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Antimicrobial resistance, infection control and planning for pandemics: The importance of knowledge transfer in healthcare resilience and emergency planning

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ABSTRACT

Over the last 70 years, the efficacy, ready availability and relatively low cost of antimicrobial drugs – medicines that kill microorganisms such as bacteria and viruses or inhibit their multiplication, growth and pathogenic action – has led to their considerable overuse. It is estimated that nearly 50 per cent of all antimicrobial use in hospitals is unnecessary or

inappropriate [1] while in neonatal care, the figure is even higher, with infection confirmed in only five per cent of neonates treated with antibiotics.[2] The more antimicrobials are used, the faster the microorganisms they target evolve into new, resistant strains, a natural process of evolution that threatens to undermine the tremendous life-saving potential of these drugs. Antimicrobial resistance (AMR) is a growing concern not only for the healthcare sector[3] but also, increasingly, for security and resilience. Pandemic influenza, comparable only to 'Catastrophic terrorist attacks' at the top of the UK's National Risk Register[4] may well result from the emergence of a strain that cannot be treated effectively with currently available drugs or from one that quickly develops resistance to the stockpiled countermeasures. Multidrug-resistant tuberculosis impacts on immigration policy, methicillin-resistant Staphylococcus aureus *(MRSA), a major cause of hospital-acquired infections is an ongoing challenge for the health sector and the increase in drug-resistant strains of malaria is problematic both in its own right and as an additional consequence of climate change. AMR places a significant burden on international governments and tackling it requires changes to thinking across a number of government departments. In 2011, the Transatlantic Taskforce on Antimicrobial Resistance (TATFAR) published* Recommendations for future collaboration between the US and EU[1] *and both the EU and the UK's Department of Health have recently developed new AMR strategies and Action Plans. This paper will explore the cross-disciplinary policy challenges that AMR presents and the difficulties that are likely to be faced in implementing the recommendations of the TATFAR report. It will compare and contrast the efficacy of some of the programmes already in place to help reduce or better target the use of antimicrobials and discuss potential areas for further research and development into tackling a growing international problem.*
Keywords: antimicrobial resistance, antibiotics, tuberculosis, MRSA, healthcare resilience

INTRODUCTION

The emergence of drug-resistant bacteria, viruses and other microorganisms is a concern for more than just the medical industry. It is forcing governments into greater collaboration, influencing immigration policy in the UK and is changing the way that one needs to think about domestic resilience. Developing new and sometimes radical ways of reducing antimicrobial use can improve not only the way that the spread of routine infections is controlled, but can also inform emergency planning for other serious health emergencies such as pandemic flu and bioterrorism attacks.

Antimicrobial resistance (AMR) – the resistance of microorganisms, including bacteria and viruses, to medicines that have previously been used to treat them – is a growing concern not only for the healthcare sector[3] but also, increasingly, for security and resilience. It has long been known that AMR may influence the planning for and response to pandemic influenza, comparable only to 'catastrophic terrorist attacks' at the top of the UK's National Risk Register[4] with 'other infectious diseases' and 'zoonotic animal diseases' also featuring significantly highly. In recent years, severe acute respiratory syndrome (SARS), H5N1 'avian flu', the H1N1 'swine flu' pandemic and foot and mouth disease, not to mention the emergence of the human immunodeficiency virus (HIV) in the 1980s, has shown the impact that unexpected disease outbreaks can have, particularly where they are difficult or impossible to treat. In and above these currently recognised health threats, AMR is becoming of increasing concern in its own right, with academics such as Rambhia and Gronvall[5] linking it to national security and the US National Center for Biotechnology Information, the World Health Organization (WHO), the EU and national government departments responsible for human and animal health all pushing it further up their security agendas in recent months. The European Commission's Seventh Framework Programme of Research and Development invested €147m in AMR research between 2007 and 2013, stating: 'Antimicrobial resistance is reaching alarming levels and is a very significant health threat to all Europeans'.[6] In the UK, the Department of Health is updating its AMR policy, with the new Five Year Antimicrobial Resistance Strategy and Action Plan, to cover the period 2013–2018, to be published in January 2013.

Disease outbreaks that impact outside the health sector, and therefore need to be of interest to emergency planners, often result from the emergence of new diseases or from new strains of known diseases that have developed resistance to the currently available drugs. In the case of a pandemic or bioterrorism attack, the microorganisms may already have, or quickly develop, resistance to any stockpiled countermeasures, including treatments and vaccines. Knowledge transfer between the resilience, security and healthcare sectors can help to address challenges across multiple disciplines: methods employed to tackle AMR may be equally applicable to controlling infection spread (see Table 1) during pandemics and bioterrorism attacks and vice versa. This is not least because the best response is not always the most scientific. Simple measures such as good personal hygiene and social distancing, as well as more accurate diagnosis and better mapping of outbreak 'hot spots', can be just as effective as the rapid development of new medical countermeasures. Lessons identified from

tackling AMR and mitigating its impact can be used to promote and explore alternatives to a reliance on drugs as the only means of infection control. The more the security and healthcare sector can work together, the more potential benefits can be gained by both sides. In particular, by better understanding the risks and threats, emergency planners can play an important role in raising awareness of the issues likely to be encountered during healthcare emergencies, ensuring effective communication of public information programmes and taking an active stance in responding to emerging healthcare challenges. Planning for and responding to pandemic flu, for example, is not only important for its own end but can have a dramatic impact on the way in which antibiotics and antiviral drugs are prescribed, as this paper will explore later. Prevention strategies that embed personal hygiene behaviours among employees can reduce infection spread and bring down levels of illness and staff absenteeism throughout the year, not only during healthcare emergencies.

THE INTERNATIONAL BURDEN OF AMR

AMR places a significant burden on international governments, both in terms of patient morbidity and financial cost. For example, more than 450,000 new cases of multidrug-resistant tuberculosis (MDR-TB) and extensively drug-resistant tuberculosis (XDR-TB) emerge worldwide each year, causing approximately 150,000 deaths.[7] Resistance to previously effective anti-malarial drugs such as chloroquine is growing in most malaria-endemic countries. A high percentage of hospital-acquired infections (HAIs), which lead to 37,000 deaths in the EU each year (a number comparable with the numbers who die in road traffic accidents),[8] are caused by bacteria such as methicillin-resistant *Staphylococcus aureus* (MRSA) and *Clostridium difficile*. In recent years, new drug-resistant strains of *E. coli, Salmonella, Streptococci* (responsible for pneumonia) and gonorrhoea have emerged.

Tackling AMR requires changes to thinking across a number of UK Government departments, including the Home Office, Foreign and Commonwealth Office and Health Protection Agency as well as the Department of Health and Department for Environment, Food and Rural Affairs, bringing together many of the agencies and departments that would also be called on to respond to a healthcare emergency on the National Risk Register. This is increasingly important as AMR gains recognition as a serious resilience threat in its own right that may well feature on such risk registers in future.

Successful implementation of policy recommendations to tackle healthcare emergencies, as well as the uptake of research findings, often depends on a change in public behaviour. This in turn may be equally dependent on effective communication campaigns that are able to raise awareness and strike the right balance between creating the appropriate amount of concern without generating unnecessary panic. In this regard, there is a lot to learn from the high-profile public health education campaigns that emerged in the wake of the AIDS epidemic of the early 1980s[9] and the way in which information on radiological health risks was communicated to the public following damage to the nuclear reactors at the Fukushima Dai-ichi power plant in Japan in March 2011.[10]

THE EMERGENCE OF MULTI-DRUG RESISTANT TUBERCULOSIS

One aspect of AMR that is already of interest to security and resilience is the impact of MDR-TB and XDR-TB on immigration policy. An infectious disease caused by the *Mycobacterium tuberculosis* bacterium, TB killed as many as one in four Europeans during the 17th and 18th centuries, but had been virtually eradicated through the use of antibiotics and improved hygiene by the 1980s. The bacterium's ability to develop resistance to antibiotics has made eradicating it completely a challenge, however. Streptomycin, the first antibiotic to fight tuberculosis, was introduced in the mid-1940s[11] but TB resistant to one drug (monotherapy) developed within months and was observed even during the clinical trials for Streptomycin's introduction.[12] This was initially countered by using a combination of two or three drugs but led, in turn, to the evolution of MDR-TB – strains of the disease resistant to more than one antibiotic.

In the 1980s the emergence of new drug-resistant strains coincided with the HIV epidemic, causing an upsurge in the number of TB patients worldwide.The increasing number of cases was declared a global health emergency by WHO in 1993 and combating it remains a challenge that is exacerbated by the drug-resistant strains. XDR-TB, defined as tuberculosis resistant to 'quadruple therapy'– rifampicin, isoniazid plus at least one quinolone and at least one injectable antibiotic – was first identified in 2006. By 2010,[13] cases had been reported in 58 countries. At least part of the reason for the emergence of XDR-TB is attributed to poorly funded TB control programmes that could not adequately treat patients and therefore acted to select out drug-resistant bacteria.[14]

In some areas of the world, more than a quarter of all people newly diagnosed with TB no longer respond to standard treatment regimens. In the UK, more than eight per cent of cases are now resistant to first line drugs, an increase of 26 per cent since 2011. Six of the 24 extensively drug resistant cases reported in the UK since 1995 occurred in 2011 (figures provided by Department of Health, August 2012). Rates of new TB cases increased year-on-year in the UK from a low of around 5,000 per year during the 1980s to 7,167 in 2004 and although they have stabilised since 2005 they still remain high, with three-quarters of MDR-TB cases recorded in people born overseas, mainly in Asia and Sub-Saharan Africa.[15] This has implications not only for immigration policy but also for the movement of travellers – for business as well as tourism – to and from areas of the world where TB is especially prevalent.

In 2011, the UK Border Agency led a review of border screening policy with the support of the Department of Health and the Health Protection Agency, to assess the efficacy of current UK immigration screening. This enabled comparison of different screening programmes in use by the UK and other nations and an evaluation of pilot pre-entry models used in the UK since 2005. Similar pre-entry models are used by the USA, Australia and Canada. In May 2012,[16] Minister of State Immigration, Damian Green, announced that the current process of screening migrants from high-incidence countries on arrival at UK airports should be phased out in favour of increasing pre-entry in-country screening, which currently takes place in 15 countries, to a further 67.[17] Such screening programmes are, however, dependent on accurate and timely diagnostic tools, which can provide immediate results. Support for the development of such technology is discussed later in this paper.

Increasing concerns over AMR are driving international cooperation and national initiatives. Since 2008, European Antibiotics Awareness Day has been held annually on 18th November and, in 2011, the WHO World Health Day was dedicated to the issue. Other examples include the review of HAIs and antimicrobial use across 17 EU countries by the European Centre for Disease Control, undertaken in 2008,[8] which aims to standardise the way data are collected so that they can be more easily analysed. The US National Institute of Allergy and Infectious Diseases, National Institutes of Health[18] has teamed up with the European Centre for Disease Control to form the Transatlantic Taskforce on Antimicrobial Resistance (TATFAR), which published its first major report, *Recommendations for future collaboration between the US and EU*, in 2011.[1] The purpose of the taskforce is to intensify cooperation in three key areas it has identified: appropriate therapeutic use of antimicrobial

drugs in the medical and veterinary communities; prevention of both healthcare and community associated drug-resistant infections; strategies for improving the supply of new antimicrobial drugs. These key findings are mirrored in the key actions of the EU Action Plan against the rising threat of AMR[19] released in November 2011 and the Five Year Antimicrobial Resistance Strategy and Action Plan 2013–2018 being developed by the UK Department of Health. The latter contains seven strategic aims including responsible prescribing to preserve existing therapies, raising awareness of the problem and strengthening international collaboration. Implementing these strategies and action plans will involve not only public sector healthcare practitioners and the pharmaceutical industry, but also veterinarians, the agricultural sector, medical retailers, the travel industry, food standards and the leisure sector as well as emergency planners more generally. Raising awareness of the issue, and the emerging threat, will ensure that mitigation strategies can be embedded early.

TOWARDS MORE APPROPRIATE USE OF ANTIBIOTICS

Of the key areas identified by the TATFAR report and the EU/UK action plans, the hardest to implement may well be addressing appropriate therapeutic use and responsible prescribing. Over the last 70 years, the efficacy, ready availability and relatively low cost of antimicrobial drugs has meant that using them to treat patients in whom infection is suspected but not confirmed, and to protect patients with compromised immune systems from the risk of infection, has become widespread. This needs to be reduced in order to preserve the efficacy of the drugs for the future. The greater the quantities in which antimicrobials are used, the faster the microorganisms that they target will evolve into new resistant strains.

AMR is a natural progression of evolution; when pressure is put on living organisms, they adapt to survive. Concerted UK efforts to reduce the incidence of MRSA infections in hospitals, which reduced the number of deaths per year from 1,652 in 2006 to 364 in 2011, and saw 25 hospital trusts registered as being MRSA free for more than a year in 2011, show the positive effect that well-planned and well-coordinated approaches can have. The success has been somewhat tempered, however, by a corresponding increase in community associated MRSA (CA-MSRA), a version of MRSA found increasingly in non-hospital settings, in particular in the changing rooms of sports facilities and gyms. CA-MSRA has used another standard evolutionary practice – migrating to less hostile environments – in order to survive and thrive as healthcare facilities increasingly target its spread. Staying aware of where

resistant strains may emerge next, and the conditions in which they are likely to thrive, will help to plan for and prevent their re-emergence.

While much has already been done to counter AMR in hospital settings, there is still a long way to go. According to TATFAR, nearly 50 per cent of all antimicrobial use in hospitals is unnecessary or inappropriate and 'the extensive use of antimicrobials has resulted in drug resistance that threatens to reverse the tremendous life-saving power of these drugs'. It must be addressed.

Determining 'appropriate use' may not be as simple as it at first appears, however, as it relies partly on understanding how and why what might have been considered appropriate use in the past has become less appropriate or inappropriate today. Before AMR was so widespread, antibiotics could be freely administered on very low risk thresholds; as the risks associated with using them increase, so too do the risk thresholds need to adapt. This requires not only reassessment of the risk but also the development of alternate ways to manage that risk.

Antibiotics are widely used to prevent infection occurring, particularly where the patient's immune system is, or is likely to become, compromised. Chemotherapy, for example, kills the patient's infection-fighting neutrophils (a type of white blood cell) as well as the cancer cells it is intended to treat, leaving patients more prone to infection during and after treatment. Therefore, chemotherapy patients are often given prophylactic – 'preventative' – antibiotics in order to protect against infections. In the USA, as many as 45 per cent of chemotherapy patients are given antibiotics in this way, although there is considerable controversy over the advantages, particularly in light of the impact it has on the development of antibiotic resistance.[20] Similarly, prophylactic antibiotics are used to prevent infections during and after surgery, with similar concerns.[21] Promoting and funding additional research into alternative approaches to major surgery can help to address this; for example, there is a growing body of research into the use of nanotechnology to destroy cancer tumours, a process that leaves surrounding healthy tissue undamaged. Such research is supported by The Alliance for Nanotechnology in Cancer, established by the US National Cancer Institute [22] and a number of UK universities are involved in ongoing research in this area, including University College London, Imperial College London, Swansea University and Cambridge University.

A study by Rogers *et al*.[23] of nearly 25,000 patients undergoing a coronary artery bypass graft showed that, while 18 per cent of patients who received a blood transfusion during surgery developed an infection, the figure was only seven per cent in those who did not. At the time of the report, more than 80 per cent of patients undergoing this procedure received a transfusion, a figure Rogers and her team considered to be unnecessarily high. She argued that, by addressing the reasons for inappropriate transfusions, the rate of infection can be brought down and, alongside it, the need to treat the resulting infections.

Rogers' study, conducted in a single state (Michigan, USA) also highlighted a common problem in infection management across the healthcare sector: inconsistent practices between one hospital and the next, even within a relatively small geographic area. In the UK, there are currently no national protocols for the use of antibiotics in the National Health Service (NHS) and hospitals stock different antibiotics based on local preferences. Such inconsistency not only means that infection risks and management are hard to evaluate but also that data on the causes, response to and outcome of infections are not collected in the same way, making analysis difficult. Promoting research and development into ways to ensure consistent recording of data on infections and the causes of infections (as well as understanding the true cause of the symptoms where antibiotics were administered but infection was not subsequently identified) is paramount to decreasing unnecessary antimicrobial use as well as enabling rapid identification of new outbreaks of disease.

In August 2012, the UK's National Institute for Health and Clinical Excellence (NICE) published a new clinical guideline on the appropriate use of antibiotics in neonatal care, where risk thresholds are particularly low.[2] To quote the consultation document for the review:

> About 10 per cent of all newborn babies are investigated for possible early-onset infection and are treated with antibiotics. However, fewer than 5 per cent of these treated babies are subsequently proven to have had an infection … Stopping unnecessary antibiotics as soon as possible will help reduce the emergence of resistant bacterial strains.

In order to facilitate this, the guideline takes an intelligent approach to risk, identifying 31 situations (consisting of 23 clinical indicators and eight risk factors) that are currently considered to be possible signs of infection and thus likely to trigger antibiotic administration. Six of these (two of the risk factors and four of the clinical indicators) are

labelled as 'red flags', with the guideline recommending that: ‘in babies with any red flags … perform investigations and start antibiotic treatment’, while, ‘in babies without red flags and only one risk factor or one clinical indicator, using clinical judgement consider … whether it is safe to withhold antibiotics’.

Moreover, studies such as one currently being undertaken by Lady Hardinge Medical College, New Dehli,[24] are showing that, for some risk factors, waiting for symptoms to develop before administering antibiotics, rather than administering prophylactics on suspicion of infection, has no adverse impact on patient outcome.

Such studies help to show that behaviours can be changed without putting patients at risk and so will help to build confidence in the suggested new procedures that will enable antibiotic use to be scaled back appropriately. This not only tackles AMR but also has significant financial benefits, an increasingly important factor in public sector decision making under the current financial climate. Decreasing the 95 per cent overuse of antibiotics in neonatal care to even 50 per cent across hospitals in general, identified as a problem by TATFAR, could potentially save the NHS more than £80m per year (based on figures obtained in a Freedom of Information Request from Chelsea and Westminster Hospital NHS Trust (of an average of cost of £1,480.90+£1,023.78+£18.44 to treat a baby with suspected infection in the Special Care Baby Unit for 48 hours, using Cefotaxamine, while the mother remains on a post-natal ward, giving an average cost of £2,523.12) and from the Office of National Statistics of 723,165 live births in 2010). The methodology used in developing the NICE guideline could equally be applied to many other areas of medical practice and infection control, with comparable financial benefits. AMR costs the EU approximately €1.5bn in healthcare expenses and lost productivity,[25] while TATFAR estimates the annual costs to the US healthcare sector to be $21–34m.

PROMOTING RAPID DIAGNOSTIC TECHNIQUES

Withholding antibiotics from a patient to whom they would previously have been administered or changing behaviour to avoid procedures that would require prophylactic administration of antibiotics or carry a risk of infection will not be completely without risk, however. Medical staff may be reluctant to change known and trusted protocols. A second approach, and one that may help to boost confidence in more cautious administration, is to improve rapid diagnostic techniques, so that when infection is suspected, it can be confirmed

or ruled out more quickly. At present, suspected infections are confirmed by culture growth from blood samples. This can take days or, in the case of some diseases, even months to confirm.

Funding and endorsing research into rapid diagnostics by organisations such as WHO, which recently endorsed a novel test for TB and MDR-TB that has the potential to provide an accurate diagnosis in 100 minutes compared to the current three months,[26] should be encouraged by governments and academic funding councils worldwide. This would benefit not only aspiring immigrants, but also all travellers departing known disease hotspots and all patients in whom infection is suspected or identified.

Such rapid, and accurate, diagnoses are of particular importance during pandemics and bioterrorism attacks in order to map the outbreak and spread of the disease, as well as to treat it. The TATFAR report identified that many doctors prescribe antibiotics to patients as a first attempt at treating an infection, with antivirals prescribed only if the first drugs fail to have an effect. Additionally, antibiotics are often prescribed to patients suspected of having a viral infection while the real cause is being diagnosed as the patient expects to be given 'something'.[1] Misdiagnosis of viral infections as bacterial can be improved by more coordinated information collection and sharing during known outbreaks, particularly where this raises awareness among healthcare staff of when and where outbreaks of viral infections are occurring. A study by the American College of Physicians showed that, from April 2009 to March 2010, during the H1N1 'swine flu' pandemic, antibiotic prescriptions decreased as the number of cases that doctors saw increased their familiarity with the viral infection and led to more accurate diagnoses.[27]

LIMITING THE SPREAD OF DISEASE

A third approach is to fund research and development into the understanding of, and ways to limit, the spread of diseases, primarily by limiting the opportunities for infected individuals to come into contact with those who are not. The classic case study for this is the Derbyshire village of Eyam, which in 1665 chose to cut itself off from the outside world as villagers began to fall victim to the Great Plague, an act of remarkable self-sacrifice that is largely credited with preventing the spread of the disease into the north of England. Although this is a dramatic example, there is considerable evidence that such social distancing is extremely

effective in preventing the spread of pandemic flu. WHO research into the 1957–1958 flu pandemic showed that, in some countries, the disease spread more quickly following large conferences and festivals.[28] Shutting schools in particular at the first sign of infection can have a dramatic effect on disease spread.

Mapping and understanding the spread of the disease was a vital component of the response to the 2009–2010 swine flu pandemic, both internationally and within the UK. Flu pandemics are caused by new strains of a disease, to which humans have little immunity (although the exact level of immunity will depend on how different the new strain is to those encountered before. The relatively small numbers of elderly patients severely affected by the H1N1 virus is thought to be at least partly due to those who were children during the 1957 and 1968 pandemics having some residual immunity). They can emerge at any time, although around three per century is generally seen. Prior to the 2009 outbreak, pandemics had occurred in 1968, 1957–1958 and 1918–1919.

At the time of the 2009 outbreak, the UK was well prepared,[29] with more than £500m worth of countermeasures stockpiled. Together with France, the UK was considered by WHO to be one of the best prepared countries in the world. UK government policymakers, however, are now questioning whether stockpiling countermeasures is the most effective, and cost-effective, first line of defence.

The importance of good hygiene

Simple, social approaches such as hand washing, covering one's mouth, using handkerchiefs and tissues, staying at home when feeling ill can be remarkably effective and promoting them benefits the community at any time, not just during pandemics. Good hygiene, of individuals and the environment has an enormous impact on infection control. In the 1850s, Florence Nightingale reduced the death rate from cholera, typhus and dysentery in a Crimean hospital from 42 per cent to just two per cent by organising a laundry service, cleaning both equipment and wards and encouraging better personal hygiene practices in her team of nurses. Even prior to the introduction of antibiotics, TB across Europe and North America began to decline from the beginning of the 20th century onwards due to improved living conditions. Today, more than 90 per cent of TB deaths worldwide occur in developing nations with poor hygiene.

Unfortunately, the ready availability of antimicrobials during the second half of the 20th century enabled a decrease in emphasis on the importance of hospital cleaning to prevent infection. Dancer[30] pointed out how, by the end of the century, this had become a neglected component of infection control, driven by the need for financial savings. Dancer's study identified, for example, increased cases of *C. difficile* in November, which was linked to the activation of the hospital heating system. As the space between the back of the radiators and the wall was not cleaned, the microbes could survive and thrive there during the summer months and were disseminated by thermal convection when the radiators were turned on for the winter. MRSA has been detected in the buttons of television sets, cushions, computer keyboards, consultant's pens and even the seams of hospital gowns.

The importance of 'proper hand hygiene and isolation practices' was also highlighted in a report published in Pope *et al*.,[31] which identified physical contact with healthcare staff as the major source of MRSA transmission between patients in the hospital setting, with poor hand washing being the principle contributing factor. The study found that compliance with hand washing recommendations was routinely below 50 per cent and compliance with MRSA precautions in general (including the use of gloves and gowns) was only 28 per cent. The methods to improve compliance explored by the study can be easily transferred to any occupational setting to prevent infection spread; for example, the provision of waterless hand sanitizers positioned at multiple exit and entrance points enabled more convenient opportunities for regular hand cleaning. Introducing such sanitizers to any workplace setting, as was recommended during the 2010–2011 swine flu pandemic, can help to keep down infection rates during disease outbreaks and flu seasons. Another key factor identified by Pope *et al*. was the value of accurate information; explaining when an infection is spread primarily by physical contact, rather than by coughing or sneezing, can help to improve compliance with hand washing. Verbal instruction, particularly from an obviously knowledgeable role model, is more likely to lead to compliance than written guidelines, as is evidence-based data on the likely success of implementing suggested changes to behaviour. In particular, the study suggested that representatives from each occupational unit, who could act as 'role models' to their colleagues, supported by strong central leadership within the organisation, have a particular impact on behavioural compliance.

Vaccination programmes and appropriate risk communication

Better understanding of the way vaccination and immunisation programmes are communicated to the public, and how this affects the rate of uptake, is also needed. During the 2009–2010 swine flu pandemic, the UK Government promoted flu vaccinations – usually available only to vulnerable groups – to the entire population but there was little uptake among healthy individuals once it was realised that symptoms were comparatively mild. A healthy, young individual may well be able to fight off the effects of infection relatively easily, but a healthy, young, *vaccinated* individual will not pass on the disease to his frail 90-year-old neighbour, whose health is more likely to be affected. Vaccination programmes, and even better personal hygiene such as hand washing and covering one's mouth during coughing, often have a greater benefit to the community than to the individual but this is not always well communicated. Emergency planners should look into the benefits of taking on a 'leadership role' in disseminating messages across their sector, together with active encouragement of vaccination uptake, such as negotiating for employees to be allowed to leave early in order to obtain a vaccination. Allocating specific days for this is also likely to provide a significant return in reducing the number of days lost to illness. Similarly, encouraging business continuity managers and HR departments to promote and disseminate literature connected to awareness campaigns such as the European Antibiotics Awareness Day leaflet 'Get well soon without antibiotics' and 'Antibiotics will not get rid of your cold' poster[32] will have a very practical impact.

Further research into the use of social media and the Internet could not only help to understand how individuals access healthcare advice and other services online but could also explore increased use of online diagnosis and consultations, thus preventing them from spreading the infection en route to, and home from, local healthcare facilities. Computer modelling technology can be used to assess the impact of decentralising many medical services from large hospitals back into the community, even to home-based care. Similarly, intelligent use of social media and modelling could help to map the spread of the disease in the early stages, identifying outbreak 'hot spots', encouraging the development of social self-help networks and disseminating information from official and peer-to-peer networks.

CONCLUSION

AMR is clearly a serious and ongoing concern. The threat it imposes is growing and there is a very real chance that, as well as impacting on security and resilience through issues such as border screening for infectious disease and the stockpiling of medical countermeasures, it may soon appear in the National Risk Assessment and on the National Risk Register in its own right. Many of the ways in which people can build resilience to it are relatively simple, but involve a willingness to move away from the prescription and widespread use of antimicrobial drugs where infection is only suspected or possible to where it is more certain. It also requires the threat posed by AMR to be acknowledged outside of the healthcare sector alone and to be fully considered more broadly by resilience planners. Combatting its spread requires building confidence in non-invasive monitoring procedures, consistent and coordinated data collection and improving diagnostic techniques to ensure that the exact nature of infections can be confirmed as early as possible. If the current levels of antimicrobial use are not addressed and reduced, there is a real danger that there will be a future in which medical techniques taken for granted during the past century become obsolete by the next. As James M. Hughes, President of the Infectious Diseases Society of America remarked when the society published its 2011 policy paper, *Combating Antimicrobial Resistance: Policy Recommendations to Save Lives*:[33] 'the way we've managed our antibiotics for the past 70 years has failed … we have a moral obligation to ensure they are available for future generations'.[34]

Table 1: Strategies to prevent infection spread

The following strategies are currently used to tackle the spread of TB, but have wider applications for infection control in general.

Directly observed therapy short course (DOTs) – DOT (watching patients to ensure they take their medication) ensures that patients regularly take the antibiotics prescribed to them and prevents the development of drug-resistant strains from inadequate treatment. Patients often stop taking prescribed medication once they start to feel better, but can still be infective at this point.

Rapid diagnosis – Delayed diagnosis increases the time that patients receive inadequate or inappropriate drugs. This in turn gives rise to increased transmission. Improved rapid culture-based molecular diagnostic techniques can address this.

New drugs – Funding into new drugs can ensure that disease strains that develop resistance to one drug can be treated using another. The number of new antibiotics available has decreased significantly in recent years and there is concern that research into new antibiotics is not an attractive prospect for pharmaceutical companies as investment may be wasted if AMR means that new drugs quickly become ineffective. Only two new classes of antibiotic have been brought to market in the last 30 years, although in May 2012, the Innovative Medicines Initiative (IMI), Europe's largest public–private pharmaceutical partnership, pledged €223.7m to the 'NewDrugs4BadBugs' programme to address this, with €109m coming from the IMI and drug manufacturers providing additional research and development facilities and other assets worth an additional €114.7m.[35]

Infection control – Ensuring the availability of adequate respirator masks for health staff, isolating diseased patients in negative pressure rooms (or at least rooms well ventilated with natural ventilation) and the use of upper-room ultraviolet lights to destroy airborne bacteria will help prevent transmission of many diseases. Smaller hospitals, or even home-based care, particularly when combined with other social distancing measures such as online consultations with medical staff, can also help to isolate infectious patients and stem the spread of the disease.

Active case finding – Identifying groups at high risk, tracing back recent contacts of people newly diagnosed and visiting suspected cases in the home, rather than asking them to attend GPs surgeries or healthcare centres can decrease the infectious period of the disease and prevent its spread. Home visiting was employed at the beginning of the 2009 swine flu pandemic in the UK.

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