance and a national action plan. In 2013 the Antimicrobial Resistance Surveillance and Research Network (AMRSN) was established by the Indian Council of Medical Research (ICMR) to support surveillance efforts.[57] The AMRSN includes seven nodal centres in four tertiary care institutions that receive laboratory reports from 20 regional centres.[58] The National programme on AMR containment was launched in 2013 by the Ministry of Health and Family Welfare of the Government of India. The National AMR Surveillance Network (NARS-Net), with two national reference labs and 40 surveillance sites across 31 states and territories is part of this programme. Resistance data are submitted by the network labs to the National Centre for Disease Control through WHONET and, after verification, uploaded to GLASS.[59]

Through NARS-Net, state AMR surveillance networks are gradually being established. The AMRSN has representation from both private and public hospitals, while NARS-Net covers state medical college hospitals in the public sector. (Our resistance figures in the model come from the AMRSN data.) There is work to be done, though. "Top policymakers in the centre are well aware of the threat of AMR, but awareness in states is lagging," says Sarang Deo, executive director of the Indian School of Business Max Institute of Healthcare Management. "At present, only four of 29 states have an action plan for AMR."

The National Programme for AMR Containment has also initiated surveillance for HAIs through the ICMR-AIIMS HAI surveillance project, which collects data from a subset of patients admitted to the ICU for over two days in enrolled tertiary care centres. There is variability between centres and physicians in terms of culturing practices, laboratory techniques and documentation. Notwithstanding these limitations, the network has established a standardised, resource-appropriate methodology for reporting and aggregating HAI data.[16] As our model focuses on all acute care wards rather than purely ICUs, we used single-institution studies for estimating the prevalence of HAIs and types of bacteria.[60,61] Expanding HAI surveillance efforts in India to include other acute care settings besides ICUs would improve the robustness of the data. "Fragmentation of healthcare facilities into public and private is an impediment to collecting representative data. Listing of all healthcare facilities would be a good place to start," says Prof Deo.

©Economist Impact 2023

Looking beyond

Improving economic estimates of AMR in HAI

Enhancing data collection

Improving economic estimates for AMR in HAIs requires a multipronged approach. Crucial to this is the collection of accurate data on the prevalence of HAIs and microbial resistance rates. The US Centers for Disease Control and Prevention (CDC) describes the preferred method for data collection as active surveillance of HAIs by trained infection control professionals in a patient-based, prospective fashion.[62] The countries in our study are at differing stages of establishing active HAI surveillance systems. There is a need to expand efforts across public and private health sectors, collate data obtained from various sources, and make these data transparent and readily available to researchers, healthcare workers and the public.

Harnessing digital technologies will improve surveillance by reducing workforce and resource requirements. In many emerging countries, AMR data are collected as line surveys or input into spreadsheets that are then coded and manually re-entered into national surveillance systems.[14] Usage should be expanded of IT tools such as WHONET that facilitate the collection of laboratory data.[5] The countries we studied are also developing their own IT tools for national surveillance. In India, the ICMR has recently developed an online, real-time data-entry system for AMR for hospitals that are part of the AMRSN.[12] The National Digital Health Mission of India/Ayushman Bharat Digital Mission that is working to digitise and integrate all patient level medical information to generate a personal medical record will be a valuable tool in supporting this surveillance.[63] Various centres in China have also developed electronic surveillance systems for tracking HAIs, such as the Real-Time Nosocomial Infection Surveillance System, which integrates data including clinical symptoms, diagnosis, microbiological reports and antibiotic use from various hospital information systems.[13] Developing IT systems that are open-access, have good interoperability and facilitate communication between central and local levels will aid implementation and acceptability.[14] Using dashboards to provide real-time information to providers and the public will improve transparency.

Using modified case definitions for HAIs in limited-resource settings

Standard case definitions for HAIs are based on those of the US CDC's National Healthcare Safety Network (NHSN) or the European Centre for Disease Prevention and Control. These definitions are complex and can be challenging to use in emerging countries due to resource and workforce constraints. Limited laboratory capacity also poses challenges to reporting HAIs

©Economist Impact 2023

based on international standards.[16] These factors may result in decreased overall HAI reporting.

The ICMR-AIIMS surveillance project, a collaboration between the ICMR, All-India Institute of Medical Sciences (AIIMS) and the National Centre for Disease Control (NCDC) uses modified definitions of HAIs that are applicable to the country and resource setting. It includes several modifications, some of which are highlighted here. Because of difficulties tracking patients who move from one hospital ward to another, ICU days are used to determine an ICU-related HAI, rather than days in the hospital. All bloodstream infections were reported by the participating centres for surveillance and then classified into CLABSI by the central system using the case report form rather than requiring surveillance sites to report CLABSIs directly. Efforts to standardise such modified definitions across emerging countries could improve HAI reporting.[16]

Improving cost estimates for antimicrobial usage

Antimicrobials are an important cost component in AMR, but information on their use and costs, especially at patient level, is sparse. We have not included antimicrobials costs in patients with resistant infections owing to lack of data, which is likely to mean significant underestimations. Tracking antimicrobial consumption and costs will enable more accurate estimates of the economic burden of AMR in HAIs. "There is a mechanism (Schedule H1 register*) to track prescription refills or sales of antimicrobials in India for certain medications, but the implementation is spotty," notes Prof Deo.

According to Dr El-Kholy, the Egypt healthcare authority (EHA) and the Egyptian drug authority monitor antimicrobial usage in EHA hospitals and other sentinel hospitals. These hospitals are using an electronic platform to record antimicrobial use and perform an economic evaluation of antibiotics.[64]

Prof Xiao describes the national antimicrobial consumption surveillance network of China, which also has some integration with agricultural consumption data. The role of governments in improving data collection and reporting on aspects including antimicrobial consumption and costs cannot be overstated.

Using economic estimates to bolster response to AMR

Raising awareness

Awareness among patients and healthcare workers

"Awareness of AMR among the general public in Egypt is very low," says Dr El-Kholy. "Most people believe antibiotics can cure a fever due to any cause and may pressure doctors to prescribe them." Prof Ponce de León sees a similar trend in Mexico, describing how, since legislation requiring an obligatory prescription for antibiotics came into place, pharmacies in Mexico employ medical officers to prescribe antibiotics to patients who request them. He says that over 17,000 pharmacies offer such prescriptions. On the contrary, according to Prof Xiao, with enhanced national-level efforts to improve AMR awareness, patients in China have started declining antibiotics. "Collaborations between the Ministry of Education, Ministry of Health, Ministry of Agriculture, and the media are important to spread the right message. We should increase awareness among people without creating the fear of using antibiotics." With the right approach, people can be empowered to use antibiotics safely and responsibly.

Providing community- and patient-level data on health outcomes and financial burden

*Schedule H1 was introduced through Gazette notification GSR 588 (E) dated August 30, 2013. It contains certain 3rd and 4th generation antibiotics, habit-forming drugs, and anti-TB drugs. The schedule H1 register maintains a separate record of these drugs, recording the name and address of the prescriber, the name of the patient, the name of the drug, and the quantity supplied.[65]

©Economist Impact 2023

can increase awareness. "If you put a number to a problem and prove that your number is right, the general public is more likely to take this problem seriously," notes Prof Gales. Her sentiment is supported by Dr Memish: "Once we estimate the economic costs, we can tell the public that this money, which can be used to offer you better healthcare, is instead being wasted due to generalised misuse of antibiotics. If you partner with us in addressing this concern, then we will be saving more lives and can improve the healthcare service. You will not need to worry about catching an infection when coming to the hospital for a simple procedure."

Mary Millard, an AMR patient advocate and former nurse, attests to the role of healthcare professionals in increasing awareness among patients. "People do not really understand or know what it means to acquire a resistant HAI. Something needs to be ignited in the patient to make them want to understand what happened to them and how it can be prevented. The onus of raising such awareness falls on healthcare professionals."

Education of health professionals is key to stemming AMR and improving awareness among patients. All countries that we studied have AMR training programmes for physicians. Experts unanimously agreed on the need for better training among nurses, pharmacists and other allied health professionals. A better understanding of the economic burden of AMR will encourage hospital administrators to set aside funding for such training.

Awareness among policymakers

Economic estimates are key to raising AMR awareness among policymakers, while engaging policymakers is critical to improving economic estimates. This "chicken and egg" situation was highlighted by our experts. "Data on the economic burden of AMR is critical," says Dr Memish. "Unless the national CDC of each of the Gulf states takes on this responsibility, no one else will."

Hospital acquired infections contribute the maximum burden of AMR and can be targeted with focused interventions. Efforts should be made to increase policymakers' focus in this space. Patient advocacy groups can play an important role in raising awareness. The International Alliance of Patient Organisations is working to engage policymakers to improve funding for AMR, especially in R&D.[66]

Establishing cost-effectiveness of AMR interventions

Experts note a lack of resources and limited healthcare budgets to roll out programmes and incentives to reduce AMR in HAIs. Budgets

"People do not really understand or know what it means to acquire a resistant HAI. Something needs to be ignited in the patient to make them want to understand what happened to them and how it can be prevented. The onus of raising such awareness falls on healthcare professionals."

Mary Millard, AMR patient advocate

©Economist Impact 2023

have been further strained since the pandemic. Accurately quantifying the economic burden of AMR in HAIs and demonstrating the cost-effectiveness of different IPC measures can facilitate ring-fenced funding for programmes and incentives. Cost-effectiveness studies should also consider the benefits of these interventions in reducing infections overall, including those caused by microbes sensitive to antibiotics.

"The public health agency of the Gulf Cooperation Council (GCC) states should calculate the economic costs of AMR in hospitals and how much money can be saved by applying interventions," says Dr Memish. "Having a baseline and then doing an assessment after interventions are applied can help demonstrate the savings. That is what the WHO is looking to work with countries on."

OECD analysis demonstrates that a package of hospital-specific IPC interventions (hand hygiene, antimicrobial stewardship programmes and enhanced environmental hygiene) are cost-effective in reducing AMR. These data can be extrapolated to emerging countries if better estimates of their AMR economic burden become available.[21] Such information will also be pivotal in encouraging hospital administrators to implement IPC measures.

Lower- and lower-middle-income countries rely heavily on external funding for establishing AMR surveillance networks. For example, the Fleming Fund in the UK, which is aligned with GLASS, has awarded about £265m (US$341m) to LMICs including India to initiate or strengthen AMR surveillance activities. However, the sustainability of such funding remains unclear, and it is imperative for countries to earmark their own funds for combating AMR.[57] Developing ring-fenced AMR funding and reinvesting funds obtained through savings from AMR interventions, stewardship programmes and regulation of antimicrobial consumption can be very useful in this regard. Such funds can be reinvested in improving laboratory capacity and supporting rapid diagnostics.

Incentivising ring-fenced AMR funding in healthcare institutions

Ring-fenced budgets obtained through cost effective interventions can be used to offer financial incentives to health facilities towards AMR reduction. For example, the NHS England

"The public health agency of the Gulf Cooperation Council (GCC) states should calculate the economic costs of AMR in hospitals and how much money can be saved by applying interventions. Having a baseline and then doing an assessment after interventions are applied can help demonstrate the savings. That is what the WHO is looking to work with countries on."

Ziad Memish, Senior consultant in infectious diseases and director of the Research & Innovation Centre at King Saud Medical City

©Economist Impact 2023

Quality Premium Scheme was established to reward Clinical Commissioning Groups (local-level care-delivery bodies since replaced by Integrated Care Systems) for improving their healthcare services. In 2015-16 an incentive was provided for the reduction of total antibiotic prescriptions by 1% and broad-spectrum antibiotic prescriptions by 10%. Data showed that antibiotic prescriptions for common respiratory illnesses by GPs declined by 3%.[67] Similar programmes can be designed at a hospital level in tertiary care settings. More nuanced features can be incorporated, such as choosing therapy in line with the hospital antibiogram—a summary of antimicrobial susceptibility for selected bacteria—and de-escalating antibiotics once culture results are available. However, care must be taken to ensure that such incentivisation does not affect patients in true need of antibiotics. Health outcomes should be evaluated alongside antibiotic consumption rates to ensure that quality of care is not compromised.

Financial incentives should not only be focused on appropriate antibiotic usage, but also on broader issues such as sanitation and hygiene. “It seems to me that one of the biggest issues in low-resource settings is sanitation in and around hospitals,” says Dr Roope. “There should be scope for considerable return on investment in better sanitation, through reducing both susceptible and resistant infections.”

©Economist Impact 2023

Conclusion and key takeaways

AMR is a looming pandemic that, left unchecked, will have escalating serious global health and wellbeing implications. Urgent action is needed—but meaningful responses will need better estimates of the scale of the threat. This is especially true in emerging economies, where the threat of AMR is predicted to be larger than elsewhere, owing to a higher risk of deaths and greater financial implications, but where investments in quantifying and tackling the problem are weaker.[4]

Our attempt at estimating the direct health system costs of AMR in HAIs in six emerging countries highlights the huge efforts being made in these countries to quantify and address this issue. With the best data accessible in the public domain through various surveillance programmes, we have been able to approximate the burden. However, more accurate data inputs are needed. Through the modelling process and interaction with experts, we identified some tools that can be leveraged to improve AMR estimates and responses.

> **"If we want the metrics in AMR to be reported, we will have to join hands with other movements that are trying to create transparency in hospital quality and make hospitals accountable for outcomes. Fighting this battle on the AMR plank may not go anywhere."**
>
> Sarang Deo, Professor and Area Leader, Operations Management; Deputy Dean, Faculty & Research; Executive Director, Max Institute of Healthcare Management, Indian School of Business (ISB)

Improve surveillance by partnering with other quality-improvement programmes

Deficiencies in active, national-level surveillance of HAIs and AMR have been attributed to fragmented systems, workforce constraints and lack of resources. China's top-down approach to managing its hospital system has facilitated national-level data collection, but this is a challenge for other countries with more decentralised systems. Resources are a universal constraint and have been further stretched since the pandemic. Partnering with other hospital programmes can reduce resource requirements and improve AMR visibility.

"If we want the metrics in AMR to be reported, we will have to join hands with other movements that are trying to create transparency in hospital quality and make hospitals accountable for outcomes," says Prof Deo. "Fighting this battle on the AMR plank may not go anywhere." The HAI and AMR occurrence

©Economist Impact 2023

suggests that healthcare systems are not operating in optimal compliance with infection-control measures. Surveillance is a key tool to monitor this problem and address it with quality improvement strategies.[68]

Enhance reporting transparency

Although our six countries do collect national level surveillance data in varying capacities, often this information is not publicly available and not consistently shared between different stakeholders and hospitals. Providing easily accessible, up-to-date data would improve awareness among the public and health workers. Research into the AMR burden will also be facilitated by data access. Therefore, stakeholders should work together to prioritise transparency. Technological barriers are among the reasons cited for the lack of integration—and wider availability—of data. The WHO is working with several countries to build technological capacity to facilitate better data collection, integration and reporting.[14] Government investment is key to sustainable improvements.

Develop better cost-tracking systems for hospital care and antimicrobials

Better cost tracking in inpatient care is necessary to estimate the economic burden of resistant HAIs more accurately. However, this is fraught with challenges, especially in the public sector, which relies on mass procurement of diagnostics and supplies. Lessons can be learnt from the UK's NHS, which has implemented the Patient Level Information and Costing System, a centralised, digital database of costing data.[69]

To track antimicrobial costs, more accurate consumption estimates are necessary. While most countries in our study have tracking systems, implementation is fragmented and weak. The European Surveillance of Antimicrobial Consumption Network tracks antimicrobial consumption in both hospital and community settings, publishing this information on a dashboard.[70] Replication of such efforts will need the development of integrated IT systems and manpower allocation. Countries should participate in GLASS to monitor antimicrobial consumption and leverage the IT support offered through it.

Establish cost-effectiveness of AMR interventions to obtain ring-fenced national budgets

Estimating the economic burden of AMR in HAIs, using strategies discussed in this paper and conducting an assessment before and after interventions have been implemented, should be used to capture cost-effectiveness and understand the cost savings achieved through AMR-control measures. These savings should be reinvested in further controlling the AMR burden through various programmes including financial incentivisation of hospitals, IT infrastructure development, capacity building of laboratories for molecular tests, rapid diagnostics availability, and workforce allocation for surveillance.

With concerted efforts and global support, the gap between countries in AMR surveillance and management can be narrowed. The benefits will be universal, safeguarding antimicrobials for when we need them the most.

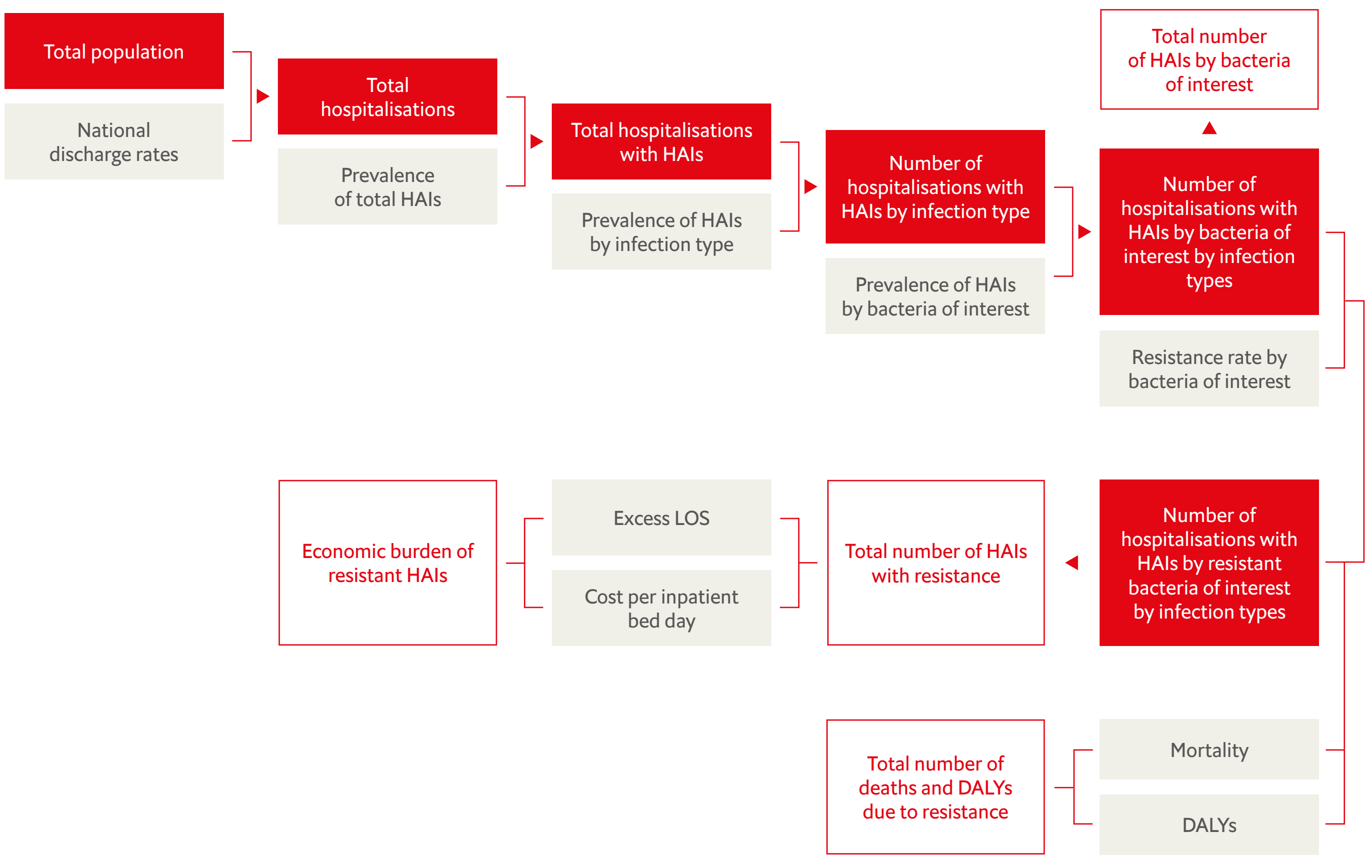
©Economist Impact 2023

Appendix

Economic modelling methodology

A patient-based quantification framework was constructed for children or adults developing an HAI in the hospital setting in a one-year timeframe, as shown in figure 9. This allows for estimation of the annual number of patients who acquire an HAI caused by one of the resistant bacteria of interest.

Figure 8: Quantification framework for development of the static economic model



NOTE: Variables depicted in grey are data inputs. Variables depicted in rectangular boxes are outputs of the input variables or intermediate outputs. Variables in boxes with a bold outline are the final outcomes of the quantification (Total HAIs; HAIs with resistance; deaths and DALYs due to HAIs with resistance; economic burden of resistant HAIs).

©Economist Impact 2023

The indicators used to perform the quantification are described in Table 1 of the main text. Table 2 gives a snapshot of important data points used to calculate HAI rates with resistant bacteria of interest. Country population was obtained from World Bank data.[71] Hospital discharge rates were retrieved from OECD data where available. For Egypt, the discharge rate was extrapolated from Turkey, as both countries have similar health spending as a percentage of GDP. The Asia-Pacific LMIC average discharge rate was used for India. For Saudi Arabia, the national admission rate was used as a proxy for discharge rate.[72-75] Data regarding HAI prevalence, HAI type, and distribution of bacteria causing HAIs were obtained from multi-institution point prevalence studies or national surveillance data, except in India where single-institution studies were used.[48,60,61,76,77] ATLAS data were used to supplement resistance rates where we could not find a suitable alternative in the published literature.[78]

Both the health and economic burden of AMR in HAIs caused by priority bacteria were calculated. A range of attributable mortality rates for resistant organisms was obtained from the literature and used to calculate total deaths.[26-30] Global Burden of Disease data were used to derive the average DALYs per resistance-related death and used to estimate the total DALYs per resistant pathogen.[2] The economic burden from the healthcare perspective was conservatively defined as direct costs associated with excess inpatient stay due to resistant infections. To calculate the direct costs to the health system during hospitalisation, the total number of excess inpatient days resulting from resistant infections was multiplied by the average excess length of stay obtained from literature, which was then multiplied by the total estimated resistant infections.[36,79-81] The total direct health-system cost due to resistant infections was then calculated using country-specific generalised cost per inpatient day.[31] Economist Intelligence Unit inflation rates were used to inflate inpatient bed day costs from 2010 to 2019.[32]

Table 2: Data inputs for modelling

PARAMETER	BRAZIL	MEXICO	SAUDI ARABIA	EGYPT	CHINA	INDIA
Total population size	211,782,878	125,085311	35,827,362	105,618,671	1,407,745,000	1,383,112,050
Discharge rate per 1000	55.2	49.9	106*	165*	185	85*
Observed prevalence of all HAIs	7.23%	13.24%	6.80%	11.30%	3.12%	3.76%
Prevalence of HAI by infection type						
P/LRTI	27.2%	26.8%	27.20%	35.9%	47.3%	28.2%
UTI	10.9%	13.1%	20.20%	15.0%	11.3%	16.9%
SSI	9.1%	13.8%	7.90%	8.7%	9.9%	23.9%
BSI	18.1%	10.9%	10.50%	13.3%	2.9%	8.5%
GI	3.6%	14.5%	9.60%	5.5%	4.6%	-
Systemic	3.6%	2.2%	-	6.5%	-	-
SSTI	-	5.8%	9.60%	9.8%	4.8%	-
CVC	10.9%	7.3%	-	-	-	17%
Other/unspecified	9.3%	3.5%	15.00%	5.4%	19.3%	5.7%
CNSI	7.3%	2.2%	-	-	-	-

©Economist Impact 2023

Distribution of HAIs by bacteria type						
E coli	6.8%	18.6%	13.20%	14.1%	12.8%	11.4%
Citrobacter	-	-	-	-	-	-
Enterobacter	9.1%	3.5%	-	2.6%	-	-
Proteus	6.8%	1.2%	-	2.8%	-	3.2%
Klebsiella	13.6%	11.6%	18.90%	18.2%	10.0%	14.6%
Providencia	-	-	-	-	-	-
Serratia	-	1.2%	-	-	-	-
A baumannii	9.1%	12.8%	6.60%	8.2%	11.3%	2.5%
P aeruginosa	2.3%	11.6%	18.90%	23.0%	14.9%	10.2%
S aureus	25.0%	3.5%	6.60%	14.8%	7.9%	16.5%
All others (not of interest)	27.3%	36%	35.80%	19.2%	43.0%	41.6%
Resistance rate by bacteria type (%)						
CR-E. coli	3.2%	1.3%	1.0%	6.0%	2.4%	28.0%
CR-Citrobacter	4.8%	0.9%	4.0%	10%	10%	33.0%
CR-Enterobacter	5.3%	4.2%	13.0%	0.9%	-	26.8%
CR-Proteus	8.3%	9.3%	8.0%	14.3%	14.3%	13.9%
CR-Klebsiella	38.5%	6.3%	7.5%	39.4%	25.3%	57.5%
CR-Providencia	17.2%	11.6%	4.0%	50%	50%	61.5%
CR-Serratia	6.9%	3.2%	4.5%	4.5%	4.5%	11.2%
CR-Acinetobacter	81.4%	79.6%	63.0%	77.4%	77.1%	88.7%
CR-P aeruginosa	29.3%	28.8%	16.0%	40.2%	27.5%	36.3%
MR-S aureus	23.3%	21.4%	32.0%	30.4%	31.4%	41.4%
Mortality rate						
CR-Enterobacterales	26 – 44%					
CR-P aeruginosa	8-18.4%					
CR-Acinetobacter	8.4-25%					
MR-S aureus	11.8-23.4%					
Excess length of stay (resistant infections)						
Excess LOS model estimates	1-4 days					
CR-Enterobacterales	3.7 days					
CR-P aeruginosa	4.5 days					
CR-A baumannii	3 days					
MR-S aureus	2.9 days					
Cost per inpatient bed day (US$)						
Model estimate	27.02	210.52	336.05	68.81	84.73	34.41
Upper CI	63.05	491.59	739.95	156.1	182.62	76.73
Lower CI	11.31	87.89	138.22	27.65	35.18	14.3

P/LRTI = Pneumonia and lower respiratory tract infection. UTI = urinary tract infections. SSI = surgical site infection. BSI = bloodstream infection. GI = gastrointestinal infection. SSTI = skin and soft tissue infection. CVCI = central venous catheter infection. CNSI = cerebrospinal infections (including intracranial and cerebrospinal fluid). StSI = sterile site infection. CR = carbapenem resistant. MR = methicillin resistant. * = Extrapolation.

©Economist Impact 2023

References

[1] World Health Oraganisation. Antimicrobial resistance. November 2021. Available at https://www.who.int/news-room/fact-sheets/detail/antimicrobial-resistance#.

[2] Antimicrobial Resistance Collaborators. Global burden of bacterial antimicrobial resistance in 2019: a systematic analysis. The Lancet. 2022 Feb;399(10325):629–55. Available at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8841637/.

[3] Tackling drug resistant infections globally: Final report and recommendations. The review on Antimicrobial Resistance. 2016. Available at https://amr-review.org/sites/default/files/160525_Final%20paper_with%20cover.pdf

[4] World Bank. 2017. "Drug-Resistant Infections: A Threat to Our Economic Future." Washington, DC: World Bank. License: Creative Commons Attribution CC BY 3.0 IGO. Available at http://documents.worldbank.org/curated/en/323311493396993758/final-report

[5] World Health Oraganisation. Global Antimicrobial Resistance and Use Surveillance System (GLASS). Available at https://www.who.int/initiatives/glass.

[6] World Health Oraganisation. Global action plan on antimicrobial resistance. 2015. Available at https://www.who.int/publications/i/item/9789241509763.

[7] Cassini A, Högberg LD, Plachouras D, Quattrocchi A, Hoxha A, Simonsen GS, et al. Attributable deaths and disability-adjusted life-years caused by infections with antibiotic-resistant bacteria in the EU and the European Economic Area in 2015: a population-level modelling analysis. Lancet Infect Dis. 2019;19(1):56-66.

[8] International Monetary Fund. Duttagupta R, Pasarbasioglu C. Emerging markets must balance overcoming the pandemic, returning to more normal policies, and rebuilding their economy. Miles to go 2021. Available at https://www.imf.org/external/pubs/ft/fandd/2021/06/the-future-of-emerging-markets-duttagupta-and-pazarbasioglu.htm.

[9] Antimicrobial resistance: More quick action is needed in BRICS and MINT economic transition countries. The BMJ opinion, October 2019. Available at https://blogs.bmj.com/bmj/2019/10/02/antimicrobial-resistance-more-quick-action-is-needed-in-brics-and-mint-economic-transition-countries/#:~:text=countries%20%2D%20The%20BMJ-,Antimicrobial%20resistance%3A%20More%20quick%20action%20is%20needed%20in,an

[10] Addressing the burden of infection and antimicrobial resistance associated with health care: focus on G7 countries. OECD-WHO briefing paper on infection prevention and control, 2022. Available at https://www.oecd.org/health/Addressing-burden-of-infections-and-AMR-associated-with-health-care.pdf.

[11] World Health Organisation. WHO publishes a list of bacteria for which new antibiotics are urgently needed. February 2017. Available at https://www.who.int/news/item/27-02-2017-who-publishes-list-of-bacteria-for-which-new-antibiotics-are-urgently-needed.

[12] Indian Council of Medical Research. India's antimicrobial resistance surveillance and research initiative. Available at https://iamrsn.icmr.org.in/index.php/amrsn/amrsn.

[13] Zhang Y, Du M, Johnston JM, et al. Incidence of healthcare-associated infections in a tertiary hospital in Beijing, China: results from a real-time surveillance system. Antimicrob Resist Infect Control. 2019;8:145. Published 2019 Aug 27. doi:10.1186/s13756-019-0582-7

[14] Vong S, Anciaux A, Hulth A, Stelling J, Thamlikitkul V, Gupta S, et al. Using information technology to improve surveillance of antimicrobial resistance in South East Asia. BMJ. 2017;358:j3781.

[15] Mahomed S, Mahomed O, Sturm AW, Knight S, Moodley P. Challenges with Surveillance of Healthcare-Associated Infections in Intensive Care Units in South Africa. Crit Care Res Pract. 2017;2017:7296317.

[16] Mathur P, Malpiedi P, Walia K, Srikantiah P, Gupta S, Lohiya A, et al. Health-care-associated bloodstream and urinary tract infections in a network of hospitals in India: a multicentre, hospital-based, prospective surveillance study. Lancet Glob Health. 2022;10(9):e1317-e25.

[17] Organisation for Economic Co-operation and Development. Cecchini M, Langer J and Slawomirski L. Antimicrobial resistance in G7 countries and beyond. Economic issues, policies and options for action. September 2015. Available at https://www.oecd.org/els/health-systems/Antimicrobial-Resistance-in-G7-Countries-and-Beyond.pdf.

[18] Hillock NT, Merlin TL, Turnidge J, Karnon J. Modelling the Future Clinical and Economic Burden of Antimicrobial Resistance: The Feasibility and Value of Models to Inform Policy. Appl Health Econ Health Policy. 2022;20(4):479-86.

[19] World Health Organisation. GLASS country participation. Available at https://www.who.int/initiatives/glass/country-participation.

[20] European Centre for Disease Prevention and Control. Assessing the health burden of infections with antibiotic resistant bacteria in the EU/EEA 2016-2020. Available at https://www.ecdc.europa.eu/sites/default/files/documents/Health-burden-infections-antibiotic-resistant-bacteria.pdf.

[21] Organisation for Economic Co-operation and Development. Antimicrobial resistance. Tackling the burden in the European Union. 2019. Available at https://www.oecd.org/health/health-systems/AMR-Tackling-the-Burden-in-the-EU-OECD-ECDC-Briefing-Note-2019.pdf.

[22] Organisation for Economic Co-operation and Development. Stemming the superbug tide: Just a few dollars more. Health and economic burden of antimicrobial resistance. Available at https://read.oecd-ilibrary.org/social-issues-migration-health/stemming-the-superbug-tide/health-and-economic-burden-of-antimicrobial-resistance_9789264307599-7-en#page4.

[23] Friedman ND, Temkin E, Carmeli Y. The negative impact of antibiotic resistance. Clin Microbiol Infect. 2016;22(5):416-22.

[24] Poudel AN, Zhu S, Cooper N, Little P, Tarrant C, Hickman M, et al. The economic burden of antibiotic resistance: A systematic review and meta-analysis. PLoS One. 2023;18(5):e0285170.

©Economist Impact 2023

[25] Zhen X, Stålsby Lundborg C, Sun X, Zhu N, Gu S, Dong H. Economic burden of antibiotic resistance in China: a national level estimate for inpatients. Antimicrob Resist Infect Control. 2021;10(1):5.

[26] Falagas ME, Tansarli GS, Karageorgopoulos DE, Vardakas KZ. Deaths attributable to carbapenem-resistant Enterobacteriaceae infections. Emerg Infect Dis. 2014;20(7):1170-5.

[27] Blot SI, Vandewoude KH, Hoste EA, Colardyn FA. Outcome and attributable mortality in critically Ill patients with bacteremia involving methicillin-susceptible and methicillin-resistant Staphylococcus aureus. Arch Intern Med. 2002;162(19):2229-35.

[28] Zhang Y, Chen XL, Huang AW, Liu SL, Liu WJ, Zhang N, et al. Mortality attributable to carbapenem-resistant Pseudomonas aeruginosa bacteremia: a meta-analysis of cohort studies. Emerg Microbes Infect. 2016;5(3):e27.

[29] Falagas ME, Rafailidis PI. Attributable mortality of Acinetobacter baumannii: no longer a controversial issue. Crit Care. 2007;11(3):134.

[30] Melzer M, Eykyn SJ, Gransden WR, Chinn S. Is methicillin-resistant Staphylococcus aureus more virulent than methicillin-susceptible S. aureus? A comparative cohort study of British patients with nosocomial infection and bacteremia. Clin Infect Dis. 2003;37(11):1453-60.

[31] World Health Organisation. Estimates of cost for inpatient and outpatient health service delivery [Internet]. 2021 [cited 2022 Oct 17]. Available at https://www.who.int/publications/m/item/who-choice-estimates-of-cost-for-inpatient-and-outpatient-health-service-delivery.

[32] The Economist Intelligence Unit. EIU data tool. EIU; 2022

[33] Wolkewitz M, Mandel M, Palomar-Martinez M, Alvarez-Lerma F, Olaechea-Astigarraga P, Schumacher M. Methodological challenges in using point-prevalence versus cohort data in risk factor analyses of nosocomial infections. Ann Epidemiol. 2018;28(7):475-80.e1.

[34] World Health Organisation. Global antimicrobial resistance and use surveillance system (GLASS) report 2022. Geneva; 2022. Licence: CC BY-NC-SA 3.0 IGO.

[35] World Health Organisation. Molecular methods for antimicrobial resistance (AMR) diagnostics to enhance the Global Antimicrobial Resistance Surveillance System. Geneva; 2019 (WHO/WSI/AMR/2019.1). Licence: CC BY-NC-SA 3.0 IGO.

[36] Stewardson AJ, Marimuthu K, Sengupta S, Allignol A, El-Bouseary M, Carvalho MJ, et al. Effect of carbapenem resistance on outcomes of bloodstream infection caused by Enterobacteriaceae in low-income and middle-income countries (PANORAMA): a multinational prospective cohort study. Lancet Infect Dis. 2019;19(6):601-10.

[37] World Health Organisation. Health systems governance and financing. Health economics. Available at https://www.who.int/teams/health-systems-governance-and-financing/economic-analysis/costing-and-technical-efficiency/quantities-and-unit-prices-(cost-inputs)/econometric-estimation-of-who-choice-country-specific-costs-for-inpatient-and-outpatient-health-service-delivery

[38] Brazilian Health Regulatory Agency. National Plan for Antimicrobial Resistance Prevention and Control in Health Services. Brazil: Brazilian Health Regulatory Agency; 2017.

[39] Global antimicrobial resistance surveillance system (GLASS) report: early implementation 2020. Geneva: World Health organisation; 2020. Licence: CC BY-NC-SA 3.0 IGO.

[40] Consejo de Salubridad General. 2018. "ACUERDO por el que se declara la obligatoriedad de la Estrategia Nacional de Acción contra la Resistencia a los Antimicrobianos". Available at http://www.dof.gob.mx/nota_detalle.php?codigo=5525043&fecha=05/06/2018

[41] Global Health Security Index, Mexico Profile. Available at https://www.ghsindex.org/wp-content/uploads/2021/12/Mexico.pdf

[42] Gobierno de México. Boletín de Infecciones Asociadas a la Atención de la Salud (IAAS). Red Hospitalaria de Vigilancia Epidemiológica (RHOVE). 2022. Available at https://www.gob.mx/cms/uploads/attachment/file/808320/BOLETINRHOVECIERRE2022_FINAL.pdf

[43] WHO. GLASS dashboard. Available at https://worldhealthorg.shinyapps.io/glass-dashboard/_w_abaeaac3/#!/.

[44] Gobierno de México. Platform for the National Network of Public Health Laboratories. Available at https://www.gob.mx/salud/acciones-y-programas/plataforma-para-la-red-nacional-de-laboratorios-de-salud-publica

[45] Garza-González E, Morfín-Otero R, Mendoza-Olazarán S, Bocanegra-Ibarias P, Flores-Treviño S, Rodríguez-Noriega E, et al. A snapshot of antimicrobial resistance in Mexico. Results from 47 centers from 20 states during a six-month period. PLoS One. 2019;14(3):e0209865.

[46] Secretaría de Gobernación (SEGOB). Diario Oficial de la Federación. Agreement for declaring the National Strategy for Action against Antimicrobial Resistance to be mandatory. Available at https://dof.gob.mx/nota_detalle.php?codigo=5525043&fecha=05/06/2018#gsc.tab=0

[47] Secretaría de Gobernación (SEGOB). Diario Oficial de la Federación. Agreement that modifies the Sole Annex of the diverse by which the National Strategy of Action against Antimicrobial Resistance is declared mandatory, published on June 5, 2018. Available at https://dof.gob.mx/nota_detalle.php?codigo=5670896&fecha=09/11/2022#gsc.tab=0

[48] Alothman A, Al Thaqafi A, Al Ansary A, Zikri A, Fayed A, Khamis F, et al. Prevalence of infections and antimicrobial use in the acute-care hospital setting in the Middle East: Results from the first point-prevalence survey in the region. Int J Infect Dis. 2020;101:249-58.

[49] World Health Organisation. Egypt National Action Plan For Antimicrobial Resistance. Egypt: WHO, country office for Egypt. 2018. [cited 2022 Jan 28]. Available at https://www.who.int/publications/m/item/egypt-national-action-plan-for-antimicrobial-resistance

[50] Egypt, Arab Rep. Tracking AMR Country Self Assessment Survey (TrACSS) 2022 country report. Available at https://amrcountryprogress.org/download/profiles/EMRO/TrACSS-2022-Egypt-Arab-Rep.pdf

[51] Ministry of Health Saudi Arabia. KINGDOM SAUDI ARABIA NATIONAL ACTION PLAN ON combating ANTIMICROBIAL RESISTANCE. 2017. Available at https://faolex.fao.org/docs/pdf/sau171813.pdf

[52] Joint External Evaluation of IHR Core Capacities of the Kingdom of Saudi Arabia. Geneva: World Health Organisation; 2017. Licence: CC BY-NC-SA 3.0 IGO. Available at https://apps.who.int/iris/rest/bitstreams/1087628/retrieve

[53] Global Health and Security Index 2021. Saudi Arabia. Available at https://www.ghsindex.org/wp-content/uploads/2021/12/Saudi-Arabia.pdf

[54] Hu F, Guo Y, Yang Y, Zheng Y, Wu S, Jiang X, et al. Resistance reported from China antimicrobial surveillance network (CHINET) in 2018. Eur J Clin Microbiol Infect Dis. 2019;38(12):2275-81.

[55] Xiao Y, Li L. China's national plan to combat antimicrobial resistance. Lancet Infect Dis. 2016;16(11):1216-8.

©Economist Impact 2023

[56] Wang J, Liu F, Tan JBX, Harbarth S, Pittet D, Zingg W. Implementation of infection prevention and control in acute care hospitals in Mainland China - a systematic review. Antimicrob Resist Infect Control. 2019;8:32.

[57] Iskandar K, Molinier L, Hallit S, Sartelli M, Hardcastle TC, Haque M, et al. Surveillance of antimicrobial resistance in low- and middle-income countries: a scattered picture. Antimicrob Resist Infect Control. 2021;10(1):63.

[58] Indian Council of Medical Research. Division of Epidemiology and Communicable Diseases. Antimicrobial Resistance Research and Surveillance Network. Annual report January 2021 to December 2021. Available at https://main.icmr.nic.in/sites/default/files/upload_documents/AMR_Annual_Report_2021.pdf

[59] National Centre for Disease Control. National Programme on AMR containment. Available at https://ncdc.gov.in/index1.php?lang=1&level=2&sublinkid=384&lid=344

[60] Nair V, Sahni AK, Sharma D, Grover N, Shankar S, Chakravarty A, et al. Point prevalence & risk factor assessment for hospital-acquired infections in a tertiary care hospital in Pune, India. Indian J Med Res. 2017;145(6):824-32.

[61] Dey R, Dutta S. Epidemiological profile of hospital-acquired infection in a tertiary care hospital of Eastern India. International journal of scientific study 2019. Available at http://www.ijss-sn.com/uploads/2/0/1/5/20153321/14_ijss_may_oa_15_-_2019.pdf

[62] Centre of Disease Control. Outline for Healthcare-Associated Infections Surveillance. April 2006. Available at https://www.cdc.gov/nhsn/pdfs/outlineforhaisurveillance.pdf

[63] National Health Authority. Ayushman Bharat Digital Mission. Available at https://abdm.gov.in/

[64] Daily news Egypt. Health ministry signs protocol to launch electronic antimicrobial surveillance platform. April 2023. Available at https://www.dailynewsegypt.com/2023/04/11/health-ministry-signs-protocol-to-launch-electronic-antimicrobial-surveillance-platform/.

[65] Press Information Bureau Government of India Ministry of Health and Family Welfare. Rules for Selling of Drugs Under Schedule H1. Dec 2013. Available at https://pib.gov.in/newsite/PrintRelease.aspx?relid=101251

[66] International Alliance of Patients' organisations. Can we do more to prevent antimicrobial resistance? Available at https://www.iapo.org.uk/news/2020/nov/23/can-we-do-more-prevent-antimicrobial-resistance

[67] GOV. UK. Financial incentives effective at reducing antibiotic prescribing. June 2018. Available at https://www.gov.uk/government/news/financial-incentives-effective-at-reducing-antibiotic-prescribing

[68] Kimble LE, Massoud MR, Heiby J. AMR control. Overcoming Global Antimicrobial Resistance. Using quality improvement to address hospital acquired infections and antimicrobial resistance. August 2017. Available at http://resistancecontrol.info/2017/using-quality-improvement-to-address-hospital-acquired-infections-and-antimicrobial-resistance/

[69] NHS Digital. Patient Level Information and Costing System (PLICS) Data collections. Available at https://digital.nhs.uk/data-and-information/data-tools-and-services/data-services/patient-level-information-and-costing-system-plics-data-collections#costing-transformation-programme

[70] European Centre for Disease Prevention and Control. Antimicrobial consumption in the EU/ EEA (EASC-Net)- Annual epidemiological report for 2021. Available at https://www.ecdc.europa.eu/en/publications-data/surveillance-antimicrobial-consumption-europe-2021

[71] World Bank. World Development Indicators. World Bank Open Data. 2022 [cited 2022 Jul 14]. Available at: https://data.worldbank.org/

[72] Ministry of Health, Kingdom of Saudi Arabia. Key Health Indicators - 2019. Health Indicators [Internet]. 2020 [cited 2022 Oct 17]. Available at: https://www.moh.gov.sa/en/Ministry/Statistics/Indicator/Pages/Indicator-1440.aspx.

[73] Organisation for Economic Co-operation and Development. Hospital discharges and average length of stay", in Health at a Glance 2021 [Internet]. OECD Paris; 2021 [cited 2022 Oct 17]. (OECD Indicators). Available at: https://www.oecd-ilibrary.org/sites/18faaea9-en/index.html?itemId=/content/component/18faaea9-en.

[74] Organisation for Economic Co-operation and Development. "Hospital discharges and average length of stay", in Health at a Glance 2021 [Internet]. OECD Paris; 2021 [cited 2022 Oct 17]. (OECD Indicators). Available at: https://www.oecd-ilibrary.org/sites/18faaea9-en/index.html?itemId=/content/component/18faaea9-en

[75] Organisation for Economic Co-operation and Development. Hospital care- Health at a Glance: Asia /Pacific 2020: Measuring Progress Towards Universal Health Coverage. 2020. Available at: https://www.oecd-ilibrary.org/sites/a84aa0c2-en/index.html?itemId=/content/component/a84aa0c2-

[76] Huerta-Gutiérrez R, Braga L, Camacho-Ortiz A, Díaz-Ponce H, García-Mollinedo L, Guzmán-Blanco M, et al. One-day point prevalence of healthcare-associated infections and antimicrobial use in four countries in Latin America. Int J Infect Dis. 2019;86:157-66.

[77] Wang J, Liu F, Tartari E, Huang J, Harbarth S, Pittet D, et al. The Prevalence of Healthcare-Associated Infections in Mainland China: A Systematic Review and Meta-analysis. Infect Control Hosp Epidemiol. 2018;39(6):701-9.

[78] Pfizer. Antimicrobial Testing Leadership and Surveillance [Internet]. [cited 2022 Oct 17]. Available from: https://atlas-surveillance.com/#/login

[79] Chen Z, Xu Z, Wu H, Chen L, Gao S, Chen Y. The impact of carbapenem-resistant Pseudomonas aeruginosa on clinical and economic outcomes in a Chinese tertiary care hospital: A propensity score-matched analysis. Am J Infect Control. 2019;47(6):677-82.

[80] Pogue JM, Zhou Y, Kanakamedala H, Cai B. Burden of illness in carbapenem-resistant Acinetobacter baumannii infections in US hospitals between 2014 and 2019. BMC Infect Dis. 2022;22(1):36.

[81] Lee XJ, Stewardson AJ, Worth LJ, Graves N, Wozniak TM. Attributable Length of Stay, Mortality Risk, and Costs of Bacterial Health Care-Associated Infections in Australia: A Retrospective Case-cohort Study. Clin Infect Dis. 2021;72(10):e506-e14.

©Economist Impact 2023

While every effort has been taken to verify the accuracy of this information, Economist Impact cannot accept any responsibility or liability for reliance by any person on this report or any of the information, opinions or conclusions set out in this report.
The findings and views expressed in the report do not necessarily reflect the views of the sponsor.

©Economist Impact 2023

ECONOMIST IMPACT

LONDON
The Adelphi
1-11 John Adam Street
London WC2N 6HT
United Kingdom
Tel: (44) 20 7830 7000
Email: london@economist.com

GENEVA
Rue de l'Athénée 32
1206 Geneva
Switzerland
Tel: (41) 22 566 2470
Fax: (41) 22 346 93 47
Email: geneva@economist.com

SÃO PAULO
Rua Joaquim Floriano,
1052, Conjunto 81
Itaim Bibi, São Paulo - SP
04534-004
Brasil
Tel: +5511 3073-1186
Email: americas@economist.com

NEW YORK
900 Third Avenue
16th floor
New York, NY 10022
United States
Tel: (1.212) 554 0600
Fax: (1.212) 586 1181/2
Email: americas@economist.com

DUBAI
Office 1301a
Aurora Tower
Dubai Media City
Dubai
Tel: (971) 4 433 4202
Fax: (971) 4 438 0224
Email: dubai@economist.com

HONG KONG
1301
12 Taikoo Wan Road
Taikoo Shing
Hong Kong
Tel: (852) 2585 3888
Fax: (852) 2802 7638
Email: asia@economist.com

SINGAPORE
8 Cross Street
#23-01 Manulife Tower
Singapore
048424
Tel: (65) 6534 5177
Fax: (65) 6534 5077
Email: asia@economist.com