Methicillin resistant *Staphylococcus aureus* (MRSA), *Clostridium difficile* and ESBL-producing *Escherichia coli* in the home and community: assessing the problem, controlling the spread

An expert report commissioned by the International Scientific Forum on Home Hygiene

CONTENTS

ACKNOWLEDGMENTS 4

SUMMARY 5

1. INTRODUCTION – INFECTIOUS DISEASE AND HYGIENE IN THE 21ST CENTURY 7

2. THE CHAIN OF INFECTION TRANSMISSION IN THE HOME 10

3. METHICILLIN RESISTANT *STAPHYLOCOCCUS AUREUS* (MRSA) 11

3.1 CHARACTERISTICS OF *STAPHYLOCOCCUS AUREUS* AND METHICILLIN RESISTANT *STAPHYLOCOCCUS AUREUS* 11

3.2 HOSPITAL-ACQUIRED, HEALTHCARE ASSOCIATED AND COMMUNITY ACQUIRED MRSA 11

3.3 UNDERSTANDING THE CHAIN OF INFECTION FOR *S. AUREUS* AND MRSA IN THE HOME 13

3.4 WHAT ARE THE RISKS ASSOCIATED WITH *S. AUREUS* AND MRSA IN THE COMMUNITY? 22

4. *CLOSTRIDIUM DIFFICILE* 24

4.1 CHARACTERISTICS OF C*LOSTRIDIUM DIFFICILE* 24

4.2 HOSPITAL-ACQUIRED AND COMMUNITY- ACQUIRED *C. DIFFICILE* 24

4.3 UNDERSTANDING THE CHAIN OF INFECTION FOR *C. DIFFICILE* IN THE HOME 25

4.4 WHAT ARE THE RISKS ASSOCIATED WITH *C. DIFFICILE* IN THE HOME AND COMMUNITY 28

5. EXTENDED-SPECTRUM ß-LACTAMASE *ESCHERICHIA COLI* (ESBLS) 30

5.1 CHARACTERISTICS OF *ESCHERICHIA COLI* 30

5.2 HOSPITAL AND COMMUNITY-ACQUIRED ESBL-PRODUCING *E. COLI* INFECTIONS 31

5.3 UNDERSTANDING THE CHAIN OF INFECTION FOR *E. COLI* AND ESBL-PRODUCING *E. COLI* IN THE HOME 31

5.4 RISKS ASSOCIATED WITH ESBLS IN THE COMMUNITY 33

6. REDUCING THE RISKS OF TRANSMISSION OF METHICILLIN RESISTANT *STAPHYLOCOCCUS AUREUS* (MRSA), *CLOSTRIDIUM DIFFICILE* AND ESBL-PRODUCING *ESCHERICHIA COLI* IN THE HOME AND COMMUNITY - DEVELOPING A RISK-BASED APPROACH TO HOME HYGIENE 35

6.1 BREAKING THE CHAIN OF TRANSMISSION OF INFECTION IN THE HOME 35

6.2 DEVELOPING A RISK-BASED APPROACH TO HOME HYGIENE 35

6.3 INTERRUPTING THE CHAIN OF INFECTION TRANSMISSION IN THE HOME 38

7. DEVELOPING ADVICE FOR CONSUMERS 43

8. DISCUSSION, CONCLUSIONS, AND DEVELOPMENT OF COMMUNICATIONS 44

GLOSSARY 48

REFERENCES 49

APPENDIX 1 – BRIEFING DOCUMENT FOR HEALTH PROFESSIONALS METHICILLIN RESISTANT *STAPHYLOCOCCUS AUREUS* (MRSA) 59

APPENDIX 2 – BRIEFING DOCUMENT FOR HEALTH PROFESSIONALS *CLOSTRIDIUM DIFFICILE* 64

APPENDIX 3 – BRIEFING DOCUMENT FOR HEALTH PROFESSIONALS EXTENDED-SPECTRUM ß-LACTAMASE-PRODUCING *ESCHERICHIA COLI* (ESBLS) 68

ACKNOWLEDGMENTS

This report by the International Scientific Forum on Home Hygiene (IFH) is the result of the work of a British group of experts appointed by the IFH to review the risks in the home and community associated with Methicillin resistant *Staphylococcus aureus* (MRSA), *Clostridium difficile* and ESBL-producing *Escherichia coli* and to provide evidence-based advice for reducing these risks. The working group members and authors of this report are:

Professor Sally Bloomfield, International Scientific Forum on Home Hygiene & London School of Hygiene and Tropical Medicine, UK

Professor Barry Cookson, Laboratory of Healthcare Associated Infection, Centre for Infections, Health Protection Agency, London, UK and London School of Hygiene and Tropical Medicine.

Dr Fred Falkiner, Senior Lecturer in Clinical Microbiology, Trinity College, Dublin and Honorary Infection Control Officer at the Adelaide and Meath Hospital, Tallaght, Dublin, Ireland

Professor Chris Griffith, Cardiff School of Health Sciences, University of Wales Institute, Cardiff, UK

Ms Viv Cleary, Public Health Specialist, Health Protection Unit, (South West), London, UKThe IFH wishes to thank the Domestos UK brand team for supporting this project via an educational grant.

The IFH wishes to thank the Domestos UK brand team for supporting this project via an educational grant.

Disclaimer
The views expressed in this report are those of its authors and are endorsed by the IFH. These views should not be considered representative of the parent institutions of the expert authors.

SUMMARY

Undoubtedly advances in hygiene during the 20th century have improved both the length and quality of human life. However with the advent of vaccination and antibiotic therapy, and with serious epidemics of infection apparently under control, hygiene has tended to lose a prominent position, and the focus of concern shifted to degenerative, chronic disease. Nowhere is this more evident than in the home where there has been a tendency to assume that the risk of infection is minimal. In the past few years, a number of trends have become increasingly apparent, which suggest a need to reassess our approach to hygiene and its promotion. These relate to the constantly and rapidly changing range of pathogenic micro-organisms to which we are exposed, as well as to the ongoing social and demographic changes occurring on a global level, which affect our resistance to infection.

In this report we have selected three "emergent" strains of bacteria that have recently been widely publicised, largely in relation to hospital-acquired infections, namely methicillin resistant *Staphylococcus aureus* (MRSA), *Clostridium difficile* and ESBL-producing *Escherichia coli*. For all three strains, a common factor related to their emergence is the use and misuse of antibiotics in both hospitals and the community. For *S. aureus* and *E. coli* the difficulty relates to the emergence of strains that possess multiple resistance to a range of antibiotics, thereby making infections with these strains difficult to treat. The problems associated with *C. difficile* relate to the fact that exposure to antibiotics can trigger the germination of this organism into a disease-causing form, which is generally carried harmlessly in the gut. Although these three micro-organisms are seen primarily as a risk in a hospital-based setting, people should be aware that they also have the potential to circulate from the hospital into other settings, including the home - and back again. Individuals must therefore be provided support in order to understand the extent of the risk to themselves and their family, and be provided with guidance on how to effectively deal with situations where infection prevention may be their responsibility, e.g. caring for someone at home who is infected or has increased vulnerability to infection, or visiting someone in hospital who might be at risk.

The target audiences for this report include health professionals, scientific writers and others who communicate directly with the public on infectious disease and home hygiene. Its purpose is to provide a source of information for these groups that can be utilised to inform the public, and provide advice on what to do in situations where there may be a risk. In accordance with IFH policy, the report also summarises the evidence base for the information provided herein. The report summarises what is known about these organisms and their pathogenic properties, their prevalence in the community, their likely mode of transmission in the home and the extent to which they represent a risk. It also describes the development of a risk management approach to hygiene in order to break the chain of transmission of these organisms in the home. The appendices contain material that can be used by health professionals and others to brief consumers and summarise the key data on each organism, together with an "advice sheet" which contains practical guidance on what to do when there is a risk of infection transmission in the home.

The data in this report suggest that, for all three species, home-dwellers that are infected or colonised with these organisms are quite frequently reported. Despite this, the overall prevalence of infected individuals or colonised carriers in the UK is relatively low. On the other hand, the evidence suggests that when these strains are introduced into the home by either an infected individual or a carrier, or via domestic animals, there is significant potential for other family members to be exposed and to become either colonised or infected. Nonetheless, for the most part, exposure to these strains is not a problem, even where colonisation occurs. However, for family members with a specific predisposing factor, or who are admitted to hospital for surgery or other procedures, clinical infection may result.

Although emergent strains such as HCA-MRSA and ESBLs inevitably attract attention, the public must be reassured that they are not more virulent than the parent strain, i.e. they have the same potential as the parent strain in terms of colonisation and the ability to overcome host defences and cause infection. The term "superbug" refers to the ability to resist the action of many clinically important antibiotics. Skin infections associated with *S. aureus*, as well as urinary tract infections associated with *E. coli*, are unpleasant (and occasionally life-threatening) but are generally self-limiting. The main concern is that these strains are a source of genes that carry antibiotic resistance and thus, for someone infected with a methicillin resistant or ESBL-producing strain, the ability to treat the infection can be severely compromised. For strains such as the PVL-producing CA-MRSA and the AP1/027 strains of *C. difficile*, the concerns relate more to their enhanced virulence. At present, these strains, and in particular the CA-MRSA strains, are relatively uncommon in the UK. However data from North America and several European countries has demonstrated their potential for spread.

The major concern in public health terms is that, as the proportion of people in the general population carrying these strains as part of their normal flora increases, there is increasing probability that clinical infections may be attributable to one of these strains. Although this report highlights significant differences between these three strains, it also suggests common patterns. Therefore, it is possible to formulate a strategy that could reduce the impact of these and other emergent strains. The key components of such a control strategy include better monitoring of antibiotic utilisation and promotion of appropriate hygiene, preventing spread from infected or colonised family members and protecting vulnerable groups from exposure, and reducing transmission amongst healthy family members.

In situations where someone is known to be infected with or carry a specific pathogen, or is at risk from a specific pathogen, hygiene recommendations are based on assessment of the critical control points for preventing spread of the particular organism. In contrast, reducing the transmission of these organisms in the healthy community depends on practice of good day-to-day hygiene, meaning that the IFH targeted approach to home hygiene should be adopted to break the chain of transmission in the home. In situations where individuals are more vulnerable to infection, this generally means targeted hygiene. The major difference is that, if hygiene practices are not consistently and rigorously applied, the risk of infection is much greater.

One of the major challenges is encouraging the public to better understand the risks associated with exposure to pathogens, and persuading them to adopt better standards of daily hygiene as a means of minimising the spread of new and potentially more dangerous strains. In recent years a significant amount of work has been carried out to evaluate hygiene behaviour in the home and develop effective methods for achieving behavioural change. Although recent scares related to SARS, avian flu, and MRSA have made people more aware of the importance of hygiene, this has been offset by the ideas promoted in association with the hygiene hypothesis, which suggest that we may have "become too clean for our own good". The IFH targeted home hygiene approach offers consumers a rational strategy as it represents the optimum means to protect the family from infection, whilst minimising interruptions in the balance between the human and natural environments.

One of the problems that this report highlights is that the factors governing the emergence of new pathogens, or new strains of existing pathogens (including those with antibiotic resistance and/or enhanced virulence), are complex and highly unpredictable. This is well recognised by international and national agencies such as the WHO, CDC, and the UK HPA, which now recognise that, when it comes to containing the global burden of infectious diseases, good hygiene practice is fundamental, and in many cases is the first line of defence. This has prompted the realisation that if infectious diseases are to be contained in a manner that is viable and sustainable, the responsibility for preventing disease transmission must be shared by the public. This is further reinforced by the recognition that the threat posed by emerging diseases such as avian influenza and SARS demands an immediate response, which requires adequate and advance preparation. To achieve this goal, greater emphasis on appropriate hygiene education in schools must be provided, and the public must be given clear, unambiguous information on the nature of the threat posed by infectious disease agents together with advice on how to target hygiene measures to minimise the risks of exposure to potentially harmful microbes.

1. INTRODUCTION – INFECTIOUS DISEASE AND HYGIENE IN THE 21ST CENTURY

Undoubtedly, advances in hygiene during the 20th century have improved both the length and quality of human life. During the second half of the last century however, with the advent of vaccination and antibiotic therapy, and with serious epidemics of infection apparently under control, hygiene has tended to lose a prominent position, and the focus of concern has shifted to degenerative, chronic disease. As a result hygiene has received declining attention as a public health issue. Nowhere is this more evident than in the home, where there has been a tendency to assume that, compared to a hospital setting, most people are "normal and healthy", and the risk of infection is thus minimal.

In the past few years however we have become increasingly aware of a number of trends that give cause for renewed concern, and stress the need to reassess our approach to hygiene and hygiene promotion. Recent data suggests that in developed countries deaths from infectious diseases (ID) are now rising again: in the USA, deaths attributable to ID rose by 22% between 1980 and 1992, climbing from the 5th to the 3rd most important cause of death. This upward trend is the result of two quite distinct factors. The first is the constantly and rapidly changing nature and range of pathogenic micro-organisms to which we are exposed, while the second factor is the social and demographic changes occurring within the global population, affecting our resistance to infection.

The constant emergence of new pathogens and the awareness that this is a continuing trend is of significant concern (Rudolf Schulke Foundation Global Hygiene Report 1996[1]). The Rudolf Schulke Report shows that, over the period 1972-1996, at least one new pathogen per year has been reported. These include species such as *Legionella pneumophila, Campylobacter jejuni* and *Listeria monocytogenes*, all of which have now been accepted as fairly common pathogens in UK society. It is now clear that many of these emerging infections have been caused by species that are normally present in the environment, but have become pathogenic to humans as a result of changes in technology (food technology, building design and operation, etc.) or society. The other key concern relates to the emergence of new strains of already known and well established pathogens, some of which have developed altered or enhanced virulence properties (e.g. they have acquired the ability to produce a specific toxin, or enhanced levels of toxin). Others represent a problem because they have acquired resistance to antibiotics. The need for improved hygiene to reduce the spread of antibiotic resistance has been recommended by working parties in Europe[2]. Reduced rates of infection and antibacterial resistance have been demonstrated where an approach combining good hygiene and lower the number of prescriptions has been evaluated[3, 4].

Of equal importance are the ongoing social and demographic changes taking place that markedly affect our ability to resist infection. Of particular concern, is the rising proportion of "at risk" groups now living in the home and community. At risk groups cared for at home now include not only the newborn, whose resistance to infection is not fully developed, but also the rapidly increasing elderly population whose immune system is less effective. It also includes patients recently discharged from hospitals, immune-compromised family members, and family members with invasive devices, catheters and inhalation systems. All of these groups, together with those who carry HIV/AIDS, are increasingly cared for at home by a home carer who may be a family member.

An evaluation of the elderly population in the UK indicates that 9 million (95%) live at home. There are 5.7 million carers in the UK which suggests that, for up to one in every 10 people, there is someone in need of care within their own home. More than half of these carers are providing assistance for somebody aged over 75 years. There are some 1,200 registered care agencies providing home care. Data from one West Midlands agency (Janet Howard, Royal Shrewsbury Hospital, personal communication) looking after 36 highly dependent patients, for example, revealed that most were fed via catheters and looked after by a team of carers who rotate over a 24-hour period. An assessment of the current prevalence of "at risk" groups in the home in UK, Netherlands and Germany, as shown in Table 1, suggests that around one in six persons in these three countries belongs to an "at risk" group. It is likely that the same applies to most European countries. Ensuring that homecare is not accompanied by increased ID risks is key, also considering that cost savings gained by the trend towards shorter hospital stays are likely to be overridden by additional costs of re-hospitalisation.

Table 1

	UK	Germany	Netherlands
Total population	60 million	82 million	16 million
Over 65 years old	9 million (15%)	13 million (16%)	2 million (12.5%)
Living with cancer – significant proportion in the community, and undergoing chemotherapy	1 million (1.6%)	–	160,000 (1%)
Under one year old	600,000 (1%)	800,000 (1%)	100,000 (0.6%)
Discharged from hospital within previous two weeks	200,000 (0.3%)	–	60,000 (0.4%)
Hospital outpatients at home	–	1,270,000 (1.5%)	–
Living with HIV/AIDS	600,000 (0.1%)	–	–
Total "at risk" persons	>1 in 5.5 (18%)	>1 in 5.5 (18%)	>1 in 7 (14%)

An additional factor that fundamentally affects the way in which infectious diseases spread is the globalisation of food supplies, and the trends towards mass travel and refugee movements. All of these serve to move new pathogens, and new strains of pathogens, rapidly around the world to areas where the local population may have little resistance.

For the public at large, understanding the nature and extent of the threats posed by the ever shifting and "invisible" hazard posed by microbes is extremely difficult. This is made worse by the difficulties in understanding that the threat can vary significantly from one section of the community (e.g. those who are ill and in hospitals) to another (e.g. those who are in the community and may be at greater risk). Communicating to the public in a manner that both informs and encourages behavioural change, but does not engender mass panic, is a genuine challenge.

In this report we have selected three micro-organisms that have been recently publicised, largely in relation to infection risks in hospitals, namely methicillin resistant *Staphylococcus aureus* (MRSA), *Clostridium difficile* and ESBL-producing *Escherichia coli*. For all three strains, the common factor related to their emergence is the use and misuse of antibiotics in the hospital and community. For *S. aureus* and *E. coli* the problem relates to the emergence of strains that possess multiple resistance to a range of antibiotics, thereby making them difficult to treat. The problems associated with *C. difficile* relate to the fact that antibiotics can trigger germination of this organism into a disease-causing form, which is normally carried harmlessly in the gut. Although these organisms are seen primarily as a risk to patients in hospitals, and thus that the responsibility for prevention lies with the hospital, people are also aware and concerned that these organisms have the potential to move to and forth from the hospital into other settings, including the home. They are thus looking for support in order to understand the extent of the risk to themselves and their family, and for guidance on how to deal with situations where preventing infection from these species may become their responsibility (e.g. caring for someone at home who is either infected or has increased vulnerability to infection, or in visiting someone in the hospital who might be at risk from hospital visitors who are colonised or infected). For the most part, investigations of these organisms, as reported in the scientific literature, have been carried out to assist national agencies in developing strategies for controlling spread in a hospital environment. The purpose of this report, however, is to look at these data specifically from the point of view of the family, and the problems that they may encounter in their own homes and their daily lives. We are aware that these are only three of the "emerging species" of current concern in the UK. However an in-depth analysis will nonetheless provide the basis for formulating general principles that have wide applicability, and which take account of the fact that the range of these organisms is constantly changing. It is thus important to consider whether our approach to home and community hygiene is appropriate to the society in which we now live.

The main target audience for this report is health professionals, scientific writers and others who communicate directly with the public on ID prevention and hygiene in the home setting. For this reason, as far as possible, the report has attempted to present the basic principles in simple, practical language. The report provides an authoritative basis for communications that health professionals and others may use to inform the population, and give advice on what to do in situations where there may be a risk to members of the family. In accordance with IFH policy, the report also summarises the evidence base.

The circulation of these pathogens between hospitals, community residential care homes, domestic homes and other community settings (restaurants, transport, workplaces, etc.) is highly complex, making it difficult to consider one particular setting (i.e. the

home, without reference to others). However, due to the scope of this report, we have confined ourselves as far as possible to considering transmission in the home setting. People are often reluctant to acknowledge that the safe haven of their homes is a potential setting for transmission of infection. It is possible, however, that the knowledge of how infection can occur in this relatively "self-contained" setting might provide additional insight in the principles of hygiene in the community and workplace.

This report is divided into eight sections. In the following section we summarise the basic principles of transmission of infection in the home. In sections 3-5, each of the three pathogens will be reviewed in relation to the clinical characteristics of their infections, their prevalence in the home and community, and their potential for transmission. In section 6 and 7, the data will be used to develop risk-based advice on hygiene measures to break the chain of transmission of these strains in the home setting. The appendices contain briefing documents on each of the three organisms together with practical advice that can be provided to the public for limiting transmission of infection and colonisation in the home.

2. THE CHAIN OF INFECTION TRANSMISSION IN THE HOME

In order to understand the extent of the threat associated with pathogens such as MRSA in the home, it is necessary to first understand the extent to which they are present in our homes and how they are spread, such that family members become exposed and infected. Within the home there is a chain of events that takes place when a family member develops an infectious disease. The chain as applied to the home (see Fig. 1) has five essential links, all of which have to be in place for an infection to pass from its original source to another person. These five links are:

- **Source of germs:** There needs to be someone or something (e.g. people, food, water, pets) that carry an organism and cause illness. The fact that one cannot get infected unless germs are present in the home is often not appreciated. However, not all people or animals who become "infected" with a pathogen develop "infectious disease". In some cases people or animals can carry or become colonised by an organism without showing any visible signs of disease, thus making it impossible to know if the pathogen is present.

- **Way out for the germs:** There needs to be a means for germs to get out of, or away from, an infected person or source in order to spread. Faeces are the main route by which intestinal pathogens are expelled from the body. Droplets from the mouth and nose, vomit, skin scales, hairs and wound fluid can contaminate hands, surfaces, fabrics, food and the air. Germs in particles and moisture from food will contaminate any surface that they come into contact with (including hands). People or animals colonised with a particular pathogen will shed the organism in the same manner as those who are infected.

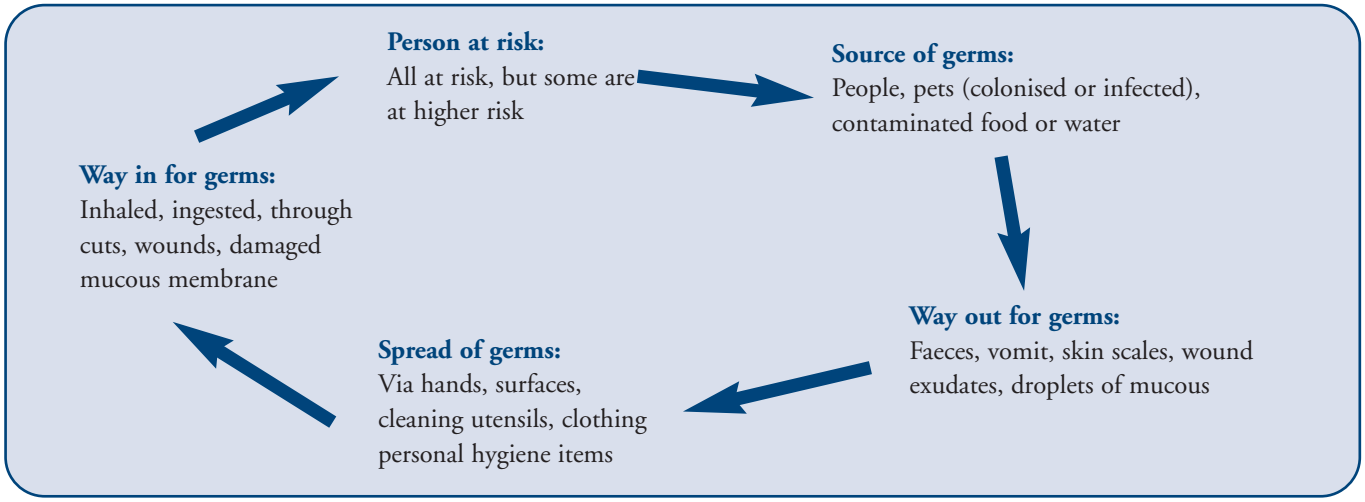
- **Spread of germs:** There must to be a way that germs can spread so that other family members become exposed. The major routes of spread are via hands, hand and body contact surfaces, food contact surfaces, cleaning utensils, clothing and linens, and personal hygiene items such as face cloths and toothbrushes. Some microbes such as fungal spores or bacteria attached to skin scales or viruses expelled in aerosolised droplets produced by coughing, sneezing or vomiting, are carried in the air. The ability to spread via these routes is determined by the ability of the pathogen to survive in the environment. Some pathogens such as HIV do not survive in the environment for any appreciable time and are thus spread only by direct contact.

- **Way in for germs:** Microbes need to enter the body for an infection to take hold. Pathogens can be inhaled or ingested, or can enter through a break in the skin (cuts and wounds), through mucous membranes (including the surface of the eye) and via tubes entering body openings and blood vessels, e.g. catheters. For a pathogen to cause disease it must gain access via the relevant "portal of entry" (i.e. different pathogens use different routes of entry to the body). The risk of colonisation and infection also depends on the number or organisms to which the person is exposed and the higher the number, the greater the risk of colonisation and infection. However, the dose response curve can vary significantly from one species to another. In addition, the "infectious dose" for a given pathogen is usually much lower for individuals at increased risk of infection.

- **Person at risk:** All are at risk of infection, but some individuals have a higher risk of contracting infection, such as those with lowered defences to infection due to age, illness, wounds or medical treatment. Others may not be infected, but may become carriers of the organism.

Understanding the chain of infection in the home is central to devising policies that can reduce the risks of spread and if one or more links in the chain can be broken, then an infection cannot take hold. This aspect is discussed in section 6.

Fig 1. The Chain of Infection for transmission in the home



3. METHICILLIN RESISTANT *STAPHYLOCOCCUS AUREUS* (MRSA)

3.1 Characteristics of *Staphylococcus aureus* and methicillin resistant *Staphylococcus aureus*

3.1.1 *Staphylococcus aureus*

Staphylococcus aureus is a Gram-positive bacterium that can colonise and infect humans. It can be carried harmlessly in the nostrils, throat, and skin (particularly in areas such as the axilla and groin)[5]. The most recent study by Kluytmans and co-workers[6] confirms previous data showing that:

- Up to one third of the population are colonised with *S. aureus* in a continuous manner and always carry the same strain.
- Up to one third of the population carry different strains of *S. aureus* intermittently.
- About one-third of the population are resistant to colonisation by *S. aureus*.

The reason for these variations in susceptibility to colonisation with *S. aureus* is still unclear, although this aspect is being explored further[7].

Usually the individual is quite unharmed by colonisation. *S. aureus* can rapidly colonise broken or abnormal skin, such as superficial wounds, ulcers, psoriasis and eczema. It may not produce any symptoms, but on occasion it produces boils or can enter the bladder or the blood stream causing bacteraemia. *S. aureus* causes disease either by the production of a toxin that produces tissue destruction or by direct invasion and destruction of tissue. Anyone with "broken" (cuts, wounds, abrasions etc) skin is at risk of contracting *S. aureus* infection from another carrier or infected source. Patients who are carrying *S. aureus* can also self-infect themselves via their own surgical or other wounds.

There are many different strains of *S. aureus* with different characteristics, all of which are constantly circulating in the community and which can evolve into new strains. Most *S. aureus* infections resolve spontaneously or in response to antibiotic treatment, but in recent years there has been increasing concern about the emergence of *S. aureus* strains that have developed resistance to multiple antibiotics. The strains of particular concern at the present time can be divided in two groups as described in the following sections.

3.1.2 Methicillin resistant *Staphylococcus aureus*

Antibiotic resistance first became apparent in *S. aureus* in the 1950s when strains of bacteria emerged that possessed penicillin-destroying ß-lactamase enzymes and became widespread. This led to the development and use of semi-synthetic penicillins such as methicillin and flucloxacillin that were resistant to the penicillin-destroying enzymes produced by *S. aureus* and other bacteria. Methicillin resistant *Staphylococcus aureus* (MRSA) was first described in 1961, almost immediately after the agent was introduced into clinical practice. It is interesting to note that MRSA also emerged in countries where methicillin had not yet been used. Staphylococci would have likely encountered penicillin-producing moulds in various environments over several million years and MRSA resistance probably represents a more primitive type of penicillin resistance compared to the *S. aureus* penicillin-destroying enzymes that appeared later on. This may also account in part for the appearance of community MRSA where there is no history of interactions with healthcare delivery[8] (see below).

Widespread use of antibiotics throughout the 1970s led to the development of resistance, predominately in MRSA, to many other antibiotics such as erythromycin, gentamicin, trimethoprim and, more recently, vancomycin.

3.2 Hospital-acquired, healthcare associated and community acquired MRSA

S. aureus is an organism that primarily infects people whose immunity to infection is compromised. Not surprisingly, therefore, it is a common cause of hospital-acquired infections necessitating antibiotic treatment. In the past 20 to 30 years, although the majority of *S. aureus* infections in hospital patients have remained sensitive to antibiotics, infections due to methicillin resistant strains of *S. aureus* (MRSA) have evolved as a major cause of hospital-acquired infection. Methicillin resistance rates vary considerably between countries. In the United States and Southern Europe, more than 40% of all *S. aureus* isolates from patients with bacteraemia are MRSA, whilst in Northern Europe MRSA isolates comprise <5% of isolates from patients with bacteraemia. It should be noted that there are several different MRSA strains around the world and that these also vary in their degree of antibiotic resistance. In the UK, for example, almost all the isolates are epidemic MRSA (EMRSA-15 and EMSRA-16). These are usually susceptible to several antibiotics e.g. gentamicin, trimethoprim, fusidic acid and rifampicin. However, in some parts of the world there are very highly resistant strains of MRSA.

Outside a hospital setting, *S. aureus* infections are common, but mostly go unrecorded unless the person develops a serious infection such as bacteraemia. Most of these infections are due to methicillin sensitive strains. In the past 10-15 years, however, it has become apparent for a number of reasons that MRSA is by no means confined to a hospital setting. Firstly, infected patients who are discharged from the hospital may continue to carry MRSA even after their infection has resolved. Similarly patients may become colonised with MRSA during a hospital stay, a condition that may persist after discharge.

In addition, new "community" strains of MRSA have more recently emerged. Experience shows that these community-acquired strains, which first became a concern in the late 1990s, are quite different from the strains that arose in hospitals. It is likely that these strains evolved separately within the community, either associated with the widespread utilisation of methicillin in general practice or by random evolution and subsequent spread.

With the recent emergence of these new strains there has been considerable confusion between MRSA strains that occur in the community in patients who have had significant exposure to healthcare and the more recently recognised community-acquired strains. For the purposes of this report we will refer to these groups of strains as "healthcare-associated MRSA" (HCA-MRSA) and "community-acquired MRSA" (CA-MRSA). Other *S. aureus* strains that are not resistant to methicillin will be referred to as methicillin-sensitive *Staphylococcus aureus* (MSSA). The situation is further confused by the fact that some community-acquired strains of *S. aureus* (both CA-MRSA and MSSA) can also carry a tissue toxin known as Panton-Valentine Leukocidin or PVL. The fundamental differences between HCA-MRSA and CA-MRSA have been discussed[9, 10] and are summarised in Table 2.

3.2.1 Healthcare-associated MRSA

HCA-MRSA strains principally affect frail and vulnerable individuals such as the elderly and the immuno-compromised. Although most HCA-MRSA infections arise in a hospital setting, the organism has the same potential to affect the elderly and immuno-compromised in a home care setting. Patients with post-operative and other wounds, and those requiring an invasive procedure such as urinary catheterisation, are at particular risk when cared for at home. If the patient is exposed to HCA-MRSA from another family member who is infected or carrying the organism, as for any *S. aureus* strain rapid colonisation can occur on broken or abnormal skin such as such as superficial wounds, ulcers, psoriasis or eczema.

In contrast HCA-MRSA (like *S. aureus*) does not generally represent a risk to young healthy individuals, but these family members can carry MRSA just as they can carry *S. aureus* and therefore act as an invisible source for spread to vulnerable family members.

Although HCA-MRSA are resistant to antibiotics, there is no evidence suggesting that they are resistant to disinfectants, antibacterials or antiseptics[11, 12].

Table 2. Comparison between healthcare-associated and community-acquired Methicillin resistant *Staphylococcus aureus*

	CA-MRSA	HCA-MRSA
Clinical spectrum	Skin and soft tissue infections	Wound infections, urinary tract infections and bacteraemia
Epidemiology	Affects healthy people in the community	Mostly affects hospital patients
Underlying condition	Dermatological	Healthcare associated risk factors
Age group	Younger	Older
Resistance pattern	Sensitive to multiple antibiotics	Resistant to multiple antibiotics
Toxin production	May produce PVL toxin	Not yet reported to produce PVL toxin

3.2.2 Community-acquired MRSA and PVL-producing MRSA

True CA-MRSA strains, which are now known to have emerged *de novo* from community-based *S. aureus* strains, have been known since the 1960s, but did not become a significant issue until the late 1990s subsequent to several reports by workers noting increases in MRSA infections acquired in the community amongst hospitalised cases without predisposing risk factors[8, 13-17]. Although these CA-MRSA strains are of concern, at present such infections are rare in the UK compared with other countries, particularly the USA, which have encountered more serious problems.

One of the key characteristics of CA-MRSA is that, by contrast with HCA-MRSA, it is more prevalent among children and young

adults where they cause infections of cuts, wounds and abrasions. Another important aspect is that CA-MRSA are resistant to fewer antibiotics compared to HCA-MRSA. This means that these infections are readily treatable, provided doctors are aware that the patient might be carrying a CA-MRSA strain.

One of the main reasons for concern is that unlike HCA-MRSA, some *S. aureus* strains circulating in the community (both CA-MRSA and MSSA) strains have acquired the ability to produce the PVL toxin, which can lead to skin and soft tissue infections. In some cases these organisms can cause severe invasive infections such as septic arthritis, bacteraemia, or community-acquired necrotising pneumonia[13]. An early skin infection often has the initial appearance of an insect bite. These infections often develop into cellulitis, furuncles, large boils or clusters of boils (up to 10cm in diameter) and deep-seated abscesses often in the thighs or buttocks. If the bacteria gain access to the lungs, fortunately a rare event, a devastating pneumonia that kills more than 40% of patients can result[14, 15].

The PVL toxin was first reported in 1932 and is encoded by a mobile bacteriophage that can transfer the ability to produce the toxin to other strains. Current surveillance data do not give any clear indications of the proportion of *S. aureus* (or CA-MRSA) circulating in the UK community that are positive for PVL toxin. The available data usually come from MRSA reference laboratories, which means that the figures reflect only the rates of PVL-producing strains amongst all MRSA isolates referred to the laboratory. Thus, for example, the MRSA Reference Laboratory in Ireland reports that, of 1,500 MRSA (hospital and community-acquired) isolates received, 28 were PVL-positive (2%). Of those isolates believed to be CA-MRSA, about 65% were PVL-positive (Falkiner, personal communication). In England, there is no mandatory reporting system for cases of community PVL-producing strains of CA-MRSA, but all evidence indicates infections associated with this organism are rare at present. HPA have issued guidance on their treatment (http://www.dh.gov.uk/AboutUs/MinistersAndDepartmentLeaders/ChiefMedicalOfficer/Features/FeaturesArticle/fs/en?CONTENT_ID=4133761&chk=oW8s4w:). The Laboratory of Healthcare Associated Infection of the HPA is aware that PVL-positive *S. aureus* has been associated with the death of 27 individuals (17 males, 10 females) over 27 months (January 2004 to March 2006). During this period, 518 patient isolates of *S. aureus* referred to the SRU were identified as PVL-positive, suggesting a mortality rate of 5% (Cookson, personal communication).

In general however it is likely that the prevalence of PVL-producing *S. aureus* strains circulating in the general community in the UK is very small, but when they do occur the majority are also methicillin resistant strains.

Experience in the USA, on the other hand, suggests that PVL-positive CA-MRSA is easily transmissible not only within families but also on a larger scale in community settings such as prisons, schools and sports teams. Skin-to-skin contact (including intact skin) and indirect contact with contaminated objects such as towels, sheets and sport equipment are the primary vehicles of transmission. Johnson[16] cites risk factors for spread of CA-MRSA as close skin-to-skin contact, cuts and abrasions, shared contaminated items or surfaces, poor hygiene and crowded living conditions.

Although CA-MRSA infections have the advantage that they are sensitive to most antibiotics other than methicillin and are thus treatable, provided they are recognised as MRSA, concerns have been expressed that, if the evolution of MRSA continues, the concepts of hospital and community MRSA strains may become blurred[17]. Community strains might more resemble hospital strains in terms of antibiotic resistance and thus would be harder to treat. In the same way, HCA strains could become more dangerous if they acquire toxin genes, and could cause serious disease in younger, healthier people. There are now concerns, most particularly in the USA[10,13], that CA-MRSA strains are migrating into the hospital setting following admission of affected patients. While this is under investigation, there is another indication that blurring between CA-MRSA and HCA-MRSA is occurring. Workers in the USA have also reported that CA-MRSA show faster replication rates than HCA-MRSA strains when grown in the laboratory[18].

3.3 Understanding the chain of infection for *S. aureus* and MRSA in the home

In the following sections we evaluate the chain of infection in the home in relation to MRSA and other strains of *S. aureus* to understand how and when it may occur in the home, and how it is spread such that family members become exposed and either colonised or infected.

3.3.1 Sources of *S. aureus* and MRSA in the home

The major sources of *S. aureus* including MRSA in the home are colonised or infected individuals and domestic animals.

Although up to 60% of the population may carry *S. aureus*, the prevalence of MRSA in the total UK community is relatively low. Overall there is no clear picture as to what proportion of the population may now be carrying antibiotic resistant strains of *S. aureus* (either HCA or CA-MRSA), but indications are that this is somewhere between 0.5%-1.5% of the population. The majority of people who are thought to be carriers of HCA-MRSA are over 65 years of age and/or have had recent healthcare usually involving a healthcare setting[19]. Indications are that, for people who have no history of recent healthcare contact, the

prevalence of MRSA is 0.03% of the general population. This means that, where *S. aureus* infection transmission or colonisation occurs at home it is most likely to involve MSSA rather than MRSA. The risks for transmission of MRSA from an infected family member to another family member depend partly on the length of time the individual carries MRSA, and the number of bacteria that they carry and shed. Hicks et al. showed that 69% of carriers were still colonised with HCA-MRSA four weeks after contact[20], while another study estimated the MRSA colonisation can persist for up to 40 months[21].

Although currently the carriage rate for HCA-MRSA in the general community is relatively low, there is concern that, with early discharge of patients and increased emphasis on community care, the numbers of carriers in the community is likely to rise. At present, however, there is no definitive evidence of such a phenomenon (Cookson 2000[8]).

CA-MRSA is currently seen as a relatively minor problem in the UK. However, a number of important aspects of the epidemiology of CA-MRSA have been highlighted by recent investigations in the USA, where CA-MRSA is more prevalent, which provide some important insights regarding the potential for future spread in the UK.

Although little information is available on the prevalence of MRSA in the domestic animals, isolation from household pets has been reported, even though the prevalence of MRSA in household pets is reportedly low. Domestic animals may carry MRSA in the nose on a transient basis, and the organisms may become trapped in fur where they can survive for prolonged periods.

Another potential source of HCA-MRSA in the home is on the surface of the uniforms of healthcare workers, which are either kept at home by the person involved, or are brought home for laundering. A number of studies have shown that uniforms can act as a vector for transmission of pathogens such as MRSA[22, 23, 24].

EVIDENCE BASE

Prevalence of HA-MRSA in the community

A number of UK studies have been carried out, which give some indication of the prevalence of HCA-MRSA in the community:

- Maudsley et al. 2004[25] carried out a study of the prevalence of MRSA in a general practice in London, screening 258 older people living in their own homes. Methicillin sensitive S. aureus was isolated from 60 (23%) participants, whilst MRSA was isolated from only two individuals. Since both of these subjects had a past history of MRSA, it is concluded that both cases were carriers of HCA-MRSA. Despite differences in methodology and response rates, Maudsley et al. 2004[25] conclude that although there are reports of HCA-MRSA[26] in the community, even in cities with high hospital MRSA levels community prevalence is low.
- Similar isolation rates were found in a study in 2002 in Nottingham (962 participants)[27] that also focussed on the elderly and reported a prevalence of 0.8%, and in a study in 2001 in Birmingham (280 participants of all age groups)[28] which reported a prevalence of 1.5%. There were differences between the studies, and the Nottingham group selected a study population with demographics likely to be representative of England. In the Birmingham study, 6% (4/63) of S. aureus isolates were MRSA and 2 of the 4 MRSA carriers reported previous contact with healthcare facilities. The Nottingham study found that recent hospital admission and diabetes were the only risk factors for MRSA carriage suggesting that these were HCA-MRSA strains.

While a number of other studies have been carried out primarily to determine the extent to which HCA-MRSA is being brought into hospitals, they continue to provide insights into the prevalence of carriage in the community:

- In an Oxford teaching hospital during 1997-2003, Wyllie et al.[29] found 479 patients with Methicillin sensitive S. aureus and 116 cases with MRSA bacteraemia admitted from the community. This accounted for 49% of all MSSA cases and 24% of all MRSA cases. Among this group, at least 91% had been previously hospitalised, confirming that they were probably HCA-MRSA.
- Ferguson et al. 2005[30] reported a study in 2004 in Lothian University Hospitals Division in which 154 episodes of MRSA bacteraemia were identified. Of the 154 episodes, 37 (24%) were identified as being acquired in the community. For patients where data was available, all but two had previously been hospitalised or had had one or more outpatient visits during the previous 12 months. None of the blood culture isolates were positive for the PVL toxin gene (although PVL-positive methicillin-susceptible *S. aureus* had been confirmed in a number of non-bacteraemia soft tissue infections over the year of the investigation). However, there was no data indicating the proportion of total hospital admissions that were positive for MRSA.

Although it is unlikely that the prevalence of MRSA in hospital admissions is a fair representation of general carriage in the

community, in general it is to be expected that the prevalence in hospital admissions would represent an overestimate, rather than an underestimate of prevalence, in the general community. Thus the data appears consistent with the conclusion that, at least in the UK, the prevalence of HCA-MRSA in the general population is relatively low at the present time. However, there are anecdotal reports that cross infection with HCA-MRSA is increasing in some nursing homes, although this data has not yet been published.

A number of investigations have also been carried out in the USA on MRSA infection rates in patients entering and leaving hospitals. In the USA, Kuehnert et al. 2005[31], using National Hospital Discharge data for 1999-2000, determined that around 0.4% of an estimated 125,969 patients discharged from hospital carried MRSA. In a French teaching hospital, Eveillard et al[32] found that at the time of admission in two acute geriatric wards with a high incidence of endemic MRSA 14.6% of patients were MRSA carriers.

Some further insights come from a USA study by Huang et al. 2003[33] who determined the 18-month risk of MRSA infection among 209 adult patients newly identified as harbouring MRSA. Twenty-nine percent of patients (60 cases) developed subsequent MRSA infections. Eighty percent of patients (48 of 60) with subsequent MRSA infection developed the infection at a new site, and 49% of new MRSA infections (44 of 90) first became manifest after discharge from the hospital. Thus, it is reasonable to suspect that colonised patients who are discharged remain at substantial risk of MRSA infection. Risk factors associated with subsequent MRSA infection after hospital discharge included longer hospital stays and the initial involvement of a bone or joint procedure.

Prevalence of CA-MRSA in the community

As far as CA-MRSA infections are concerned, at present these are considered extremely rare in the UK. The first reported UK case of CA-MRSA infection was in Cardiff in 2003 by Shetty and Barnes[26]. This was a 13-month-old child who had never been hospitalised, had not been attending day care, and as such was the first documented case of community-acquired MRSA infection in a child in the UK with no identified predisposing factors.

In 2005 HPA stated[34] that 100 isolates of CA-MRSA had been confirmed microbiologically in England and Wales over the previous three years. An additional 40 isolates of suspected CA-MRSA are currently undergoing characterisation. This represents less than 0.005% of the MRSA isolates received by the Health Protection Agency's Staphylococcus Reference Laboratory (SRL) each year. Holmes et al. have also reported on the prevalence of *S. aureus* isolates carrying PVL genes in England and Wales[35].

In order to get a better picture of whether CA-MRSA bacteraemia is emerging in the UK, a 13-month study of bacteraemia in children caused by MRSA was started in June 2005[36]. The study is being undertaken in the UK and the Republic of Ireland. Analysis of reports routinely submitted to HPA have suggested that, although the numbers of cases of MRSA bacteraemia in children remain low, there has been nonetheless an upward trend, rising from 4 in 1990 to 76 in 2004. HPA report that the number of cases has remained constant in the last few years with around 70 to 75 infections documented each year. However as the data were derived from voluntary reporting it is likely that this is an underestimate of the true incidence of infection. The aim of the study is to obtain a robust estimate of the incidence of MRSA bacteraemia in children and to define the proportion of cases that are either healthcare-associated or community-acquired. Other studies may be funded to explore the incidence of CA-MRSA in the UK in 2006.

There are no data available to indicate what proportion of the "healthy" UK population might be carrying CA-MRSA. Vandenesch and Etienne 2004[37] concluded that, for countries where CA-MRSA cases have been identified, even though some data are available from isolates collected at hospitals, it is possible that these represent only the tip of the iceberg in relation to the number of healthy carriers in the community.

As stated previously, although CA-MRSA infections are currently rare in the UK, other countries, particularly the USA, have encountered more serious problems; CA-MRSA strains have been detected in the United States, France, Switzerland, Germany, Greece, Ireland, the Nordic countries, Australasia, Netherlands and Latvia[38, 39, 40. 41, 42].

In the United States CA-MRSA is now a significant concern, although it is generally concluded that the rates of colonisation in the community are still low, it is nonetheless thought to be increasing[43, 44, 45, 46]. For example, Moran et al. 2005[47] reported that the proportion of CA-MRSA cases among patients with skin and soft tissue infections seeking treatment at a Los Angeles (USA) area emergency department increased from 29% in 2001 to 2002 to 64% in 2003 to 2004. Dietrich et al. 2004[48] conducted a review of children 0 to 18 years old with MRSA isolated by a Rhode Island Hospital microbiology laboratory between 1997 and 2001. *S. aureus* was isolated from 1063 children. Of these children, 57 had MRSA. During this period, both the absolute number of MRSA cases and the proportion of *S. aureus* cases due to MRSA rose more than threefold due to increases in both CA-MRSA and HCA-MRSA infections. Of the 57 MRSA cases, 23 (40%) were CA-MRSA.

Johnson[16] estimates that rates of carriage in USA among children with no risk factors for MRSA colonisation range from 0.8% to 3.0%[49, 50]. Those among adults have generally been lower. Salgado et al. 2003[51] carried out a meta-analysis of published studies (mainly but not exclusively in the USA) reporting the prevalence of CA-MRSA among MRSA isolates from hospitalised patients or the prevalence of MRSA colonisation among community members. It was found that among studies that excluded persons with health care contacts, the prevalence of MRSA was 0.2%. It was also reported that, most individuals with CA-MRSA had at least one health care–associated risk, suggesting that the prevalence of MRSA among persons without risks remains low. However, a study of an apparently healthy population of 500 children and their guardians in New York showed an unusually high carriage rate of nasal MRSA of 35% and 28% respectively. Bacterial competition and a lack of strong selection may limit the community spread of MRSA and could result in a sporadic distribution pattern[52].

Another study from the USA carried out in 2001–2002 by Kuehnert and co-workers[53] indicated that the colonisation prevalence of *S. aureus* and MRSA were 32.4% and 0.8%, respectively. Whilst the prevalence of *S. aureus* colonisation was highest in participants 6–11 years old, MRSA colonisation was associated with an age >60 years and female gender, but not with recent health-care exposure. The PVL gene was present in nine (2.4%) of the 372 isolates tested.

A number of important aspects regarding the epidemiology of CA-MRSA have been highlighted by recent investigations in the USA and provide insights into the potential for spread in the UK:

- Whereas at the outset CA-MRSA was seen predominantly as an infection affecting children, a recent study in Minnesota found that the median age of patients with CA-MRSA was 23 years compared to 68 years for patients with health care–associated infection[14].
- In a recent review, Johnson[16] concluded that the primary risk factors for CA-MRSA colonisation and infection are younger age, belonging to a minority group, and low socioeconomic status. Underlying medical conditions do not appear to be a major risk factor, but intravenous drug use, gay massage parlours, close-contact sports such as rugby, football or wrestling and incarceration were found to be risk factors[43, 44, 54]. In these situations, skin abrasions are common, leaving the person more prone to contracting CA-MRSA. The Health Protection Agency states that for UK reported cases of CA-MRSA they are unaware of any link to gyms or health clubs in England and Wales. Dietrich et al. 2004[48] reported that risk factors for acquisition of CA-MRSA included intrafamilial spread and child-care attendance. They also cited household contacts and child care attendance as risk factor for MRSA.

Most recently Fridkin 2005[55], (CDC) evaluated MRSA infections in patients identified from population-based surveillance in Baltimore, Atlanta, and from hospital-laboratory–based sentinel surveillance of 12 hospitals in Minnesota. During 2001 and 2002, 1,647 cases of CA-MRSA infection were reported, representing between 8% and 20% of all MRSA isolates. The annual disease incidence varied according to the site (25.7 cases per 100,000 population in Atlanta vs. 18.0 per 100,000 in Baltimore) and was significantly higher among persons less than two years old compared to those who were two years of age or older. It was also higher among blacks than among whites in Atlanta. Overall, 23% of patients were hospitalised for the MRSA infection. The authors concluded that "Community-associated MRSA infections are now a common and serious problem. These infections usually involve the skin, especially among children, and hospitalisation is common".

Prevalence of MRSA in domestic animals

Indications are that Staphylococci are commonly carried by animals, but tend to be host-adapted varieties. *S. intermedius* is the most common isolate from dogs, but human strains may be isolated. Although little information is available on the prevalence of MRSA in the domestic animals, isolation from household pets has been documented:

- Cefai et al. 1994[56] reported persistent carriage of MRSA in a health-care worker where the source or colonisation (or recolonisation) was identified as a domestic dog.
- Manian et al. 2003[57] described two dog owners suffering from persistent MRSA infection, who suffered from relapses whenever they returned home from the hospital. Further investigation revealed that their dog was carrying the same strain of MRSA.
- Rankin et al. 2005[58] carried out a study to determine the presence of S. aureus PVL toxin genes in MRSA strains isolated from companion animals. Eleven MRSA isolates from 23 animals were found to be positive for the PVL toxin genes as well as for methicillin resistance (mecA) genes.
- van Duijkeren et al. 2004[59] isolated MRSA from the nose of a healthy dog, the owner of which worked in a Dutch nursing home and was colonised with MRSA. Pulsed-field gel electrophoresis and typing of the staphylococcal chromosome showed that the MRSA strains were identical.

- Enoch et al. 2005[60] reported a pet therapy dog that acquired MRSA in a district general hospital in the UK after visiting care-of-the-elderly wards. The dog and owner were asymptomatic and had no observable source of MRSA. Two other pet therapy dogs were screened before visiting the hospital and were found to be MRSA negative. Further investigations suggested that the dog was colonised following contact with a human carrier.
- A survey conducted at a veterinary hospital on one day in February 2004 by Loeffler et al. 2005[61] identified MRSA carriage in 17.9% of veterinary staff, 9% of dogs, and 10% of environmental sites.

The available evidence suggests that MRSA is most likely acquired in animals by transmission from humans, although this is by no means proven[62].

3.3.2 Shedding of *S. aureus* and MRSA, and survival in the home environment

Carriers of *S. aureus* typically shed the organism from the skin surface, most usually associated with skin scales, but whereas some people are extensive shedders, others are not. The extent of shedding also varies over time, and typically may increase when the carrier has a cold or is being treated with antibiotics.

S. aureus is an organism that typically cannot proliferate outside a human or animal host. In contrast, however, as a bacterial species, it is particularly resistant to desiccation and can survive in the environment for significant periods. Therefore, once high density contamination occurs, it may also persist for extended periods.

EVIDENCE BASE

The carriage and dispersal of *S. aureus* outside the human body has been reviewed by Solberg 2000[63]. He reported that carriers of *S. aureus* typically shed the organism from the skin surface, most usually associated with skin scales, but whereas some people are extensive shedders, others are not. The extent of shedding also varies over time, and typically may increase when the carrier has a cold or is under antibiotic therapy. Solberg 2000 presented the results of 157 patients with persistent MRSA carriage and 18 patients with MRSA lesions in a medical department in Bergen, Sweden. They found that the numbers of organisms recovered from the hands of nasal carriers varied widely, from 10 to 2 x 10^6 colony forming units (cfu). They also found correlation between the numbers found on hands and the numbers liberated into air.

Survival of *S. aureus* on hands and surfaces has been shown by a range of field studies in hospital, as well as laboratory investigations (Ayliffe et al. 1967[64], Scott and Bloomfield 1990[65], Oie 1996[66], Wagenvoort et al. 2000[67]). Scott and Bloomfield 1990 showed that when *S. aureus* was inoculated onto clean cloths and surfaces (200-300 cfu/sq cm) and allowed to dry, the organism could be isolated from surfaces for up to four hours, and on a soiled surface for up to 24 hours. In the study by Wagenvoort 2000 et al, suspensions of two outbreak and three sporadic strains MRSA, with and without added hospital dust, were dried onto surfaces and viability determined at intervals over a one-year period. A gradual decline was noted for all strains. All survived longer than six months, but the two outbreak strains survived significantly better and for 1–3 months longer. Survival patterns of the MRSA strains with and without added dust were similar.

A recent study (Huws et al. 2006) has shown that MRSA can infect and replicate in amoeba such as Acanthamoeba polyphaga[68]. It was found that, within 24 hours of introduction into a suspension of amoeba, the MRSA had infected up to 50% of the amoeba in the sample. These amoeba are ubiquitous in the environment and can be found on inanimate surfaces. The presence of pathogens such as MRSA within amoebic cysts may significantly enhance their survival and spread in the environment.

In another recent study Reynolds and Gerba[69] surveyed 27 homes in two US cities. Out of 494 soft surfaces sampled, 17 sites in 11 homes tested positive for MRSA, which was detected most frequently on bathroom rugs and bed linens but also on fabric from couches, draperies, pet beds and children's car seats. Additionally, a gym bag, purse, and kitchen dishcloth tested positive. Although this study suggests that MRSA is not uncommon in the home environment, more research is needed to evaluate the virulence factors, antibiotic resistance patterns, and other characteristics of these household isolates, with respect to risk of infection and disease manifestation.

Several investigations have been carried out which demonstrate that, in settings in which there is an infected individual or carrier, MRSA can be isolated from the hands of patients and healthcare providers in addition to a range of environmental surfaces, including surfaces frequently touched by hands. Since hands are known to be an important route for transmission of MRSA, identification of MRSA on frequently touched surfaces is particularly important. Although these investigations were largely carried out in hospitals, they show the potential for contamination of the home environment, where there is a family member carrying and shedding MRSA. Hand contact and other surfaces from which MRSA has been isolated include computer keyboards, pens, television sets, clothing, mattresses, pillows, beds and chairs, and door handles:

- In a survey of two hospitals, Devine et al.[70] found that of 25 ward-based computer terminals, MRSA was identified in six (24%). Five of the positive terminals were from the hospital that had a significantly higher rate of MRSA transmission.
- French et al. 1998[71] found that nine out of 36 pens carried by doctors and nurses on six wards affected by MRSA were contaminated with MRSA, which furthermore had the same antibiotic resistance patterns as isolates from infected patients.
- Four of 28 television sets on eight wards were reported to be contaminated with MRSA (Stacey et al. 1998)[72] .
- Nadwua et al. 1991[73] isolated MRSA from bed curtains, nappy bins, chairs and foam mattresses in a postnatal ward where there was an outbreak of MRSA.
- Oie et al. 2002[74] found *S. aureus* contamination on 27% of door handles and MRSA contamination in 8.7% of these. MRSA was detected on door handles of rooms with and without MRSA patients. The density of contamination was 1-2.6 x 10^4 cfu MSSA/door handle, and 1-6.0x10^3 cfu MRSA/door handle.
- Blythe et al. 1998[75] studied 1000 specimens from 41 rooms previously occupied by patients with MRSA, focussing on areas close to patients, and surfaces likely to be frequently touched by patients and staff. MRSA was isolated from surfaces in 10 rooms (46%) including mattresses, pillows, chairs, tables, bed frames, electrical equipment, TVs, floors window sills, carpets and door handles.
- In a similar study Rahman 1993[76] found heavy MRSA contamination of items such as mattresses, beds, floors, chairs and a television set in the affected wards.
- Oie and Kamiya 1996[66] showed that MRSA survived for several weeks on dry mops used to sweep the floors of wards occupied by patients infected with MRSA.
- Moore et al. 1991[77] detected MRSA on surfaces including mattresses, a hand basin, a lavatory seat, a bath and a bath mat in a maternity hospital during an MRSA outbreak.
- During a hospital outbreak of MRSA, Rampling et al. 2001[78] found that 10.7% of 673 environmental samples were positive for MRSA. Contaminated sites included radiators, flat surfaces, furniture, floors, beds and door handles.
- Most recently Sexton et al. 2006[79] studied the environment of isolation rooms of 25 MRSA hospital patients for up to four weeks, sampling horizontal surfaces and the air using settle plates as well as an air sampler, while continuing regular daily cleaning according to the hospital protocol. A high proportion of samples were positive for MRSA; 269/502 (53.6%) surface samples, 70/250 (28%) air samples and 102/251 (40.6%) settle plates. Over half of the surface samples taken from the beds and the mattresses were positive for MRSA. Identical or closely related isolates were recovered from the patient and their environment in 14 (70%) patients.

Although it is assumed that hands are one of the main routes of transmission of infections, in reality there are only a few studies reporting isolation of MRSA from the hands of either patients of caregivers in settings where there is an MRSA outbreak[80, 81]. In a study of an outbreak in an Australian hospital, Pearman et al.[81] found that, of 8 staff members who were colonised, MRSA was isolated from the hands of 4 individuals.

3.3.3 Spread of *S. aureus* and MRSA in the home

In recent years a wide range of laboratory and field studies have been carried out that focussed specifically on the spread of pathogens in a domestic setting. These studies show that, in situations where good hygiene practice is not observed, bacterial and viral species including *S. aureus* are readily transferred in the home during normal daily activities via hands, cleaning cloths and a range of surfaces such that family members are regularly exposed to potentially infectious doses of these organisms.

EVIDENCE BASE

A number of field-based studies related to the home environment have been published in recent years. Although the majority of these studies involve organisms other than *S. aureus*, they show the potential for spread of pathogens in the home via hands and other surfaces during normal daily activities[82, 83, 84, 85, 86, 87]. In addition, there are a number of studies indicating that MRSA is readily transferred via hands, cloths and other surfaces within the home environment.

Laboratory studies on the spread of *S. aureus* and MRSA in the home

A number of laboratory studies have evaluated the potential for transmission of *S. aureus* via hands and environmental surfaces. Scott and Bloomfield[88] carried out a series of tests to evaluate transfer to and from surface and cloths contaminated with a wild type strain of *S. aureus* and left to dry over 24 hours. Table 1 shows that during the drying period, for up to four hours, significant numbers of cfu could be transferred by contact from the contaminated surface to a stainless steel bowl and to fingertips. Transfer to fingertips and a laminated surface also occurred when the contaminated cloth was used to wipe a clean surface. For the cloth, significant transfer was observed even after drying for up to 24 hours.

Table 1 Survival and transfer of *S. aureus* via cloths, hands and surfaces

Drying period (hours)	Source of contamination			
	Surface contaminated with 200-400 cfu per contact area		Cloth contaminated with 2976 cfu/ 25 sq cm	
	No. of cfu transferred by contact to:		No. of cfu transferred by contact to:	
	Fingertip	Stainless steel bowl	Fingertip	Laminate surface (25 sq cm)
0	53	42	107	33
1	92	43	115	28
4	64	17	74	8
24	19	1	>200	>200
48	–	–	>200	>200

Exner et al. 2004[89] carried out tests in which the first (field 1) of four flooring pieces was inoculated with *S. aureus*. After drying, a mop was wetted with cleaning product, and swept over the contaminated field followed by the other four fields and then back to field 1. Under these conditions, water and surfactants did not achieve complete reduction of *S. aureus* in Field 1 and the contamination was disseminated from Field 1 to other fields.

The potential for transmission via clothing and bedding, and in association with laundry has also been demonstrated:

- In homes where there is an MRSA carrier, MRSA has been isolated from laundered items (personal communication from Martin Exner, May 2001).
- The potential of fabrics to spread MRSA infections has been investigated by Neely and Maley 2000[90]. These workers inoculated suspensions of MRSA onto cotton and polyester and plastic fabrics (10^4 to 10^5 per swatch). The MRSA strain was found to survive for up to 50 days on various materials.
- Sattar et al. 2001[91] demonstrated significant transfer of *S. aureus* from contaminated fabrics to hands and other fabrics.
- The risks for cross-contamination by household laundry was demonstrated many years ago following an investigation of an outbreak of *S. aureus* skin infections among families in Boston (Kundsin 1966)[92]. A significantly higher prevalence of infection was found in families who used a community laundry compared with families who used their own washing machine. Community washing machines were found to be operating at a temperature of 50-65 °C, which was considered inadequate for disinfection of laundry.

- Shiomori et al. 2002[93] determined the number of airborne MRSA before, during and after bedmaking for 13 inpatients with MRSA infection or colonisation. The number of airborne contaminants was significantly higher 15 min after bedmaking than during the resting period, although the differences in counts after 30 min were not significant. MRSA was also detected on surfaces including floors and bed sheets suggesting that MRSA was recirculated in the air. Significant dispersal of *S. aureus* into the air during bedmaking for MRSA colonised patients was also demonstrated by Solberg 2000[63].

Field studies on the transmission of *S. aureus* and MRSA in the home

The potential for transmission to other family members where there is a family member in the home carrying MRSA, is borne out by a number of investigations of health care workers which indicated that the organism can be transferred between family members and family pets either by direct contact or via environmental surfaces.

1. Masterton et al. 1995[94] reported a UK outbreak of MRSA, where a nurse was found to be colonised. The patient's parents and fiancée, who shared the same house, were also colonised with the same strain. The family was treated with antimicrobials but this failed to eradicate the organism. Investigation of the home revealed MRSA on door handles, a computer desk shelf and computer joystick in the patient's bedroom, but not elsewhere. The home was thoroughly vacuumed and damp dusted and all pillows and bedding were replaced. After subsequent antimicrobial treatment, three subsequent consecutive weekly cultures from the throat, both nostrils, groin and armpit did not yield MRSA.

2. Allen et al. 1997[95] investigated a UK nurse who became colonised with MRSA. Tests showed that carriage (nose, throat, armpit and perineum) was eliminated by antimicrobial treatment, but each time the MRSA colonisation returned. During this period both her son (probably due to storage of family toothbrushes in close proximity) and husband also became colonised. Sampling showed MRSA contamination on the three-piece suite, bedroom mattress, duvet, pillows and padded headboard, living room carpets, dining room, hall and three bedrooms, living room rug, dining chairs, kitchen stools, two items of clothing and a spare sofa bed in the son's bedroom. The problem was finally terminated after a co-ordinated commercial cleaning of the house, thermal disinfection of all linen and replacement of soft furnishings. Two weeks later repeat environmental samples were all negative for MRSA and monthly screens of the nurse for six months, were also all negative.

3. Cefai et al. 1994[56] reported a case of two UK nurses (married to each other, one of them caring for an infected patient) who were found to be nasal MRSA carriers. Weekly checks for three weeks following antimicrobial treatment showed no MRSA. Six months after the first isolation, a second patient was found to be colonised with the organism. Repeat screening showed the same staff nurse and his wife were colonised. At this time MRSA was isolated from a nose swab taken from the dog.

4. Scott et al. 1988[96] reported an outbreak of epidemic methicillin-resistant S. aureus on a rehabilitation geriatric ward. Intensive screening of patients and staff revealed an unusually high carriage rate in the nursing staff (38%), which was believed to be related to a ward cat that was heavily colonised from the environment. Infection control measures and removal of the cat led to rapid resolution of the outbreak.

5. A study by Calfee et al. 2003[97] suggested that MRSA colonisation occurs frequently amongst home and community contacts of patients with nosocomially-acquired MRSA. MRSA was isolated from 14.5% of 172 individuals who were the household/community contacts of 88 MRSA colonised patients discharged from a hospital in Virginia, USA. Household contacts who had close contact with the patient were 7.5 times more likely to be colonised than those who had less frequent contact (53% vs. 7%). In each case, analysis of antimicrobial susceptibility and DNA patterns suggested that the MRSA isolated from the household contact was identical, or closely related, to that carried by the index patient indicating person-to-person spread.

6. Kniehl et al. 2005[98] described a recent study in Germany, of healthcare workers (HCWs) who had close and regular contact with MRSA-colonised patients. MRSA was identified from nasal swabs of 87 workers treated with topical antimicrobials. They were advised to disinfect their bathrooms and personal hygiene articles, and wash bed linen and pillows. Seventy-three (84%) of HCWs lost their carrier status when tested after three days, and this was maintained after further sampling over three months. In 11 cases MRSA was detected, but only in "later" swabs, indicating recolonisation. In eight of these 11 cases, screening identified colonisation of close household contacts. Environmental sampling detected contamination in seven of the eight home environments. Contaminated surfaces included pillows, bed linen, brushes, cosmetics and hand contact surfaces, as well as household dust. When eradication treatment was applied to household contacts and surfaces were cleaned and disinfected, carriage cleared in most cases within a few weeks. However, when home environments were heavily contaminated, despite adequate medical treatment, eradication took up to two years.

A number of other individual cases are reported where family members in the home of an infected person have been found to be colonised with MRSA (Hollis et al. 1995[99], Hollyoak et al. 1995[100], L'Heriteau et al. 1999[101], Shahin et al. 1999[102]). The potential for intrafamilial transmission is demonstrated by the case study reported by Hollis et al. who found that following the identification of an index case (a sibling infected with MRSA), two other siblings in the home and the mother became infected or

colonised. The study suggested that transmission of the MRSA strain occurred at least three times within this family, and that at least one family member was colonised with the same strain for up to seven months or more.

Most recently, a study of the impact of hygiene on transmission of what was likely to be an outbreak of CA-MRSA in a community setting has been reported. Turabelidze et al. 2006[103] carried out a case-control study, involving 55 culture-confirmed cases of MRSA in a prison in the USA to examine risk factors for MRSA infection with a focus on personal hygiene factors. An interviewer collected information about relevant medical history, personal hygiene factors (including hand washing, shower, laundry practices, and sharing personal items), use of gymnasium and barbershop, and attendance of educational classes. The risk for MRSA infection increased with lower frequency of hand washing per day and showers per week. Inmates who washed their hands ≤ six times per day had an increased risk for infection compared with that of inmates who washed their hands >12 times per day. Inmates who took ≤ seven showers per week had an increased risk for infection compared to that of inmates who took >14 showers per week. In addition patients were also less likely than controls to wash personal items (80.0% vs. 88.8%) or bed linens (26.7% vs. 52.5%) themselves instead of using the prison laundry. When personal hygiene factors were examined for cases and controls, patients were more likely than controls to share personal products (e.g., cosmetic items, lotion, bedding, toothpaste, headphones), especially nail clippers (26.7% vs. 10%) and shampoo (13.3% vs. 1.3%), with other inmates. To evaluate an overall effect of personal hygiene practice on MRSA infection, a composite hygiene score was created on the basis of the sum of scores of three individual hygiene practices, including frequency of hand washing per day, frequency of a shower per week, and number of personal items shared with other inmates. A significantly higher proportion of case-patients than controls had lower hygiene scores (<six) (46.7% vs. 20.0%). Sharing of towels and soap was also identified as significant risk factors in recurrent outbreaks of CA-MRSA in a football team in the USA[54].

The potential for transmission of MRSA in the home in situations where good hygiene practice is not observed is also demonstrated by a range of hospital studies that reported termination of outbreaks associated with programmes of hygiene education (including hand washing combined with rigorous environmental cleaning). These studies are summarised in section 6.3.

3.3.4 "Way in" for *S. aureus* and MRSA

For *S. aureus* to produce colonisation and/or infection of the skin, it must enter via the skin surface. This occurs most usually where there are cuts or abrasions or other conditions that damage the integrity of the skin surface such as pressure sores. Infection can also readily occur at catheter insertion sites or through skin sutures. Skin conditions such as psoriasis or eczema also increase the risk of colonisation or infection with *S. aureus*. While it is believed that the number of organisms required to cause infection varies, it is usually lower for vulnerable groups with respect to healthy family members. Marples (1976)[104] showed that up to 106 cells may be required to produce pus in healthy skin, but as little as 10^2 may be sufficient where the skin is occluded or traumatised. Although there is no specific data available in this regard, it is possible that HCA-MRSA is a less aggressive pathogen than MSSA strains, but that the new CA-MRSA may have enhanced infectivity.

3.3.5 People at risk of acquiring *S. aureus* and MRSA in the home

The risk groups for acquiring HCA-MRSA and CA-MRSA are significantly different. Although *S. aureus* is an opportunistic pathogen that can infect anyone, HCA-MRSA usually only affects the elderly and those who are immunocompromised in a manner that affects the integrity of the skin or mucous membrane, i.e. those with surgical or other wounds or are undergoing catheterisation. In the home environment family members are only at risk of contracting MRSA in situations where there is also another family member or a pet that is carrying MRSA. This is probably most likely to occur in families with a health care worker who has become colonised through contact with patients carrying MRSA.

For CA-MRSA, those at particular risk appear to be younger, generally healthy people who practice contact sports or other activities that put them at higher risk of acquiring cuts and abrasions of the skin. Intravenous drug users also appear to be at greater risk, partly through needlestick use, but also due to a lower general resistance to infection. These groups are only at risk of acquiring CA-MRSA in situations where they come into contact with CA-MRSA, transmitted from others who are carrying or infected with CA-MRSA. At present it would appear that CA-MRSA strains are mostly circulating amongst the lower age groups. This means that it is probably not the fact that younger people are at greater risk of infection than healthy adults that is responsible for the higher prevalence of CA-MRSA amongst younger age groups, but it is the fact that they are more likely to be exposed to CA-MRSA. However, as stated previously, the prevalence of CA-MRSA even within this younger age group appears to be low in the UK population at present.

As stated previously, *S. aureus* is an organism that readily colonises humans, but only occasionally leads to infection. Where someone is exposed to CA or HCA-MRSA colonisation can occur as readily with these strains as with other strains of *S. aureus*. Thus colonisation with HCA-MRSA is most likely to occur in healthcare settings, whilst exposure to CA-MRSA is most likely to occur in association with sport or other contact activities amongst younger people. The risk of developing an MRSA infection during hospitalisation is five times higher for someone who is carrying the organism when they enter the hospital.

3.4 What are the risks associated with *S. aureus* and MRSA in the community?

In general, based on current evidence, the risks associated with CA- and HCA-MRSA transmission in the home and community are currently relatively small. Although up to 60% of people carry *S. aureus* as part of normal skin flora, only a relatively few individuals carry HCA or CA-MRSA strains. While there is no particular cause for alarm, it is recognised that reducing the risks of transmission of MRSA in the home is important for a number of reasons:

In particular:

- When patients who are still infected or colonised with MRSA are discharged from the hospital back to their homes, the organism may colonise other family members or contacts, or can be disseminated into the home environment where it can survive for significant periods of time. Although the patient may recover from the infection, they can become re-infected if re-exposed to the organism either from another family member who has become colonised, or from surface contamination persisting in the home environment.

Moreover, although carriage of MRSA amongst healthy family members (either acquired as a result of hospitalisation or in the community) is not a risk in itself, there are a number of reasons why it makes sense to minimise dispersal of MRSA in the home environment and reduce opportunities for exposure amongst family members that could lead to colonisation:

- When carriers of MRSA are admitted from home into the hospital for surgery, there is significant risk of self infection.
- When a family member who is a carrier of MRSA is admitted to a healthcare facility, they represent a source of infection, which they may transmit to other patients.
- When a family member who is a healthcare worker becomes colonised with MRSA at home, they may transmit the organism to patients in the healthcare institution where they are employed.
- For family members carrying PVL-producing strains of CA-MRSA, colonisation of cuts and abrasions with this strain may result in serious and potentially fatal infections of skin and soft tissue.

The risks from MRSA in the home are exacerbated by the fact that if it is allowed to become "endemic" in the home environment it can persist for very long periods and can be difficult to eradicate.

Home hygiene practices that can be used to limit the transmission of *S. aureus* and MRSA are discussed in section 6.

KEY POINTS

Up to one third of the population are colonised with *S. aureus* in a continuous manner and always carry the same strain. Up to one third of the population carry different strains of *S. aureus* intermittently.

Individuals are usually unharmed by colonisation. S aureus can also colonise broken or abnormal skin, such as superficial wounds, ulcers, psoriasis and eczema.

S. aureus may not produce any symptoms, but on occasion it produces boils or can enter the bladder or the blood stream causing bacteraemia.

S. aureus causes disease either by the production of a toxin that produces tissue destruction or by direct invasion and destruction of tissue.

Methicillin resistant *Staphylococcus aureus* (MRSA) is a strain of Gram-positive bacterium *Staphylococcus aureus* that is resistant to many antibiotics, such as erythromycin, gentamicin, trimethoprim and vancomycin.

MRSA strains can be classified into two groups: healthcare-associated MRSA (HCA-MRSA) strains and community-acquired MRSA (CA-MRSA) strains.

HCA-MRSA is a major cause of hospital-acquired infection. Although most HCA-MRSA infections arise in a hospital setting, the organism has the same potential to affect the elderly and immuno-compromised in a home care setting.

In the home environment family members are only at risk of contracting MRSA in situations when there is also another family member or a pet carrying MRSA. This most likely occurs in families where someone is a healthcare worker.

HCA-MRSA strains principally affect frail and vulnerable individuals such as the elderly and those who are immunocompromised in a manner that affects the integrity of the skin or mucous membrane, i.e. those with surgical or other wounds or have catheters present.

CA-MRSA is more prevalent among children and young adults and infects cuts, wounds and abrasions. For CA-MRSA, those at particular risk appear to be younger, generally healthy people who practice contact sports or other activities that put them at higher risk of acquiring cuts and abrasions of the skin. Intravenous drug users also appear to be at greater risk, partly through needlestick use.

Although HCA-MRSA are resistant to antibiotics, there is no evidence suggesting that they are resistant to disinfectants, antibacterials or antiseptics.

CA-MRSA are resistant to fewer antibiotics than HCA-MRSA, with the consequence that these infections are readily treatable - provided doctors are aware that the patient might be carrying a CA-MRSA strain.

Some CA-MRSA strains can also carry a tissue toxin known as Panton-Valentine Leukocidin or PVL, which can lead to skin and soft tissue infections.

- PVL-positive CA-MRSA is easily transmissible not only within families but also on a larger scale in community settings such as prisons, schools and sports teams.

Although CA-MRSA strains are of concern, at present such infections are rare in the UK compared with other countries, particularly the USA, which have encountered more serious problems.

Chain of transmission of *S. aureus* (including MRSA) in the home

Source of infection in the home: the major sources of *S. aureus* including MRSA in the home are colonised or infected individuals and domestic animals.

Shedding and survival: carriers of *S. aureus* typically shed the organism from the surface of the skin, most usually associated with skin scales. *S. aureus* typically cannot proliferate outside a human or animal host, but is particularly resistant to desiccation and can survive in the environment for significant periods on surfaces including floors.

Spread: *S. aureus* is readily transferred in the home during normal daily activities via hands, cleaning cloths and a range of surfaces, including hand and body contact surfaces. Transfer can also occur via clothing and household linens.

Way in: via the skin surface, usually through cuts or abrasions or other conditions that damage the integrity of the skin surface, at catheter insertion sites or through skin sutures, and in the presence of skin conditions such as psoriasis or eczema.

The risks associated with CA- and HCA-MRSA transmission in the home and community are currently relatively small, but reducing the risks of transmission of MRSA in the home from a known infected person is important to avoid risk of re-infection. Although carriage of MRSA amongst healthy family members is not a risk in itself, there are a number of reasons why it makes sense to reduce opportunities for exposure amongst family members, which could lead to colonisation.

4. *CLOSTRIDIUM DIFFICILE*

4.1 Characteristics of *Clostridium difficile*

Clostridium difficile is an anaerobic, rod shaped Gram-positive bacterium. It was first described in 1935, as a component of the faecal flora in healthy babies, but was not recognised as a cause of toxin-associated disease until 1978. *C. difficile* may be present as one of the 'normal' bacteria in the healthy gut.

C. difficile bacterium has two forms, an active, vegetative form that cannot survive in the environment for prolonged periods, but which causes disease, and a dormant spore form, that can survive in the environment for prolonged periods, but which does not cause disease. *C. difficile* is transmitted by the faecal-oral route. *C. difficile* colitis is a disease of the colon that occurs primarily among individuals who have been using antibiotics. *C. difficile* colitis occurs when certain antibiotics disturb the balance of 'normal' bacteria in the gut. The antibiotic disrupts the other bacteria that normally are living in the colon and prevent *C. difficile* from transforming into its active, disease-causing form. When *C. difficile* does transform into its active form, some but not all strains of *C. difficile* produce toxins that inflame and damage the colon causing diarrhoea of varying severity. The diarrhoea may resolve once antibiotic treatment is stopped, though the severe inflammation of the bowel can sometimes be life threatening. Other symptoms can include fever, loss of appetite, nausea and abdominal pain or tenderness. This spectrum of symptoms has come to be known as *Clostridium difficile*-associated disease (CDAD). CDAD may develop fairly rapidly in patients undergoing antibiotic treatment, but the period of susceptibility may continue for a considerable period of time such that CDAD may not develop until some time after the course of antibiotics has been completed. There is some evidence that transformation of *C. difficile* into its active form can be triggered by the antibiotic treatment itself, but further work is required to determine whether or not this is the case. Strains of *C. difficile* that do not produce toxins are non-pathogenic.

While most *C. difficile* colitis is caused by antibiotics, *C. difficile* colitis also can occur in patients without such exposure. For example, patients with *ulcerative colitis* and *Crohn's disease* have been known to develop *C. difficile* colitis without exposure to antibiotics. In the USA, cases of CDAD have recently been reported in people in the community, where none of these predisposing factors were present.

As stated previously, many infants and young children, and even some adults, harbour the organism in their gastrointestinal tract. It is thought that *C. difficile* does not cause colitis in these individuals since: 1) the bacteria remain in the colon as non-active spores, and 2) the individuals have developed antibodies that protect them against the *C. difficile* toxins.

4.2 Hospital-acquired and community-acquired *C. difficile*

C. difficile has now been established as the leading cause of hospital-acquired infectious diarrhoea in adults. However, CDAD may also occur outside of hospitals in people who are carrying the organism in their gut or are exposed to the organism in their home or community. All evidence indicates that, as in the hospital setting, only certain people at home are at risk of developing CDAD. Persons at higher risk include those who have undergone treatment that may impair or disrupt the microflora of the intestine, such as certain antibiotics, surgery, immunosuppressive therapy and antacids. In addition, gastric acid suppressants are now emerging as a risk factor. The elderly are particularly at risk, and over 80% of cases are in the over 65-age group. Repeated enemas and/or gut surgery increase a person's risk of developing the disease. Multiple and severe underlying diseases and prolonged hospital stay are also risk factors. Although children under two years frequently carry *C. difficile*, (see below) they are usually asymptomatic.

Recently a new type of *C. difficile* (usually referred to in the UK as ribotype NAP1/027), closely related to one previously found in North America, has been detected in the UK, including at Stoke Mandeville Hospital. In the USA the emergence of this new strain of *C. difficile* has caused hospital outbreaks in several states. The new strain appears to be more virulent, and has the ability to produce greater quantities of toxins[105]. In addition, unlike many previous *C. difficile* strains, it is resistant to fluoroquinolone antibiotics[106]. It is not possible to assess how prevalent this strain might be in the general population in the UK as sufficient data have not been collected. However, it is known that type 027 now accounts for 28% of all isolates from hospital patients in England, and this has risen from practically zero in the last two years. In the USA in 2005, a number of community-acquired CDAD cases involving these strains were reported in patients where there was minimal or no exposure to healthcare settings and no history of recent antibiotic treatment[107]. These reports reflect the rapidly changing epidemiology that appears to be taking place with *C. difficile*.

4.3 Understanding the chain of infection for *C. difficile* in the home

In the following sections the chain of infection in the home in relation to *C. difficile* will be evaluated in order to understand how and when it may occur, and how it is spread such that family members become exposed and are either colonised or develop CDAD.

4.3.1 Sources of *C. difficile* in the home

C. difficile occurs quite commonly in the home where the major sources are people who are colonised or have CDAD, and domestic animals. Up to two thirds of infants carry *C. difficile* asymptomatically during first few months of life (thought to reflect acquisition from hospital). The organisms are also harboured by up to 3% of healthy adults and colonisation rates are higher in the over 65 age group. There are no data, however, to indicate what proportion of carriers are carrying toxin-producing strains, but surveillance data suggests that although isolation rates for *C. difficile* have decreased since 2000, the proportion of those isolates which are toxin producers has increased.

Carriage of *C. difficile* in household pets is also quite common. Although carriage appears to be transient, up 23% of household pets are affected. In most cases, however, the strains carried by pets appear to be non-cytotoxigenic strains.
C. difficile also occurs quite frequently in the environment outside the home and can be isolated from farm animals and vegetables, although there is no data to indicate what proportion of these strains are toxigenic.

Another potential "source" of *C. difficile* in the home is on the surface of the uniforms of healthcare workers that are either kept at home by the person involved, or are brought home for laundering. A number of studies have shown that uniforms can act as a vector for transmission of pathogens such as *C. difficile*[25, 26, 27].

EVIDENCE BASE

Until recently, surveillance of *C. difficile* infection in England and Wales was performed by the Health Protection Agency through a voluntary reporting system. The epidemiology of *C. difficile* infections in the UK has been summarised in the recent report of the National *Clostridium difficile* Standards Group (Anon 2004[108]). The report states that, although the number of positive isolates increased to a peak of over 14,000 isolates from 1998-2000, provisional data suggest it has tailed off more recently. In contrast, the number of positive *C. difficile* toxin tests rose steadily throughout the 1990s reaching a peak of over 8,000 positives in 2001. In January 2004, a mandatory reporting system was introduced for *C. difficile*, which required all faecal specimens from clinicians and general practitioners for patients over the age of 65 to be tested. In the first year of reporting there were 44,488 reports from 166 trusts[109].

During the first month of life up to two thirds of infants become colonised with *C. difficile*. This probably reflects acquisition from the hospital environment, but for reasons that remain unclear most colonised neonates are asymptomatic carriers even when toxin production can be demonstrated. During childhood, carriage rates decline to adult levels, while both sporadic and outbreak CDAD begin to appear[110, 111]

The presence of *C. difficile* in faeces can be demonstrated in up to 3% of healthy adults[112]. Rates of colonisation and infection increase markedly beyond the age of 65, such that for England and Wales *C. difficile* is the predominant enteric pathogen among people in this age group[113] .

On the basis that *C. difficile* infections mostly occur in at risk groups, plus the fact that opportunities for transmission of the organism are greater in hospitals, CDAD is primarily a nosocomial disease. Asymptomatic carriage has been reported in about 7% in residents of long-term care facilities[114], 14% of hospitalised elderly patients on acute medical wards, and 20% of elderly patients on chronic care wards[115], in whom it is between three and five times more common than symptomatic disease[116, 117].

At the present time there are no data to indicate what proportion of the 44,488 cases of *C. difficile* reported to surveillance in the UK are related to community acquisition. In the USA, it is estimated that 20,000 infections with *C. difficile* occur in the community each year. Data from Sweden indicate that 42% of cases of *C. difficile* infection present in the community, half of whom do not have a history of hospitalisation within the previous month[118]. In Ireland, 11% of cases presenting with cytotoxin positive *C. difficile*-related diarrhoea had no hospitalisation within the previous 60 days[119]. The Intestinal Infectious Disease (IID) Survey in England identified *C. difficile* as the third most common cause of IID in patients aged >75 years seen by GPs[120].

More recently, the incidence of community *C. difficile*-related diarrhoea detected in teaching (urban) and semi-rural district general hospital microbiology laboratories in England was the same (2.1%) when faecal samples selected at random from those submitted from general practice were examined for cytotoxin[121]. Risk factor data were collected for 56 community *C. difficile* diarrhoea cases and 182 age- and sex-matched controls: 50% of cases but only 11% of controls had received antibiotic therapy in the month before diarrhoea; 32% of cases and 15% of controls had been hospitalised in the six months prior to diarrhoea. However, a large proportion of cases (39%) had neither of these risk factors. The National *C. difficile* Standards Group concluded

that "the distinction between nosocomial and community-acquired CDAD is likely to become blurred as trends towards earlier hospital discharge and more intensive community nursing continue".

There are also indications that *C. difficile* may be carried by domestic pets[122]. Lefebvrea et al. 2006[123] evaluated the prevalence of zoonotic agents in a group of 102 dogs from a variety of sources across Ontario. Canada and zoonotic agents were isolated from 80 of 102 (80%) animals. The primary pathogen was *C. difficile*, which was isolated from 58 (58%) faecal specimens; 71% (41/58) of these isolates were toxigenic. The authors also reviewed other reports from the USA and Australia, which indicated asymptomatic carriage in the general canine population between 0 and 37%.

Borriello et al. 1983[124] reported that carriage of *C. difficile* in household pets is common. Although carriage appears to be transient and not associated with gastrointestinal disease, they report that up to 23% of household pets are affected. Although carriage was reportedly higher in animals that had previous antibiotic treatment (31% compared with 19%), the differences were not statistically significant. In most cases non-cytotoxigenic strains were identified. Both cytotoxigenic and non-cytotoxigenic strains were also isolated from the animals' surroundings.

Al Saif and Brazier 1996[125] report that the organism is also widespread. A study in South Wales showed that 7.1% of 2,580 samples yielded isolates of *C. difficile*. The highest proportion of samples positive for *C. difficile* was obtained from river waters, with 14 (87.5%) of 16 samples positive, and from seawater with seven (44%) of 15 positive samples from six beaches on the Bristol Channel. In addition, seven (46.7%) of 15 samples of lake water were positive. Twenty-two (21%) of 104 soil samples, taken from random sites in Cardiff, were positive, as were 20% of environmental samples from four Cardiff hospitals. *C. difficile* was also isolated from 50% of eight swimming pool waters examined and one (5.5%) of 18 samples of tap water. Carriage of *C. difficile* in 524 faecal samples from various assorted farm animals was about 1%, while it was 10% in dogs and 2% in cats. In private residences, the organism was present in 12 (2.2%) of 550 samples. While 2.4% of 300 raw vegetable samples were positive, none of 107 assorted fish gut contents tested positive.

4.3.2 Shedding of *C. difficile* and survival in the home environment

Indications are that *C. difficile* is shed in faeces from an infected person or someone who is carrying the organism in their gut. Release of spores is easily accomplished as *C. difficile* causes diarrhoea, which is often explosive. It has been estimated that infected patients excrete over 100 *C. difficile* per gram of faeces (Wilcox, 2003[126]).

To a greater extent even than *S. aureus*, *C. difficile* is an organism that is resistant to drying and can survive in the environment in its dormant spore form for very long periods of time. Contamination of the environment is thought to be a major factor in the spread of the organism.

EVIDENCE BASE

Spores of *C. difficile* have been found to survive up to 56 days, in temperatures of 4ºC and -20ºC (Freeman and Wilcox, 2003 [127]) and are fairly resistant to many common cleaning agents. Kim et al. 1981[128] reported that the spores are resistant to drying and can survive on hospital floors for at least five months.

A range of studies have been reported that show extensive contamination of hands and environmental surfaces in settings where there is an infected person or a carrier (Mulligan et al. 1979[129]; Kim et al. 1981[128]; Malamou-Ladas et al. 1983[130]; Kaatz et al. 1988[131]; McFarland et al. 1989[117]; Cartmill et al. 1994[132]; Skoutelis et al. 1994[133]; Samore et al. 1996[134]; Verity et al. 2001[130]; Wilcox et al. 2003[136]). The majority of these studies were carried out in hospitals, nursing homes, extended care facilities, and nurseries for newborn infants, but Kim et al. 1981[128] also found that 12% of environmental surfaces were positive for *C. difficile* in the home of an infected infant recently discharged from hospital. Items and/or surfaces found to be contaminated included bedpans, furniture, bed frames, bedding, floors, carpets, toilet seats, sinks and other bathroom sites, linens, telephones, fingernails, rings and floors and nappy buckets. Various workers have reported isolation rates from environmental samples ranging from 4%[130] to 25%[135], 31%[138] and 35%[145]. Verity et al. 2001[135] reported that the bed frame was the most common surface from which *C. difficile* was recovered, although the floor was the most contaminated site in terms of total number of colonies. Kaatz et al. 1988[131] reported that floors and bathroom sites were the most heavily contaminated areas. Samore et al.[134] found that floors were the most frequently *C. difficile* positive site (48%), whereas contamination of bed frames was less common (18%). Wilcox et al.[136] reported that commodes, toilet floors and bed frames were found to be *C. difficile* positive on approximately 50% of occasions. Radiators, non-toilet floors and curtain rails were less frequently (30%) contaminated.

These workers also reported that *C. difficile* spores were generally found in significantly greater quantities in the environment of infected patients in comparison with non-carriers. They also reported that organisms were recovered from beds, toilets, floors, mops and furniture, and objects, even in areas where infected patients were not known to have visited. Fekety et al. 1981[137] and Kim et al. 1981[128] reported isolation of *C. difficile* from the stools and hands of hospital staff that were asymptomatic for the disease.

4.3.3 Spread of *C difficile* in the home environment

Although it is assumed that *C. difficile* is transmitted via the faecal-oral route, the precise mode of transmission is not known. In recent years, however, a variety of laboratory and hospital-based studies have been carried out to evaluate the spread of *C. difficile*. These studies, together with two reports indicating transmission in the home, suggest that, in situations where good hygiene practice is not observed, *C. difficile* is likely to be readily transferred around the home during normal daily activities via hands, cleaning cloths, and such surfaces that family members are regularly exposed to potentially infectious doses of this organism.

Since *C. difficile* is transmitted via the faecal-oral route, it is possible that it is also transmitted via food that is contaminated via the hands of the preparer. At the present time, however, there is no definitive data available to show whether this is the case. The results reported by Al Saif and Brazier[125] suggest that consumption of beef, pork or lamb is unlikely to be a source of exposure to *C. difficile* as it was not found to be a part of the faecal flora of these animals. Likewise, although 1.6% of faecal samples from poultry were found to carry *C. difficile*, they concluded this food source also appeared to have low risk potential.

EVIDENCE BASE

Although most investigators[135, 136] and authorities[108, 138, 139] conclude that hands and environmental surfaces are involved in the transmission of *C. difficile*, the evidence is by no means equivocal; in many cases it has proven difficult to determine whether environmental contamination is a cause or a consequence of diarrhoea. It may be that hospitals outbreaks in which a single clone contaminates the environment heavily enough to result in cross-contamination and cross-infection (Cartwright et al., 1995[140]) occur against a high background of clusters of infection. This is related to risk factors, and in particular ward populations coupled with antibiotic use, making it difficult to distinguish sporadic infections from outbreaks. Physical proximity to a symptomatic case has been reported as important for transmission with a risk of 12%[141].

Evidence supporting and/or questioning the role of hands and the environment comes from a number of studies. The majority of these studies relate to hospital outbreaks, but one study (Kim et al. 1981[128]) suggested intrafamilial spread in the home environment of an infected infant.

- A number of studies report that staff hands were found to be most heavily contaminated in areas where there was also heavy environmental contamination (Fawley and Wilcox 2001: Samore et al.[134]). Contamination may also occur after non contact procedures, such as taking patient histories and completing treatment charts (Kim et al. 1981[128]).
- Wilcox et al.[136] investigated two wards where infected patients were present. Although it found that in one ward the incidence of CDAD was significantly associated with the proportion of culture-positive environmental sites, in the other ward the only significant correlation between CDAD and *C. difficile* culture-positive environmental sites was in patient side-rooms.
- A number of studies confirm the similarity between patient and environmental isolates (Cartmill et al., 1994[132]; AI-Saif et al.1998[142]), or have identified the spread of single clones throughout and between hospitals (Costas et al. 1994[143]).
- Clabots et al. 1992[144] studied 634 patients admitted to a hospital ward and found that 65 were colonised with C. difficile on admission, whilst 54 initially negative patients acquired *C. difficile* on the ward. For the initially negative patients, acquisition of *C. difficile* was preceded by a documented introduction of that strain to the ward by another asymptomatic ward admission in 16 out of 19 instances suggesting that *C. difficile*-colonised new admissions are a major source of CDAD.
- Bacon et al. 1988[145] found that 16% of 187 infants in a neonatal unit were colonised with *C. difficile*. It was found that a specific strain became the predominant strain isolated from the babies, and from the environment and hands of HCWs suggesting that transfer via both hands and the environment was responsible for transmission to infants. C. difficile was isolated from 8.3% of environmental and 36.8% of hand surfaces sampled.
- Wilcox and co-workers[146, 147] reported that approximately 30% of patients experience recurrences of CDAD, but that these are frequently caused by different strains. This suggests that the patient environment is the source of such recurrences.
- Macfarland et al.[117] studied transmission of *C. difficile* in a medical ward that hosted 428 patients over an 11-month period. Patient-to-patient transmission was evidenced by the fact that significantly more frequent and earlier acquisition occurred among patients exposed to roommates with positive cultures. Of the hospital personnel caring for patients with positive cultures, 59% had positive cultures for *C. difficile* from their hands.
- Johnson et al. 1990[148] reported the value of disposable vinyl glove use by hospital personnel for all body substance

contact in reducing rates of acquisition 5-fold and suggested their findings provided indirect evidence for hand-mediated spread of *C. difficile* on wards. A decrease in the incidence of *C. difficile* diarrhoea from 7.7 cases/1,000 patient discharges during the 6 months before intervention to 1.5/1,000 during the 6 months of intervention on the glove wards was observed. No significant change in incidence was observed on the 2 control wards during the same period (5.7/1,000 versus 4.2/1,000). Kim et al. 1981[128] studied the case of an infant who developed a recurrent *C. difficile* infection at home that required rehospitalisation. Environmental sampling showed that 12.2% of samples were positive for *C. difficile* and one of four other family members carried *C. difficile* in stool. In contrast, in a control home where none of the family members were carriers, none of the 84 environment samples were positive for *C. difficile*.

- In the USA in 2005, where a number of community-acquired CDAD were reported in patients where there was minimal or no exposure to healthcare settings and no history of recent antibiotic prescriptions[107], investigations indicated that, in some cases, close contact was responsible for transmission between family members.

The potential for transmission of *C. difficile* in the home in situations where good hygiene practice is not observed is also demonstrated by a range of hospital studies reporting termination of outbreaks following programmes of hygiene education (including hand washing combined with rigorous environmental cleaning). These studies are summarised in section 6.3

4.3.4 "Way in" for C. *difficile*

For colonisation of the gut with *C. difficile* to occur, the organism must be consumed orally. This can occur by direct hand to mouth transfer, or may also occur via contaminated food or water. The infectious dose of *C. difficile* can be very small and studies have shown that consumption of as few as one to two spores may be sufficient to establish colonisation and CDAD in clindamycin-treated mice[149].

4.3.5 People at risk of CDAD in the home

Whereas it would appear that colonisation of the gut with *C. difficile* can occur quite readily if someone is exposed to *C. difficile*, the development of CDAD is confined to those who are at special risk who include those who have undergone treatment that disrupts gut microflora e.g. therapy with antibiotics, immunosuppressive agents and antacids, surgery and repeated enemas. Indications are that the elderly are particularly at risk, and >80% of reported cases are in the over-65 age group. Multiple and severe underlying diseases and prolonged hospital stay are also risk factors.

4.4 What are the risks associated with *C. difficile* in the home and community

Based on current evidence, it must be concluded that in general the risks associated with transmission of *C. difficile* in the home and community are relatively small at present. Although *C. difficile* appears to be widespread in the environment, and is quite frequently present in the gut flora of humans and animals, indications are that only a proportion of these strains are toxin producers, and that gut carriage of these strains only causes CDAD in situations where the gut flora is disturbed, most usually as a result of taking antibiotics. Although there is no particular cause for alarm, it is recognised that reducing the risks of transmission of *C. difficile* in the home is important for a number of reasons:

- When patients who are still infected or colonised with *C. difficile* are discharged from hospital back to their homes, the organism may be transmitted to other family members or contacts, or can be disseminated into the home environment where it can survive for significant periods. While a patient may recover from a *C. difficile* infection, re-infection can occur if they are exposed to the organism either from another family member who has become colonised, or from surface contamination persisting in their own home environment.

In addition, although carriage of *C. difficile* amongst healthy family members is not a risk in itself, there are a number of reasons why it makes sense to minimise dispersal of *C. difficile* in the home environment and reduce opportunities for exposure amongst family members, which could lead to colonisation:

- When someone in the home requires a course of antibiotic treatment, this person is at increased risk of developing CDAD if they are a carrier of *C. difficile*, or are exposed to it via other family members, or if spores persist in their home environment.
- When a family member who is a carrier of *C. difficile* is admitted to hospital they are at increased risk of developing CDAD where they undergo antibiotic therapy or other treatments that destabilise the bowel.
- When a family member who is a carrier of *C. difficile* is admitted to hospital they are a source of infection and may transmit the micro-organism to other patients.

- When a family member who is a healthcare worker becomes colonised with *C. difficile* at home, they may transmit the organism to patients in the healthcare setting where they are employed.

These risks are exacerbated by the fact that, once it is allowed to become "endemic" in the home environment, it can persist for very long periods of time and can be problematic to eradicate.

Home hygiene practices that can be used to limit the transmission of *C. difficile* are considered in section 6.

KEY POINTS

Clostridium difficile is an anaerobic, rod shaped Gram-positive bacterium that exists in two forms: an active, vegetative form that causes disease, but cannot survive in the environment for prolonged periods, and a dormant spore form, which can survive in the environment for prolonged periods, but does not cause disease.

C. difficile causes colitis, an inflammatory bowel condition. *Clostridium difficile*-associated disease (CDAD) may even be life-threatening in severe cases.

C. difficile has now been established as the leading cause of hospital-acquired infectious diarrhoea in adults, but CDAD may also occur outside of hospitals.

Persons at higher risk include the elderly, and those who have undergone treatment that may impair or disrupt the microflora of the intestine (such as therapy with certain antibiotics, immunosuppressants, antacids, and gastric acid suppressants, or surgery). The antibiotic or other treatment disrupts the other bacteria that are normally living in the colon and prevent *C. difficile* from transforming into its active, disease-causing form. When *C. difficile* transforms into its active form, some but not all strains of *C. difficile* produce toxins that inflame and damage the colon causing diarrhoea of varying severity.

Chain of transmission of *C. difficile* in the home

Source of infection in the home: people who are colonised or have CDAD, domestic animals and uniforms of healthcare workers.

Shedding and survival: *C. difficile* is shed in faeces from an infected person or someone who is carrying the organism in their gut. *C. difficile* can survive in the environment in its dormant spore form for very long periods of time. Contamination of the environment is thought to be a major factor in the spread of the organism.

Spread: *C. difficile* is readily transferred in the home during normal daily activities via hands, cleaning cloths and a range of surfaces, including hand and body contact surfaces. Transfer can also occur via clothing and household linens.

Way in: for colonisation of the gut with *C. difficile* to occur, the organism must be consumed orally. This can occur by direct hand–to-mouth transfer, or via food or water which becomes contaminated e.g via the hands of the food preparer.

The risks associated with transmission of *C. difficile* in the home and community are relatively small, but reducing the risks of transmission of *C. difficile* from a known infected person is important to avoid risk of re-infection. Although carriage of *C. difficile* amongst healthy family members is not a risk in itself, there are a number of reasons why it makes sense to reduce opportunities for exposure amongst family members, which could lead to colonisation.

5. EXTENDED-SPECTRUM ß-LACTAMASE *ESCHERICHIA COLI* (ESBLS)

5.1 Characteristics of *Escherichia coli*

Escherichia coli is a rod-shaped Gram-negative bacterium which is found in large numbers in the normal gut of all humans. There are many different strains of *E. coli* with different characteristics, all of which are constantly circulating in the community and evolving into new strains. *E. coli* can colonise the human gut without causing any symptoms, but is an opportunistic pathogen, which can cause disease in situations where it gains access to a susceptible person, e.g. via the urinary tract. *E. coli* is most frequently associated with bacterial sepsis (bacteraemia), neonatal meningitis, infections of the urinary tract and gastroenteritis in travellers to countries with poor hygiene. Most infections (with the exception of gastroenteritis) are endogenous and come from patients' own gut flora. Invasion of the urinary tract occurs by transfer from faeces (which may sometimes occur by cross infection as well as by self-infection) and can lead to infection, which mainly occurs in people who are more vulnerable to infection.

E. coli is one of the most common bacteria causing gastrointestinal and urinary tract infections (UTIs), which can sometimes progress to cause more serious infections such as life threatening bacteraemias. It is the most common agent causing urinary tract infections and the second most common agent causing bacteraemia. Strains of *E. coli* that cause gastroenteritis can be divided into four groups, namely enterotoxigenic, enteroinvasive, enteropathogenic and enterohaemorrhagic. *E. coli* O157:H7, which first became a concern some 10 years ago, belongs to the enterohaemorrhagic group. It is characterised by the ability to produce a verocytotoxin that causes severe abdominal pain and bloody diarrhoea. There is no evidence to suggest that ESBL-producing strains of *E. coli* are present in the community that cause gastroenteritis.

5.1.1 Extended-spectrum ß-lactamase (ESBL) *E. coli*

ESBL (extended-spectrum ß-lactamase) producing *E. coli* are antibiotic resistant strains. In most respects they are no different from other stains of *E. coli* in that they can be harboured as part of the normal bowel flora and can cause urinary tract infections, bacteremia and meningitis in susceptible individuals. A key feature of these strains is that they carry specific genes that enable them to produce enzymes that destroy a large number of common antibiotics, making the infections they cause very difficult to treat. In many instances, only two oral and a very limited group of intravenous antibiotics remain effective. ESBL-producing strains of *E. coli* were first noted in 2003 when South East and West Midlands regions of England reported to the Health Protection Agency about the appearance of infections with highly cephalosporin-resistant strains of *E. coli*, some of which were thought to have arisen in the community. As infections with such strains of *E. coli* were rarely reported in England, and virtually never from the community, this represented a new trend.

The resistance of these bacteria is due to the production of a particular class of extended-spectrum ß-lactamase enzymes (ESBLs), called CTX-M, which attack and destroy ß-lactam antibiotics (penicillins and cephalosporins) thereby conferring resistance. Most CTX-M-producing *E. coli* are resistant to multiple antibiotics, including ampicillin and the cephalosporins. Frequently, they are also resistant to other antibiotics such as quinolones and trimethoprim. As these are some of the most important and widely used classes of antibiotics, there are limited options for oral treatment of these infections.

ESBL-producing microbes are not new and were first recognised in the 1980s. The new strains, however, produce a particular type of ESBL, the CTX-M type, which is able to degrade a wider range of cephalosporin antibiotics. Earlier ESBLs belonging to the CTX-M family were largely identified in Klebsiella, and were almost exclusively associated with hospitalised patients.

As stated above, UTIs and bacteraemia caused by *E. coli* can be life-threatening, which is why the emergence of the ESBL-producing strains is a serious concern. Early epidemiological studies revealed that many patients (often elderly and with serious illnesses) infected with CTX-M-producing *E. coli* subsequently died. The Health Protection Agency has reported a high mortality rate, with 28 deaths among the first 105 cases in one heavily affected Trust[150]. Clinical analysis of patients who died indicated that the infection probably contributed directly to the death in 19% of cases. However, the majority of those who died were elderly and also had underlying health problems.

5.2 Hospital and community-acquired ESBL-producing *E. coli* infections

Of particular concern is the fact that CTX-M ESBL-producing *E. coli* have now become widespread in England as a cause of urinary tract infections and bacteraemia. Their emergence has been rapid and recent. According to a recent HPA report, these strains were unrecorded in the UK prior to 2000, but there has been a subsequent increase in the number of ESBL-producing *E. coli* infections in England. The data published by Woodford et al[151]. suggest that the ESBL-producing *E. coli* strains have become widely disseminated through the UK, although outbreaks have been focused in specific areas such as Shrewsbury and Southampton.

One of the concerns is that these strains are spreading not only in hospitals, but also in the community. Woodford et al. in 2004[151] showed that of 291 of 500 isolates of ESBL-producing *E. coli* from infected patients sent to the UK Reference Laboratory, about 25% were from patients in the community. Most infections reported to GPs in the community, as in hospitals, were in elderly people or others with underlying medical conditions. In some cases, patients had been recently hospitalised, which means that the individual may have become colonised or infected whilst in the hospital. For some community cases however, there were no apparent risk factors.

There is evidence to show that ESBL-producing strains are carried in faeces. HPA reports that screening of diarrhoea samples in one hospital suggested faecal carriage of ESBL-positive *E. coli* in 4.6% of acute hospital in-patients and 2.6% of patients in the community. Munday et al[152]. carried out a study in 2003 to detect the presence of ESBL-producing Enterobacteriaceae within the faecal flora of both community and hospital-based patients in York in which 1,000 faecal samples from community and hospital-based patients were submitted to screening for diagnosis of diarrhoeal disease. Of these, 565 were from general practice (community) patients, 394 from hospital inpatients, 20 from hospital outpatients and 21 from retirement homes/long-stay hospices. The relative distribution of ESBL-positive isolates from the hospital and community was 1.4 to 1. These included nine *E. coli*, seven *Enterobacter cloacae*, four *Citrobacter freundii* and a single isolate each of *Klebsiella* spp. and *Salmonella* spp. The overall prevalence of ESBL in isolates of Enterobacteriaceae from York was 1.9%. ESBL-producing isolates were found in both the community and hospital, with the CTX-M type most common.

Livermore and Hawkey[153] suggest that the implications of gut carriage as reported in the York study (and also in a recent study in Spain) is that CTM-X producing *E. coli* strains have now entered via the food chain into the healthy community producing a reservoir of colonised healthy individuals, thereby increasing the risk of transmission to vulnerable groups.

Lefebvrea et al. 2006[123] evaluated the prevalence of zoonotic agents in a group of 102 dogs from Ontario, Canada. Zoonotic agents were isolated from 80 out of 102 (80%) animals. The primary pathogen was *Clostridium difficile*, which was isolated from 58 (58%) faecal samples; ESBL-producing *E. coli* was isolated from one (1%) dog, while extended-spectrum cephalosporinase-producing *E. coli* were isolated from three (3%) dogs.

Further research is needed to answer questions about the sources of the current outbreak, why and how it has spread so rapidly, and why it sometimes affects patients in the community, without the usual risk factors. A case control study is currently underway in London and the South East regions to further investigate risk factors for community-acquired urinary tract infection with ESBL-producing *E. coli*, which may answer some of these questions.

5.3 Understanding the chain of infection for *E. coli* and ESBL-producing *E.coli* in the home

In the following sections we evaluate the chain of infection in the home in relation to *E. coli* to understand how and when it may occur in the home, and how it is spread such that family members become exposed, colonised and/or infected. It is reasonable to assume that the chain of infection for ESBL-producing strains is no different than that of the "parent" *E. coli* strains.

5.3.1 Sources of *E. coli* and ESBL-producing *E. coli* in the home

The major sources of *E. coli* in the home are people, all of whom are carrying one or more strains of *E. coli* in their gut, in addition to domestic animals. Although the evidence suggests that a small but increasing number of healthy people in the community must now be carrying ESBL-producing *E. coli* as part of their normal bowel flora, the overall prevalence in the community is relatively low. Although little information is available on its prevalence in domestic animals, isolation of ESBL-producing *E. coli* from household pets has been reported.

5.3.2 Shedding, survival and spread of *E. coli* and ESBL-producing *E. coli* in the home

E. coli is shed in faeces from someone who is harbouring the organism in their gut. *E. coli* is a species that typically cannot grow and multiply outside a human or animal host. Unlike *S. aureus* and *C. difficile*, it has a relatively limited ability to survive on hands, cleaning cloths and environmental surfaces, but can however survive for short periods on hands and other dry surfaces in sufficient numbers to allow transmission to other surfaces.

EVIDENCE BASE

Scott and Bloomfield[65] carried out a series of tests to determine survival and transfer from a surface and a soiled cloth that was contaminated with a wild type strain of *E. coli* and then left to dry for 24 hours. Table 1 shows that during the drying period significant numbers of organisms (colony forming units, cfu) could be transferred by contact from the contaminated surface to a stainless steel bowl and to fingertips for up to four hours. Transfer to finger tips and a laminate surface also occurred when the contaminated cloth was used to wipe a clean surface. For the cloth significant transfer was observed even after drying for up to 24 hours and the data further suggest that the organisms were actually multiplying on the surface of the cloth during the drying period.

Table 1 Survival and transfer of *E. coli* via cloths, hands and surfaces

Drying period (hours)	Source of contamination			
	Surface contaminated with 200-400 cfu per contact area		Cloth contaminated with 2976 cfu/25 sq cm	
	No. of cfu transferred by contact to:		No. of cfu transferred by contact to:	
	Fingertip	Stainless steel bowl	Fingertip	Laminate surface (25 sq cm)
0	57	56	6	34
1	65	52	6	26
4	52	23	3	21
24	3	0	>200	>200
48	–	–	>200	>200

At the present time there is no data available to show how infections involving ESBL-producing strains are transmitted in the hospital or community. Transfer of *E. coli* contamination in these settings is most likely to occur via the hands, but may also involve cleaning cloths and hand contact surfaces (e.g. door handles, tap handles, toilet seats, etc.), but as yet there is no data to confirm this. For those who are carrying ESBL strains of *E. coli*, infection of the urinary tract may occur by self-infection from faecal flora.

Colonisation of the gut with *E. coli* involves transmission by the faecal-oral route, which can involve not only direct hand to mouth transfer, but also transfer via the food chain. Food can become contaminated either during handling by someone who is carrying the organism, or the organism can enter the food chain during food production prior to retail purchase. This is an area warranting further investigation, although there is little to indicate that ESBL-producing *E. coli* is prevalent in UK food animals at present. HPA report that CTX-M-producing *E. coli* were found in diarrhoeal calves at one farm in Wales, but these had CTX-M-9/14 like enzymes, and not CTX-M-15, meaning that they were unrelated to the problem in humans. The concern is that food can act as a vector to disseminate ESBL strains more widely in the community, thereby increasing the risk of infection with ESBL-producing strains for vulnerable individuals.

Although there are no data directly related to the transmission of ESBL-producing *E. coli* in the home and community, some information is available that indicates the potential for transmission of *E. coli* strains from person to person within the home. In a recent study of sporadic 0157 infections in Wales, Parry and Salmon (1998)[155] calculated that in households where there was an infected person the transmission rate to another family member was 4% to 14%, although many of the secondary cases were asymptomatic.

5.3.3 "Way in" for *E. coli* and ESBL-producing *E. coli*, and people at risk

For any strain of *E. coli* to colonise the gut, it must be consumed orally. This may occur via water or food, or by direct hand to mouth transfer. There is no data to indicate what the "infectious dose" might be, although for strains that cause gastroenteritis, such as *E. coli* O157, it is known that the infectious dose is very small. Any family member is at risk of becoming colonised with ESBL-producing strains of *E. coli*, but only if they are exposed to the organism either directly or indirectly by someone who is carrying this strain. Since *E. coli* does not survive well in the environment, transmission is more likely to occur when there is close proximity between the carrier and the recipient. This means that spread between family members is the most likely means of transmission within the community.

For an *E. coli* infection to occur, the organism must gain entry to the body, which probably occurs most often via the membranes of the urinary tract. From here it may gain access to the blood stream leading to meningitis or septicaemia. For the most part, it is believed that an individual becomes infected by transfer of *E. coli* from their own bowel flora, but cross infection from other family members via hands and surfaces is also possible. There is no data that might indicate what the "infectious dose" might be. Indications are that infection from exposure to *E. coli* is most likely to occur in those who are immunocompromised. Patients who are catheterised are at particular risk of developing *E. coli* urinary tract infections. In general women are more at risk of urinary tract infections because their urethra is shorter in length.

5.4 Risks associated with ESBLs in the community

In the home environment family members are only at risk of becoming colonised or infected with ESBL-producing as opposed to non-ESBL-producing E.coli strains in situations where there is another family member or a pet carrying the resistant strain. Since the majority of urinary tract infections from *E. coli* involve self-infection from the gut flora, the key to reducing the impact of these ESBL-producing strains would appear to lie in reducing the circulation of this organism within the healthy community. At the present time, there is relatively limited understanding about the origins and epidemiological properties of ESBL-producing strains of *E. coli*. with which to formulate strategies for preventing spread. However it is reasonable to assume that as with *S. aureus* and *C. difficile*, poor hygiene practice amongst family members in the home may have a role in facilitating the spread of this strain amongst family members and in the immediate community.

KEY POINTS

Escherichia coli is a rod-shaped Gram-negative bacterium that is found in large numbers in the normal gut of all humans. There are many different strains of *E. coli* with different characteristics, all of which are constantly circulating in the community and evolving into new strains.

Most infections (with the exception of gastroenteritis) are endogenous and come from patients' own gut flora. Invasion of the urinary tract occurs by transfer from faeces (which may sometimes occur by cross infection as well as by self-infection) and can lead to infection.

Infection from *E. coli* is most likely to occur in those who are immunocompromised and in individuals who are catheterised; women are also at higher risk of urinary tract infections from *E. coli* because their urethra is shorter in length.

E. coli infections are most frequently associated with bacterial sepsis (bacteraemia), neonatal meningitis, infections of the urinary tract and gastroenteritis in travellers to countries with poor hygiene. *E. coli* is one of the most common bacteria causing gastrointestinal and urinary tract infections (UTIs), which can sometimes cause more serious infections such as life threatening bacteraemias.

ESBL (extended-spectrum ß-lactamase) producing *E. coli* are antibiotic resistant strains of *E. coli* which are capable of producing enzymes that destroy a large number of common antibiotics, including ampicillin, cephalosporins, quinolones and trimethoprim, making the infections they cause very difficult to treat.

The resistance of these bacteria is due to the production of a particular class of extended-spectrum ß-lactamase enzymes (ESBLs), called CTX-M, which degrade penicillins and cephalosporins.

Of particular concern is the fact that infections resulting from CTX-M ESBL-producing *E. coli* have become widespread in England both in hospitals and in the community.

Chain of transmission of *E. coli* in the home

Source of infection in the home: the major sources of *E. coli* in the home are people, all of whom are carrying one or more strains of *E. coli* in their gut, in addition to domestic animals. Although the evidence suggests that a small but increasing number of healthy people in the community must now be carrying ESBL-producing *E. coli* as part of their normal bowel flora, the overall prevalence of this strain in the community is relatively low.

Shedding and survival: *E. coli* is shed in faeces from someone who is harbouring the organism in their gut. *E. coli* is a species that typically cannot grow outside a human or animal host. It has a relatively limited ability to survive on hands, cleaning cloths and environmental surfaces, but can survive for short periods on hands and other dry surfaces in sufficient numbers to allow transmission to other surfaces.

Way in: for any strain of *E. coli* to colonise the gut, it must be consumed orally. This may occur via water or food, or by direct hand-to-mouth transfer. For the most part, it is believed that an individual becomes infected by transfer of *E. coli* from their own bowel flora, but cross-infection from other family members via hands and surfaces is also possible.

At the present time, there is relatively limited understanding about the origins and epidemiological characteristics of ESBL-producing strains of *E. coli*, but it is reasonable to assume that as with *S. aureus* and *C. difficile*, poor hygiene practice amongst family members in the home may have a role in facilitating the spread of this strain amongst family members and the immediate community.

6. REDUCING THE RISKS OF TRANSMISSION OF METHICILLIN RESISTANT *STAPHYLOCOCCUS AUREUS* (MRSA), *CLOSTRIDIUM DIFFICILE* AND ESBL-PRODUCING *ESCHERICHIA COLI* IN THE HOME AND COMMUNITY - DEVELOPING A RISK-BASED APPROACH TO HOME HYGIENE

The data presented in sections 3, 4 and 5 of this report indicate that, for all three species, family members living at home who are infected or who are carriers of these organisms are quite frequently reported in the scientific literature. Despite this, however, the available data indicates that the overall prevalence of infected people or carriers in the total UK community is relatively low. Notwithstanding, when these pathogens are introduced into the home by someone who is infected or is a carrier, or via domestic animals, there is significant risk of other family members becoming colonised or infected. This is most evident for species such as *S. aureus* and *C. difficile*, which are both readily dispersed from a colonised or infected person, and can also survive on environmental surfaces for very long periods of time. Although clinical infection is usually confined to those family members where there is a specific predisposing factor, both colonisation and infection in the home contributes to the circulation of these species in the community.

6.1 Breaking the chain of transmission of infection in the home

In sections 3, 4, and 5 we evaluated how the various pathogens under consideration in this report are introduced into the home, and the chain of events that can lead to a family member becoming colonised or infected. Understanding the chain of infection in the home is key to devising policies that can reduce the risks of spread. The simple principle is that, if one link in the chain is broken, an infection cannot take hold. In practice, since pathogens may be transmitted by more than one route, and because it is impossible to achieve effective compliance (e.g. people do not always wash their hands when they should, and when they wash their hands they do not always do it properly), it is usual to promote intervention at several points that are critical for transmission.

In this section the procedures that can be used to break the chain of infection are considered with specific reference to the organisms under consideration in this report:

- **Isolating the source of germs** – To an extent it may be possible to keep an infected person away from other family members
- **Limiting the way out for germs** – Dissemination of germs from an infected person can be limited by processes such as keeping infected wounds covered and disposing of dressings safely. Safe disposal of faeces is vital for preventing the spread of pathogens carried in the gut
- **Breaking the spread of germs** – The optimum approach to breaking the spread of germs is through "targeted hygiene", which is described later in this section
- **Limiting the way in for germs** – For organisms such as *S. aureus* that infect through the skin, the chance of microbes entering the body can be reduced by covering cuts and wounds. Good hygienic practices are vital to prevent infection when handling catheters, drainage tubes and wounds. Food hygiene is key to preventing spread of germs transmitted via an oral route
- **Protecting people at extra risk** – To an extent, it may be possible to protect those at higher risk by keeping them away from infected family members

There will always be germs around that contaminate people, pets, food and surfaces and there will always be people who are more susceptible than others to infection. To an extent, we can limit the exit and entry of germs from and into the body, but the one link that we have most control over is the method of spread. Preventing the spread of infection is achieved by good hygiene.

6.2 Developing a risk-based approach to home hygiene

As part of its work to promote better understanding of hygiene and better hygiene practice, the International Scientific Forum on Home Hygiene (IFH) has produced guidelines and training materials on home hygiene practice[156, 157, 158]. A key feature of the IFH approach to home hygiene is that it recognises the need to look at hygiene holistically from the point of view of the family and the range of problems they face in order to reduce infectious disease (ID) risks.

By encouraging the concept that the home is a setting in which a range of human activities occur, including food hygiene, personal hygiene (particularly hands) and hygiene related to care of vulnerable groups, and that home hygiene is a series of interrelated procedures based on the same underlying microbiological principles, this provides the opportunity for a rational approach based on risk assessment and risk management. Risk management (also known as HACCP or Hazard Analysis Critical Control Points) is now the accepted approach for controlling microbial risks in food and other manufacturing environments and is

becoming accepted as the optimum means to prevent such risks in home and hospital settings. In the past few years, research focussing on the home has given a better understanding of how ID spreads in the home environment, and how the risks can be reduced. These data have been used to develop a risk management approach to hygiene, which, when applied to the home, has come to be known as 'targeted hygiene'[159].

The IFH risk approach to home hygiene initiates with the premise that homes always contain potentially harmful microbes from people, pets, food, and other sources. Therefore ID prevention is not about eradication, but about targeting measures in the places and at the proper time, in order to limit the risks of exposure. In applying a risk-based approach to hygiene, the first step is hazard characterisation, which involves identifying the sources of pathogens in the home, and whether and when they are likely to be present in numbers that represent a risk (an infectious dose). The second stage is risk assessment, which depends on considering this data together with an assessment of the probability of human exposure to the hazard as a result of the spread of these agents via hands and other surfaces, or by direct person-to-person contact. Hygienic cleanliness (reducing the level of contamination to a level that does not pose significant risk) is applied at critical points where the risk of infection transmission is significant.

As stated above, pathogenic and potentially (or opportunistic) pathogenic species are introduced continually into the home on people, pets, and insects, in food, water, and sometimes via the air. These are the major sources of infection. Additionally, sites where stagnant water accumulates such as sinks, U-bends, toilets and cleaning cloths can support microbial growth and become a source of infection. It is also entirely possible that healthcare workers may bring organisms such as MRSA and *C. difficile* into the home on their clothing, particularly in situations where uniforms are brought home to be stored or for laundering. From these facts it is possible to assess which surfaces represent the greatest risk in terms of the probability of spread and human exposure (i.e. which surfaces have a high risk of disseminating contamination such that family members become exposed). These represent the "critical points" or the situations where hygiene interventions are likely to be most effective in reducing the risks of transmission. A risk management approach can be achieved by grouping sites and surfaces in the home into a number of categories: reservoir sites, reservoir/disseminators, hands, contact surfaces, laundry and "other surfaces" (Table 2) (Bloomfield and Scott 1997[160], Bloomfield 2002[159]).

- Harmful microbes are likely to occur on the **hands** of people who are designated carriers. This applies not only to carriers of skin flora species such as *S. aureus*, but faecal carriers of pathogens are of equal concern, particularly following toilet visits. Pathogens are also likely to occur on the hands of any family member following contact with contaminated food, people, pets or other contaminated surfaces such as door-, tap- and toilet-flush handles. Hand hygiene must be considered as key to breaking the chain of transmission of infection in the home as in other settings.

- For **potential reservoir sites** such as sink U-bends or toilets which provide an ideal environment for microbial growth, although the probability of finding pathogens in the toilet is high, the risk of transfer under "normal" conditions is relatively small – but can increase considerably in certain situations (e.g. where someone has very loose/fluid diarrhoea). When someone has fluid diarrhoea, toilet flushing can produce splashing or aerosol formation that can transfer contamination to contact surfaces around the toilet[161, 162].

- Since **reservoir/disseminator sites** such as wet cleaning cloths carry a high risk of transfer and thus exposure, it is imperative that these are decontaminated in a suitable manner.

- Although the probability of contamination for **hand contact and food preparation surfaces** is relatively much lower, it is still significant, particularly following preparation of raw food or after contact with faecal material. Since there is constant risk of cross contamination, hygiene measures are critical for these situations.

- Where an infected individual or carrier is present in the home (or where people who work in healthcare settings bring protective clothing home for laundering) **laundry** may become contaminated. These organisms represent an exposure risk mainly to those handling soiled laundry, but there is also potential for transfer of contamination between soiled clothing and other items during the laundering process.

- **Floors, walls, furniture etc**. may become contaminated, but the risks are mainly due to those pathogens that can survive under dry conditions. In general floors are considered relatively low risk, but where there is known contamination e.g. soiling of floors by pets, there may be some risk to crawling infants who play on the floor. Cleaning of floors without vacuum extraction can also cause re-circulation of dust-borne pathogens onto surfaces that come into contact with hands and food.

Table 2. Developing a risk approach to hygiene in the domestic setting

Site(s)	Chance of germs being present	Risk of spread of germs	Assessment of need for a hygiene procedure
Reservoirs (Toilets, U-tubes, etc.)	Highest	Variable	Relatively little except where known high risk (e.g. Shigella spp. Outbreak)
Reservoir/disseminators (wet cloths & cleaning utensils)	Highest	Constant	Always
Hands	Sometimes	Constant	Always`
Hand, food, water contact surfaces	Sometimes	Constant	Always
Laundry	Sometimes	Occasional	Known high risk
Floors, walls, etc.	Low	Occasional	Relatively little except where known risk (e.g. spillage)

Based on this approach and using the available data, as reviewed in sections 3, 4 and 5 of this report, it is possible to identify critical control points for preventing transmission of each of the three organisms under consideration.

6.2.1 Methicillin resistant *Staphylococcus aureus*

The data reviewed in section 3.5 shows that *S. aureus* is shed constantly from the skin surface on skin particles, from a carrier, sometimes in very large numbers. As stated above, MRSA may be brought into the home on the clothing of family members who are healthcare workers (or even cleaning staff), who come into contact with infected or colonised patients or in their environment during daily activities. Although *S. aureus* does not usually multiply in the home environment, even in situations where there is adequate moisture, an important characteristic is its ability to survive for in significant numbers for several days on dry surfaces. As stated previously, the number of organisms required to cause infection varies but is usually lower for vulnerable individuals compared to healthy family members; as little as 10^2 organisms may be sufficient where the skin is occluded or traumatised, and perhaps even less if the skin is sutured.

The data suggest that MRSA is transferred easily from one surface to another on dust and skin particles either by contact or via air. When there is an MRSA shedder in the home, organisms can be found on hands and also on any environmental surface including walls, baths, basins, floors and furnishings. Other surfaces where it is commonly found are surfaces that come into close contact with the body, including clothing (particularly underclothing), towels, facecloths, linens and mattresses, and hand contact surfaces such as pens and computer keyboards.

This suggests that the critical control points for preventing transmission of MRSA are the hands, cleaning utensils (including cloths, mops, dusters, brushes, etc.) and hand and body contact surfaces, together with clothing and linens such as bed linen, towels and facecloths, which come into direct contact with the body.

Since the "portal of entry" for MRSA infection is the skin, particularly if damaged, personal hygiene including the care of cuts abrasions and other wounds is important. Since direct person-to-person contact is a causative factor in transmission of MRSA, particularly CA-MRSA in children and adults during sport and play, encouraging good hygiene habits such as not sharing towels, toothbrushes or other items is also important.

MRSA quite frequently occurs on floor surfaces. Although these surfaces are unlikely to cause infection by direct contact, accumulation of dust and skin scales in the home environment increases the risks of recirculation of MRSA back onto hand and body contact surfaces if cleaning is carried out without dust extraction.

6.2.2 *Clostridium difficile*

The data reviewed in section 3.5 shows that *C. difficile* is introduced into the home via infected individuals or asymptomatic carriers, and possibly via domestic animals, which is shed in faeces. Since people who develop *C. difficile*-associated disease have diarrhoea, which is often explosive, this increases the risk of spread. *C. difficile* may also be brought into the home on the clothing of family members who are healthcare workers (or even cleaning staff), who have contact with infected or colonised patients or their environment in their day-to-day work.

To a greater extent even than *S. aureus*, *C. difficile* can survive in the environment in significant numbers for days or even weeks on surfaces. As stated previously, the "dose" of *C. difficile* required to initiate CDAD in patients undergoing antibiotic therapy may be as little as one or two spores.

The potential for contamination of the home environment by *C. difficile* is confirmed by data reviewed in section 3.5 which show that, in a hospital setting, where there is an infected person or a carrier of *C. difficile*, the organism is spread extensively to environmental surfaces where it can survive for very long periods of time. Items and/or surfaces that may be contaminated included furniture, bed frames, bedding, floors, carpets, toilet seats, sinks and other bathroom sites, linens, telephones, fingernails, rings and nappy buckets.

The critical control points for preventing transmission of *C. difficile* in the home are the hands, cleaning utensils (including cloths, mops, dusters brushes etc) and hand contact surfaces. There is also potential for ingestion via contaminated food, which means that food contact surfaces are also critical points. Clothing, particularly underclothing, is also a potential risk; transmission can occur via the hands of the person handling the laundry. The risk applies both to soiled laundry and to laundry that is not properly laundered to kill or remove *C. difficile* spores. Floors in particular can become heavily contaminated with *C. difficile*. Although these surfaces are unlikely to cause infection by hand to mouth transfer, accumulation of dust in the home environment will increase the risks of recirculation of *C. difficile* onto hand and food contact surfaces, if cleaning is carried out without dust extraction.

Toilets can represent an infection risk for transmission of *C. difficile* in situations where the infected person has diarrhoea. A number of studies involving enteric pathogens or indicator organisms[161, 162] now show that where the toilet becomes heavily contaminated, flushing of the toilet can produce splashing and aerosol formation, which settles out on surfaces in the toilet area. The immediate surfaces of the toilet, i.e. the toilet seat, toilet lid, toilet bowl and flush handle, are particularly likely to be contaminated.

6.2.3 ESBL-producing *E. coli*

The data reviewed in section 4.5 shows that ESBL-producing *E. coli* is introduced into the home via people who are infected or who are asymptomatic carriers of the organism. The organism is shed in faeces from anyone who is carrying the organism in their gut.

E. coli is a species that typically cannot grow and multiply in the environment outside a human or animal host. Unlike *S. aureus* and *C. difficile* it also has relatively limited ability to survive on hands and environmental surfaces, but can survive for short periods on these surfaces in sufficient numbers to allow transmission to other surfaces, to food, or from hand to mouth. There is little to indicate the numbers of organisms that are required to cause infection.

Although there is at present scanty data showing how this organism is spread in the community, transmission of ESBL-producing *E. coli* in the home is most likely to occur via the hands and cleaning cloths or via hand contact surfaces (e.g. door handles, tap handles, toilet seats, etc.), which thus represent the critical control points. There is also a possibility of transfer via food as a result of poor food hygiene. Clothing, particularly underclothing, is a potential risk, particularly to the person handling the soiled laundry, but the risks are likely to be insignificant once the laundry is thoroughly dried.

6.3 Interrupting the chain of infection transmission in the home

A key to reducing the transmission of pathogens such as *S. aureus*, *C. difficile* and *E. coli* in the home is the application of timely and effective hygiene procedures in places where there is significant risk, in order to break the chain of transmission. Since the "infectious dose" for some pathogens can be relatively small, particularly in relation to people with impaired immunity to infection, intuitively one must argue that, in at-risk situations, the aim should be to get rid of as many contaminants as possible. Decontamination of surfaces may be achieved either by detergent-based cleaning, the application of a "microbicidal process", (either heat or a chemical disinfectant), or a combination of both. In general, for hand hygiene and for cooking and eating utensils, all available evidence suggests that contamination can be effectively removed using soap or detergent and hot water. The function of the soap or detergent is to facilitate detachment of the organisms from the surface. The rinsing process then removes the organisms from the skin surface leaving it "hygienically clean".

All the available evidence suggests that when surfaces are cleaned with a cloth or mop without rinsing, this removes visible soiling and a large proportion of the contamination; however it still leaves behind residual contamination that can then be transferred to other surfaces via cloths and hands. This suggests that, in situations where thorough rinsing is not an option, use of a disinfectant or a heat process that kills residual contaminants is advisable. Areas where a chemical disinfectant may be required include large surfaces and surfaces such as handles that cannot be adequately rinsed.

Chemical disinfection or, for laundry, the combined action of heat and the use of a bleach-based laundry powder, is also a recommended option for cleaning cloths, mops, clothing, and linens where there is evidence that microbes become strongly attached. These conclusions are based on the results of a number of 'in-home' studies that demonstrate circumstances where soap or detergent-based cleaning routines produced only a limited effect in eliminating microbial contamination from hands and other surfaces. These are described in a 2002 review by Beumer et al[163] and in more recent studies by Cogan et al. 1999, 2002[82, 83], Barker et al. 2003, 2004[84], Exner et al. 2004[89], Kusumaningrum et al. 2003[165].

EVIDENCE BASE

One of the problems in developing hygiene policies, and determining which are the critical hygiene procedures, is the lack of quantitative data from intervention or case-control studies on their health impact. Experience increasingly shows the difficulties in conducting such studies, which stem from the very large population sizes required to produce a significant result, and the extreme difficulties in controlling variables. In many cases studies involve multiple interventions, which make it difficult to determine the separate effects of each intervention. In view of these limitations, as outlined above, IFH has developed a risk management approach to home hygiene in which the microbiological data related to each stage of the infection transmission cycle is assessed in order to identify the critical control points for preventing transmission of infection. In the previous sections, the microbiological data has been reviewed. In the final part of this section, data from relevant intervention studies is summarised. At the present time, very few intervention studies have been carried out to assess the health impact of hygiene procedures in the home.

The impact of hand hygiene

As far as hand hygiene is concerned, there is general agreement that this process is key to reducing transmission of pathogens across all settings, and this is generally well supported by data from intervention studies. As far as MRSA is concerned, there is good evidence from studies carried out in healthcare settings that hand hygiene can reduce the transmission of MRSA between patients on the hands of hospital staff, and hand washing is widely recognised as the single most important factor for prevention of colonisation and infection[166, 167]. The specific importance of hand hygiene in preventing transmission of *C. difficile* was demonstrated by Johnson et al. 1990[148] who showed that use of disposable vinyl gloves by hospital personnel for all body substance contact produced a five-fold reduction in rates of acquisition.

The impact of hand hygiene in community settings in reducing the overall transmission of pathogens transmitted by the faecal-oral route is suggested by two systematic reviews of the impact of hand washing in community settings[168, 169].
Curtis and Cairncross carried out a meta-analysis of published studies to determine the impact of hand washing at critical times (e.g. after toilet visits or before handling food or feeding a child) on the incidence of diarrhoea. The study suggested that hand washing can reduce the risks of diarrhoeal diseases transmitted via the faecal-oral route by 42%-47%, although it must be kept in mind that a large number of these studies were carried out in developing country communities where access to sanitation was limited. In virtually all of the studies, hand washing was one of the factors studied, but in some studies, it was combined with other hygiene interventions.

The impact of environmental hygiene

The potential health impact of environmental cleaning and disinfection has been the subject of considerable debate in recent years, most of which has centred around a hospital setting. The benefits of routine decontamination of hospital floors was first brought into question by the studies on cleaning of hospital floors by Ayliffe and co-workers during the 1960s[170, 64]. From these studies they concluded that, because of the rapid rate with which floors became recontaminated, "at most times, daily disinfection contributes little or nothing to the bacteriological cleanliness of ward floors except in area such as ICU where the environment is protected from recontamination". These conclusions were later re-inforced by data from US hospitals during the 1970s and 1980s (Maki et al. 1980[171], McGowan 1981[172]) and other studies[173, 174] which suggested that although control procedures could be used to reduce the incidence of contamination in the hospital environment, there was no evidence of any reduction in the incidence of infection.

Strategies to control and prevent the transmission of MRSA, *C. difficile* and other pathogens in hospitals are currently under review, with increasing pressure to adopt a risk management approach to hospital hygiene[175, 176]. Whilst good infection control practices, such as compliance with hand hygiene, enhanced screening, patient isolation and prudent use of antibiotics, are all considered important strategies, there is increasing emphasis on the need for environmental decontamination, and for more

effective methods of environmental decontamination[79, 177, 178]. Studies involving microbiological sampling methods suggests that one of the problems associated with environmental decontamination is that conventional hospital cleaning protocols may be ineffective in eliminating contamination[179, 75, 135, 180, 181]. There is growing awareness that the effectiveness of environmental cleaning procedures depends as much on the way they are applied as on the products used; several workers have shown that decontamination may not be fully effective because contact between surfaces and detergent or disinfectant is inadequate[89, 182]. The need for greater emphasis on providing effective hygienic cleaning procedures for use in the home is also indicated by a number of recent laboratory and in home studies[82, 83, 84, 84, 164].

In the last few years a range of studies have been carried out suggesting that properly targeted and effective hygiene procedures play an important part in reducing the incidence of specific infections such as *C. difficile* and MRSA infections. In many of these studies, infection was brought under control by an integrated programme involving promotion of hand hygiene, environmental cleaning, hygiene education and restricted movement of patients, making it impossible to determine the separate effects of the different interventions. In two of these studies, however, reduced infection rates were achieved by moving patients to newly opened or refurbished units, while other factors (e.g. nursing staff or cleaning programmes remained unchanged and the environment was seen as the only variable factor).

The impact of environmental hygiene in reducing MRSA infections in hospitals

1. Rampling et al. 2001[78] described an outbreak of infection/colonisation with MRSA which continued for 21 months despite rigorous infection control measures. The outbreak was eventually terminated by an intervention that included "increasing the domestic cleaning hours to almost double the usual level and implementing an education programme of isolation and hand hygiene procedures". The authors stated that "we have demonstrated that a prolonged outbreak of MRSA could not be controlled until the organism was eliminated from the ward environment".

2. Schmitz et al. 1998[183] reported an outbreak of MRSA in a surgical unit involving 14 patients, which was halted by a "major cleaning programme along with improvements in the ward fabric". The authors concluded that cleaning deficiencies were an important factor in this outbreak.

3. In a district hospital, Dealler et al. 2004[184] reported increasing prevalence of MRSA colonisation in an intensive care unit (ICU) over 2 years, whereby a high percentage of patients who had been in the ward for more than 2 weeks became colonised, although no staff carriage was found. At this point, a six month refurbishment of the ICU took place, and patients and equipment were transferred to a temporary ICU. The same staff were used, and no attempt was made to carry out any extra disinfection of staff or equipment. In the new ICU, no new MRSA cases occurred for three months but gradually, the number of cases (colonisations and infections) rose until MRSA again became a common organism. When patients were returned to the refurbished unit, again no new MRSA infections or colonisation occurred for at least three months, despite multiple MRSA infections being brought into the ICU from elsewhere.

4. In the same ICU in 1995, it was found that MRSA infections and colonisations were taking place in the summer (about one case per month) but not in the winter. A ventilation fan, used only in summer, was found to be colonised with an MRSA strain indistinguishable from that isolated from the patients. When the fan was switched off in the summer of 1996, no new MRSA infections occurred on the ward that year.

The impact of environmental hygiene in reducing *C. difficile* infections in hospitals

1. Wilcox et al. 2003[136] carried out a two year study on two wards to determine the effects of cleaning with neutral detergent and with hypochlorite disinfectant in reducing the incidence of CDAD. A total of 1,128 environmental samples were examined, 35% of which grew *C. difficile*. The environmental prevalence of *C. difficile* was similar during the two different cleaning regimens. Use of hypochlorite disinfectant 1000 ppm available chlorine on ward X was associated with a significant decrease of CDAD incidence on ward X, from 8.9 to 5.3 cases per 100 admissions, with 17 fewer cases of cytotoxin-positive diarrhoea than during detergent-based cleaning, but there was no significant effect on ward Y. The authors concluded that the use of hypochlorite for environmental cleaning may reduce incidence of CDAD, but emphasised the potential for confounding factors.

2. Cartmill et al. 1994[132] described a six month *C. difficile* diarrhoea outbreak in three Manchester hospitals involving 175 patients in 34 wards. The pattern of spread suggested that a ward index case was followed by several secondary cases. The outbreak strain extensively colonised the hospital environment. An extensive programme of infection control measures was implemented including education of staff, increased vigilance, strict enteric precautions, cohort nursing in a designated ward, rigorous cleaning procedures including emptying and 'deep' cleaning of wards where cases had occurred, restriction of staff and patient movement and restriction of antibiotic use. Subsequent to these measures there was a substantial and sustained decrease in the number of new cases.

3. In an interventional study in a bone marrow transplant unit where there was a high endemic prevalence of *C. difficile*, Mayfield et al. 2000[185] found that the incidence of diarrhoea in patients decreased significantly after substitution of a quaternary ammonium

solution by hypochlorite for environmental disinfection. When cleaning with the quaternary ammonium solution was reintroduced, the incidence of diarrhoea nearly returned to baseline levels. However, the results were not reproducible for patients on other units.

4. In an outbreak setting, Kaatz et al. 1988[131] isolated *C. difficile* from 31% of ward environmental samples. When the ward was disinfected with unbuffered hypochlorite (500 ppm available chlorine), surface contamination decreased to 21% of initial levels and the outbreak subsequently ended.

5. Struelens et al. 1991[186] reported an outbreak of *C. difficile* infection on a ward in a Brussels hospital. Intensive control measures were introduced including screening of patients, patient isolation and "meticulous" daily environmental decontamination. Surface disinfection reduced environmental contamination 4-fold. In the following 12 months the incidence of infection fell from 1.5 to 0.3 cases/1000 patient admissions.

6. Zafar et al. 1998[187] reported a 60% decrease in *C. difficile* infections (155 per year to 65 per year) over a seven year period in an acute care hospital following implementation of protective measures including education, patient isolation, promotion of hand washing, and use of a phenolic disinfectant for environmental cleaning.

In contrast with hospitals, there is little data from interventional studies to demonstrate the health impact of environmental hygiene in the home, although the studies described in section 3 demonstrate the role of environmental cleaning in the home in eliminating persistent MRSA carriage in health care workers.

The importance of a targeted approach to home hygiene is reinforced by the studies of Larsen and Duarte (2001)[188] who examined home hygiene practices and prevalence of infection amongst household members in 398 households of an inner city population in New York. The infections investigated were non-specific; infection was defined as two or more family members of the same household with the same symptoms that included fever, cough, cold, diarrhoea, vomiting, sore throat, skin infection or other infection. “Hygiene” practices studied were mostly non-targeted cleaning practices such as daily personal bathing or showering, daily cleaning of bathrooms and toilets, frequent changing of dish-sponges (1-14 days), or use/non use of antimicrobial cleaning products for these activities. Unsurprisingly only two specific “targeted” practices, using a communal laundry and not using bleach in communal laundering, were predictive of increased risk of infection transmission.

In the past decade the move towards evidence-based medicine has gained momentum. At the same time, there has been a tendency to demand that evidence from intervention or case control studies should take precedence over evidence from other forms of investigations, e.g. microbiological risk assessment approaches. In this report we have reviewed the significant amount of data using both approaches, which have been generated to determine the impact of hygiene procedures in preventing the transmission of infection. These provide valuable insights, but in many cases it is recognised that data from interventional studies designed to give direct measures of the health impact are far from conclusive, with numerous confounding factors, and in some cases the findings are inconsistent with microbiological data (e.g. microbiological data which strongly suggests that environmental surfaces may be involved in the spread and transmission of pathogens and increase the risk of infection). It is well recognised that a more rigorous approach to hygiene interventional studies is needed, and a guidance document on design and reporting of intervention studies is currently presented for consultation (http://www.bsac.org.uk/_db/_documents/Orion_5_(3).doc). In the following sections we have developed guidance for reducing the risks of transmission of MRSA, *C. difficile* and ESBL-producing E.coli strains in the home environment. In developing this guidance we have followed the precautionary principle (which is now incorporated in some European legislation) that lack of direct evidence of a health impact from applying a particular hygiene procedure is not evidence of no effect.

KEY POINTS

For a family member to contract an infectious disease, a chain of events has to take place. The chain as applied to the home has five essential links, all of which have to be in place for an infection to pass from its original source to another person. If one link in the chain is broken, an infection cannot take hold.

In practice, since pathogens may be transmitted by more than one route, and because it is impossible to achieve effective compliance (e.g. people do not always wash their hands when they should, and when they wash their hands they do not always do it properly) it is usual to promote intervention at several points that are critical for transmission.

Strategies that can be used to break the chain of infection are

- **Isolating the source of germs** – It may be possible to keep an infected person away from other family members
- **Limiting the way out for germs** – Dissemination of germs from an infected person can be limited by processes such as keeping infected wounds covered and disposing of dressings in a safe manner. Safe disposal of faeces is vital for preventing the spread of pathogens carried in the gut
- **Breaking the spread of germs** – The optimum approach to breaking the spread of germs is through "targeted hygiene"
- **Limiting the way in for germs** – For organisms such as *S. aureus* that infect through the skin, the chance of microbes entering the body can be reduced by covering cuts and wounds. Good hygienic practices are vital to prevent infection when handling catheters, drainage tubes and wounds. Food hygiene is key to preventing spread of germs transmitted via an oral route
- **Protecting people at extra risk** – To an extent, it may be possible to protect those at higher risk by keeping them away from infected family members

The link that we have most control over is the method of spread. Preventing the spread of infection is achieved by good hygiene.

Good hygiene is achieved by adopting a risk assessment approach (based on HACCP) in order to identify critical pathways for transmission of pathogens in the home. Hygienic measures (which involve reducing the level of contamination to a level that does not pose significant risk) are then applied at critical points at the proper time in order to limit the risks of spread exposure of family members to these organisms.

In order to reduce risks of infection from Methicillin resistant *Staphylococcus aureus* (MRSA), *Clostridium difficile* and ESBL-producing *Escherichia coli* in the home:

- The critical control points for preventing transmission of MRSA are hands, cleaning utensils (including cloths, mops, dusters, brushes, etc.), hand and body contact surfaces, together with clothing and linens such as bed linen, towels and facecloths. Good personal hygiene and care of cuts and abrasions is also important. Accumulation of dust and skin scales on surfaces including floors increases the risks of recirculation back onto hand and body contact surfaces if cleaning is carried out without dust extraction.
- The critical control points for preventing transmission of *C. difficile* in the home are hands, cleaning utensils (including cloths, mops, dusters brushes etc), hand contact and food contact surfaces, and clothing, particularly underclothing. Accumulation of dust on surfaces, including floors, increases the risks of recirculation of *C. difficile* onto hand and food contact surfaces, if cleaning is carried out without dust extraction. Toilets can represent an infection risk for transmission of *C. difficile* in situations where an infected person has diarrhoea.
- The critical control points to prevent the transmission of ESBL-producing *E. coli* in the home are most likely hands, cleaning cloths or hand contact surfaces (e.g. door handles, tap handles, toilet seats, etc.). Clothing, particularly underclothing, is a potential risk but the risks are likely to be insignificant once the laundry is thoroughly dried.

Decontamination or "hygienic cleaning" may be achieved either by detergent-based cleaning, the application of a "microbicidal process" (either heat or a chemical disinfectant), or a combination of both. In general, for hand hygiene and for cooking and eating utensils, hygienic cleaning can be effectively achieved using soap or detergent and hot water, provided this is accompanied by thorough rinsing.

In situations where thorough rinsing is not an option, use of a disinfectant or a heat process that kills residual contaminants is advisable. Areas where a chemical disinfectant may be required include large surfaces and surfaces such as handles that cannot be adequately rinsed. Chemical disinfection or, for laundry, the combined action of heat and the use of a bleach-based laundry powder, is also recommended for cleaning cloths, mops, clothing, and linens since there is evidence that microbes become strongly attached to these sources.

7. DEVELOPING ADVICE FOR CONSUMERS

The purpose of this report is to provide a clear scientific basis for communications developed by health professionals and others that are used to inform consumers and give them advice on what to do in situations where there may be a risk to members of the family.

Appendices 1, 2 and 3 contain briefing documents on each of the three organisms considered. The target audience for these documents is health professionals, particularly community health professionals, who have responsibility for advising the public on hygiene in the home. It also includes the health professional media and others who communicate directly with health professionals and the general public. The appendices summarise the key data on each organism including clinical features, prevalence in the community and how they are spread in the home. They also include a framework of practical guidance on what to do to reduce the risks transmission of these organisms.

As part of its work in developing and promoting home hygiene, the IFH has produced "Guidelines for the prevention of infection and cross infection in the domestic environment"[156, 157]. These Guidelines are based on the IFH "risk assessment" approach to home hygiene as outlined in section 6. In formulating these guidelines, the available experimental and epidemiological data on transmission of infectious agents in the home and other settings and the means of prevention was considered. In collaboration with the UK Infection Control Nurses Association, IFH has also produced a teaching/self learning resource on home hygiene for practising health professionals in the community[158]. This training package combines the practical expertise of the ICNA and the IFH's scientific understanding of how infections are spread in the home. This resource describes a targeted approach to home hygiene in simple, practical language to those who have the responsibility to teach home hygiene to the public. It contains guidance on general hygiene, hand hygiene, food hygiene, hygiene related to pets and hygiene related to care of vulnerable groups and those who are infected. The practical guidance on hygiene included in the briefing documents appended to this report is consistent with the guidance given in the IFH Guidelines, recommendations and training materials.

8. DISCUSSION, CONCLUSIONS, AND DEVELOPMENT OF COMMUNICATIONS

This report has examined three bacterial species, namely methicillin resistant *Staphylococcus aureus* (MRSA), *Clostridium difficile* and ESBL-producing *Escherichia coli*, all of which have become a significant source of public health concern. While they are primarily viewed as a source of infections acquired in hospitals, they are also increasingly seen as a source of infection in the community. In recent years, these organisms have been widely featured in the media and have become a concern to the public, particularly to those who undergo hospitalisation, and those who are involved in the care of infected family members, or family members who are more vulnerable to infection.

For all three strains, the common factor related to their emergence is the use and abuse of antibiotics in the hospital and community. In addition, for CA-MRSA the emergence of populations of antibiotic resistant strains has taken place alongside the emergence of strains that produce a potent tissue toxin. Likewise, for *C. difficile* the problem is compounded by the emergence of strains that show enhanced toxin production. It seems reasonable to assume that since pathogens are spread more readily from an infected person, acquisition of "enhanced virulence factors" gives these strains increased potential for spread in the community in preference over the parent strain.

A primary aim of this report is to better understand the extent to which these organisms are a risk to the family in a domestic setting. The data presented in sections 3, 4 and 5 suggest that, for all three species, family members living at home who are infected or who are carriers of these organisms are quite frequently reported in the literature. Despite this, the overall prevalence of infected people or carriers in the total UK community is relatively low at present, and thus the risks of becoming colonised or infected with these strains are relatively limited. However, when these strains are introduced into the home by someone who is infected or is a carrier, or via domestic animals, there is significant potential for other family members to be exposed and to become either colonised or infected. Even then, for the most part exposure to these strains is not a problem even where colonisation occurs. However, for those family members where there is a specific predisposing factor or after hospital admission for surgery or other procedures a clinical infection may result.

Although emergent strains such as HCA-MRSA and ESBLs inevitably attract public attention, a key factor in communicating with the public is to reassure them that they are not more virulent than the parent strain (i.e. they have the same ability as the parent strain in terms of colonisation of the human body and the ability to overcome host defences and cause infection). The term "superbug" refers to the ability to resist the action of antibiotics. Skin infections associated with *S. aureus* and urinary tract infections associated with *E. coli*, although unpleasant and occasionally life-threatening, are generally self-limiting. The main concern is that these strains are a source of genes that confer antibiotic resistance and that, for someone infected with a methicillin resistant or ESBL-producing strain, the ability to treat the infection can be severely compromised. For strains such as the PVL-producing CA-MRSA and the AP1/027 strains of *C. difficile*, the concerns relate more to their enhanced virulence. At the present time these strains, particularly the CA-MRSA strains, are relatively uncommon in the UK, but experience in North America and several European countries demonstrates their potential for spread.

The major concern in public health terms is that, as the proportion of people in the total population carrying these MRSA or ESBL-producing strains rather than the parent strains as part of their normal flora increases, the probability also increases that where an infection does occur, it may be due to one of these strains. Similarly, as the probability of carriage of *C. difficile* increases, there is a growing chance that someone who requires a course of antibiotic treatment may carry *C. difficile* in their gut, and is thus at risk of developing CDAD. One of the problems facing public health authorities is the fact that there is no way of knowing (without microbiological testing) who is colonised with one of these strains and it is thus difficult to monitor the rate at which this "pool of infection" may be increasing. For *S. aureus* and *C. difficile*, the problem is further compounded by the fact that these two species have a particular ability to survive for very significant periods on environmental surfaces, which significantly increases their potential to spread and colonise healthy members of the community or infect vulnerable groups.

Although the data summarised in this report indicate significant differences between the three strains, it also suggests certain common themes. From this it is possible to formulate a strategy that, if implemented, could reduce the impact of these and other emergent strains in the hospital and community. It is suggested that the key components of this strategy should include the following:

1. Antibiotic stewardship

Better control of antibiotic utilisation is vital to controlling pathogens whose spread relates to the use and misuse of antibiotics. Consideration of how this might be achieved is outside the scope of this report and will not be further discussed.

2. Preventing spread from infected family members

Preventing spread into the environment and to other family members from someone who is known to be infected has two potential benefits:

- Patients may recover from the infection, but can become re-infected if they are re-exposed to the organism. Environmental contamination is a particular risk for MRSA and *C. difficile* that can persist on environmental surfaces for significant periods of time.
- Reducing the risks of colonisation of healthy family members reduces opportunities for circulation in the community and thus keeps prevalence in the community to a minimum.

3. Protecting vulnerable groups from infection

Protecting vulnerable groups from exposure to these strains not only protects them from an infection that may be difficult to treat, but also prevents them from becoming a source of infection and inhibits circulation of the pathogen within the healthy community.

4. Reducing prevalence amongst healthy family members

Although carriage of MRSA, *C. difficile*, ESBL-producing *E. coli*, and other similar strains amongst healthy family members is not a risk in itself, there are a number of reasons why it makes sense to avoid dispersal of these organisms in the home environment and reduce opportunities for exposure amongst family members, which could lead to colonisation. For example:

- When carriers of MRSA are admitted to the hospital for surgery, there is significant risk of self infection.
- When a family member who is a carrier of MRSA or *C. difficile* is admitted to the hospital, they represent a source of infection that may be transmitted to other patients.
- When a family member who is a healthcare worker becomes colonised with MRSA or *C. difficile* at home, they may transmit the organism to patients in a healthcare setting.
- For family members carrying PVL-producing strains of CA-MRSA, colonisation of cuts and abrasions with this strain may result in serious and potentially fatal skin and soft tissue infections

The family members who are most likely to be colonised with MRSA or *C. difficile* are those who are healthcare workers or work in healthcare settings, where they may have acquired the organism from infected patients or their environment.

In situations where someone is known to be infected with or carrying a specific pathogen, or where family members need to protect against a specific pathogen (e.g. CA-MRSA), hygiene advice to the family can be based on assessment of the critical control points for preventing spread of the particular organism. In contrast, reducing the circulation of these organisms in the healthy community by reducing opportunities for spread of colonisation amongst family members and domestic animals depends on practice of good daily hygiene. Good day-to-day hygiene means adopting the IFH targeted approach to home hygiene as outlined in section 6, in the IFH Guidelines and Recommendations on home hygiene, or in the IFH home hygiene training resource[156, 157, 158]. In situations where someone is more vulnerable to infection, for the most part this still means targeted hygiene. The major difference is that, if hygiene practices are not consistently and rigorously applied, the risk of infection is much greater.

One of the major problems is persuading the public to share the responsibility and to adopt better hygiene standards as a means of minimising the spread of new and potentially more dangerous strains in the community. It is possible that, in the same way that fear of HIV (but not hepatitis) encouraged behavioural changes with regard to handling of needlesticks in hospitals, the knowledge that vulnerable groups at home are at increasing risk of acquiring infections that are resistant to treatment might also serve to motivate behavioural changes.

In recent years a significant amount of work has been carried out to evaluate hygiene behaviour in the home and develop effective methods for achieving behavioural change. Traditional approaches can raise awareness, but do not necessarily achieve the desired effects. Methods which are being used to modify behaviour are based on social marketing and community mobilisation involving education campaigns and community participation. On one hand there is evidence to suggest that the most effective way to change behaviour is based on social marketing of single messages (e.g. hand washing). However, the complexity and shifting nature of the infectious disease threat demands an approach that is not just rule-based, but is founded on more effective education. Only in this way can people better understand the threat, and adapt behaviour accordingly.

In the UK, community mobilisation activities are currently being implemented on a significant scale by the Food Standards Agency, but these are entirely focussed on one aspect of hygiene, namely food hygiene. The IFH is concerned that a particular barrier to promoting better overall standards of hygiene is the fact that public authorities tend to regard the various components of home hygiene (food hygiene, hand washing, care of vulnerable groups, water and sanitation) as separate issues. In most countries these separate aspects of hygiene are dealt with by distinct agencies, which means that the hygiene advice that the family receives is often fragmented. Advice on preventing transmission of colds and flu, for example, is given quite separately from advice on handling of food, or caring for a newborne baby or an elderly person, or someone infected with MRSA. In some cases advice on different aspects of hygiene may conflict. It also means that the community does not have a comprehensive understanding about how infectious diseases are spread in the home; thus hygiene practice is largely rule-based. This makes it difficult for hygiene knowledge to be adapted to different risks, such as those posed by pathogens with dissimilar properties and routes of transmission, or to the varying needs of different family members with various levels of vulnerability to infection. This report suggests that there are significant differences between the critical control points for preventing transmission of MRSA, *C. difficile* and ESBL-producing *E. coli* in the home setting. One of the problems about persuading people to adopt a targeted approach to home hygiene is the fact that people still tend to see home hygiene as synonymous with "getting rid of dirt" and "creating a microbe free home". Understanding targeted hygiene depends on promoting an understanding of the chain of infection transmission in the home, which provides a simple model for visualising the spread of all types of germs in the home.

Although recent scares related to SARS, avian flu and MRSA have made people more aware of the importance of hygiene, this has been somewhat offset by concepts that have been promoted in association with the hygiene hypothesis, which suggests that we may have "become too clean for our own good". From a detailed review of the available data[189, 190] IFH has concluded that although there is good evidence that reduced exposure to microbes may be associated with dysregulation of the immune system and increased susceptibility to atopic diseases, there is no evidence that this is linked to "hygiene" (i.e. things done to protect ourselves from infectious diseases). IFH believes that the targeted home hygiene approach offers consumers a rational way forward, in that it represents the optimum means to protect the family from infection, whilst at the same disturbing the balance of our human and natural environment to the least extent.

One of the problems that this report highlights is that the factors governing the emergence of new pathogens, or new strains of existing pathogens, are complex and highly unpredictable. Thus, while it is not surprising that CA-MRSA has emerged separately in a number of countries, it is not clear why these have spread more rapidly in the USA compared to European countries, other than the popularity of high contact sports such as American football in the teenage community. Similarly, surveillance data from the UK indicates that infections related to ESBLs are focussed in specific areas such as Shropshire and Hampshire, although there is no data to show why these areas are particularly affected. Another aspect to consider is the extreme "fluidity" of the situation, which is exemplified by the recent and rapid emergence of ESBL-producing *E. coli* and the 027 strains of *C. difficile*.

International and national agencies such as the WHO, CDC as well as the UK HPA, now recognise that when it comes to containing and reducing the global burden of infectious diseases, good hygiene practice is key. Indeed, in many cases, particularly when dealing with the emergence of a new pathogen, the first line of defence is implementation of good hygiene practices. The threat posed by emerging diseases such as avian influenza and SARS, which demand an immediate response, together with the ongoing threat posed by antibiotic resistance, has prompted the realisation that if infectious diseases are to be contained in a manner that is viable and sustainable, the responsibility for preventing disease transmission must be shared by the public. If this is to be achieved there is a need for greater emphasis on more appropriate hygiene education in schools and on providing the public with clear well presented information on the nature of the threat posed by infectious agents and advice on how to timely target hygiene measures in appropriate situations.

KEY POINTS

Key components of a strategy to reduce the impact of MRSA, *C. Difficile*, *E. coli* and other emergent strains in the hospital and community should include:

1. Antibiotic stewardship
2. Preventing spread from infected family members
3. Protecting vulnerable groups from infection
4. Reducing prevalence amongst healthy family members

Carriage amongst healthy family members is not a risk in itself, but there are a number of reasons why it makes sense to avoid dispersal of these organisms in the home environment and reduce opportunities for exposure amongst family members, which could lead to colonisation.

Although recent "scares" (SARS, avian flu and MRSA) have made people more aware of hygiene, this has been offset by the hygiene hypothesis, which suggests that we may have "become too clean for our own good". Although reduced exposure to microbes may be associated with increased susceptibility to atopic diseases, there is no evidence that this is linked to "hygiene".

International and national agencies now recognise that when it comes to containing and reducing the global burden of infectious diseases good hygiene practice and shared responsibility is key. If "prevention through hygiene" is to be achieved, there is a need for greater emphasis on more appropriate hygiene education in schools and on providing the public with clear well presented information.

GLOSSARY

For the purpose of this document the following definitions apply:

Microbe or Micro-organism Microbes or micro-organisms include bacteria, fungi, viruses and protozoa.

Pathogen A pathogen is a microbe or micro-organism (bacteria, virus, fungi or protozoa) that can cause an infectious disease.

Germ Commonly used term to describe a microbe or micro-organism (bacteria, virus, fungi or protozoa) that can cause an infectious disease.

Infection or infectious disease When a person becomes exposed to a pathogenic micro-organism, the organism can invade the body and cause disease. Where a disease is caused by a micro-organism it is referred to as an infection or an infectious disease.

Colonisation When a person is exposed to a microbe, it can invade the body and become part of the "resident flora" without causing an infectious disease. When a person becomes colonised with a particular strain of micro-organism he or she is often referred to as a "carrier".

Dose:response The risk of colonisation or infection following exposure to a pathogen increases as the number or organisms to which the person is exposed: the higher the number, the greater the risk of colonisation and infection. The "dose response" curve can vary significantly from one species to another. Additionally the "infectious dose" for a given pathogen is usually much lower for those who are at increased risk of infection.

Faecal-oral Infectious diseases that are shed in the faeces of an infected or colonised person or animal, and then infect another person by being swallowed, either as a result of direct hand to mouth transfer or via contaminated food or water, are said to be transmitted via the "faecal-oral route".

Chemical disinfection (European Standard EN1276) Reduction of the number of micro-organisms in or on an inanimate matrix, achieved by the irreversible action of a product on their structure or metabolism, to a level judged to be appropriate for a defined purpose.

Hygienic cleaning (IFH Guidelines for prevention of infection and cross infection in the home environment) A procedure that removes soil or organic material from an object and also reduces the number of micro-organisms on that surface to a level where there is no longer a threat to health by transmission of micro-organisms. The reduction in the number of micro-organisms is achieved by removal of the micro-organisms by detergent-based cleaning followed by rinsing, by the action of an agent which has bactericidal, virucidal or fungicidal activity, or by a combination of both processes.

Disinfectant cleaner (IFH Guidelines for prevention of infection and cross infection in the home environment) A product that removes soil or organic material from an object or surface and also causes destruction of micro-organisms through an inherent bactericidal, virucidal or fungicidal process: the combination of soil removal and destruction reduces the number of micro-organisms on that surface to a level where there is no longer a threat to health by transmission of micro-organisms.

REFERENCES

1 Memorandum on the threat posed by infectious diseases. Need for reassessment and a new prevention strategy in Germany. Rudolphe Schulke Foundation. Weisbaden: mph-Verlag GmbH, 2006.

2 Official Journal of the European Communities 1999; C195: 1-3.

3 BMA submission to the Lords Select Committee into antimicrobial resistance. London: British Medical Association, 1997.

4 Schmitz F-J, Verhoef J, Idel H, Hadding U, Heinz HP, Jones ME. Impact of hygienic measures on the development of methicillin resistance among staphylococci between 1991 and 1996 in a university hospital. J Hosp Infect 1998; 38: 237-40.

5 Kluytmans J, van Belkum A, Verbrugh H. Nasal carriage of Staphylococcus aureus: epidemiology, underlying mechanisms, and associated risks. Clin Microbiol Rev 1997; 10: 505-20.

6 Nouwen JL, Ott A, Kluytmans-Vandenbergh MF, Boelens HA, Hofman A, van Belkum A, Verbrugh HA. Predicting the Staphylococcus aureus nasal carrier state: derivation and validation of a "culture rule". Clin Infect Dis 2004; 39: 806-11.

7 Nouwen J, Boelens H, van Belkum A, Verbrugh H. Human factor in Staphylococcus aureus nasal carriage. Infect Immun 2004; 72: 6685-8.

8 Cookson BD. Methicillin-resistant Staphylococcus aureus in the community: new battlefronts, or are the battles lost? Infect Control Hosp Epidemiol 2000; 21: 398-403.

9 Naimi TS, LeDell KH Commo-Sabetti K, et al.. Comparison of community and healthcare associated MRSA infection. JAMA 2003; 290: 2976-84.

10 Diederen BMW, Kluytmans JAJW. The emergence of infections with community-associated methicillin resistant Staphylococcus aureus. J Infect 2006; 52: 156-68.

11 Bloomfield SF. Significance of biocide usage and antimicrobial resistance in domiciliary environments. J Appl Microbiol 2002; 92 (suppl): S144-57.

12 Cookson B. Clinical significance of the emergence of bacterial antimicrobial resistance in the hospital environment. J Appl Microbiol 2005; 99: 989-96.

13 Miller LG, Perdreau-Remington F, Rieg G, et al.. Necrotising fasciitis caused by community-association methicillin resistant Staphylococcus aureus in Los Angeles. N Engl J Med 2005; 352: 1445-53.

14 From the Centers for Disease Control and Prevention. Four pediatric deaths from community-acquired methicillin resistant staphylococcus aureus - Minnesota and North Dakota, 1997-1999. JAMA 1999; 282: 1123-5.

15 Frazee BW, Salz TO, Lambert L, Perdreau-Remington F. Fatal community-associated methicillin-resistant Staphylococcus aureus pneumonia in an immunocompetent young adult. Ann Emerg Med 2005; 16: 401-4.

16 Johnson LB, Louis D, Saravolatz L. Community-acquired MRSA: current epidemiology and management issues. Infect Med 2005; 22: 16-20.

17 Community-acquired MRSA Potential for even greater disaster? http://www.mrsainfection.org/community-mrsa.php.

18 Bug that came in from the cold: CA-MRSA in hospital. Hosp Infect Control 2006; April, 42-3.

19 Morgan M, E vans-Williams D, Salmon R, et al.. The population impact of MRSA in a country: the national survey of MRSA in Wales 1997. J Hosp Infect 2000; 44: 227-39.

20 Hicks NR, Moore EP, Williams EW. Carriage and community treatment of MRSA: what happened to colonised patients after discharge? J Hosp Infect 1991; 19: 17-24.

21 Sanford MD, Widmer AF, Bale MJ, Jones RN, Wenzel RP. Efficient detection and long-term persistence of the carriage of methicillin resistant Staphylococcus aureus. Clin Infect Dis 1994; 19: 1123-8.

22 Perry C, Marshall R, Jones E. Bacterial contamination of uniforms. J Hosp Infect 2001; 48: 238-41.

23 Loh W, Ng VV, Holton J. Bacterial flora on the white coats of medical students. J Hosp Infect 2000; 45: 65-8.

24 Babb JR, Davies JG, Ayliffe GA. Contamination of protective and nurses uniforms in an isolation ward. J Hosp Infect 1983; 4: 149-57.

25 Maudsley J, Stone SP, Kibbler CC, et al.. The community prevalence of methicillin-resistant Staphylococcus aureus (MRSA) in older people living in their own homes: implications for treatment, screening and surveillance in the UK. J Hosp Infect 2004; 57: 258-62.

26 Shetty A, Bames RA. Community-acquired MRSA infection in a child. J Hosp Infect 2003; 53: 315.

27 Grundmann H, Tami A, Hori S, Halwani M, Slack R. Nottingham Staphylococcus aureus population study: prevalence of MRSA among elderly people in the community. BMJ 2002; 324: 1365-6.

28 Abudu L, Blair I, Praise A, Cheng KK. Methicillin-resistant Staphylococcus aureus (MRSA): a community-based prevalence survey. Epidemiol Infect 2001; 126: 351-6.

29 Wyllie DH, Peto TEA, Crook D. MRSA bacteraemia in patients on arrival in hospital: a cohort study in Oxfordshire 1997-2003. BMJ 2005; 331: 992.

30 Ferguson CA, Saunders D, Gibb AP. Are MRSA bacteraemias all hospital acquired? J Hosp Infect 2005; 61: 178-9.

31 Kuehnert MJ, Hill HA, Kupronis BA, Tokars JI, Solomon SL, Jernigan DB. Methicillin-resistant Staphylococcus aureus hospitalizations, United States. Emerg Infect Dis 2005; 11: 868-72.

32 Eveillard M, Ernst C, Cuviller S, et al.. Prevalence of methicillin-resistant Staphylococcus aureus carriage at the time of admission in two acute geriatric wards. J Hosp Infect 2002; 50: 122-6.

33 Huang SS, Platt R. Risk of methicillin-resistant staphylococcus aureus infection after previous infection or colonization. Clin Infect Dis 2003; 36: 281-5.

34 Community MRSA in England and Wales: definition through strain characterisation. (http://www.hpa.org.uk/cdr/archives/archive05/News/news1105.htm)2005; 15 no 11: News.

35 Holmes A, Ganner M, McGuane S, Pitt TL, Cookson BD, Kearns AM. Staphylococcus aureus isolates carrying Panton-Valentine leucocidin genes in England and Wales: frequency, characterization, and association with clinical disease. J Clin Microbiol 2005; 43: 2384-90.

36 Enhanced surveillance of MRSA bacteraemia in children to commence in June 2005. CDR Weekly 2006; 15; 21; p 1 (http://www.hpa.org.uk/cdr/archives/archive05/News/news2105.htm)

37 Vandenesch F, Etienne J. How to prevent transmission of MRSA in the open community? Eurosurveillance 2004; 9: 5.

38 Dufour P, Gillet Y, Bes M, et al.. Community-acquired methicillin-resistant Staphylococcus aureus infections in France: emergence of a single clone that produces Panton-Valentine leukocidin. Clin Infect Dis 2002; 35: 819-24.

39 Witte W, Cuny C, Strommenger B, Braulke C, Heuck D. Emergence of a new community acquired MRSA strain in Germany. Euro Surveill 2004; 9: 16-8.

40 Rossney A, Morgan P, O'Connell B. Community acquired PVL-MRSA in Ireland: a preliminary report. Euro Surveill 2005; 101: 134.

41 Miklasevics E, Hæggman S, Balode A, et al.. Report on the first PVL-positive community acquired MRSA strain in Latvia. Euro Surveill]2004; 9: 29-30.

42 Wannet WJB, Heck MEOC, Pluister GN, et al.. Panton-Valentine leukocidin positive MRSA: The Dutch situation. Euro Surveill 2004; 9: 28-9.

43 Centers for Disease Control and Prevention. Methicillin-resistant Staphylococcus aureus skin or soft tissue infections in a state prison - Mississippi, 2000. MMWR Morb Mortal Wkly Rep 2001; 50: 919-22.

44 Centers for Disease Control and Prevention. Outbreak of community associated methicillin-resistant Staphylococcus aureus skin infections - Los Angeles County, California, 2002-2003. MMWR Morb Mortal Wkly Rep 2003; 52: 88.

45 Frank AL, Marcinak JF, Mangat PD, Schreckenberger PC. Increase in community-acquired methicillin-resistant Staphylococcus aureus in children. Clin Infect Dis 1999; 29: 935-6.

46 Purcell K, Fergie JE. Exponential increase in community-acquired methicillin-resistant Staphylococcus aureus infections in South Texas children. Pediatr Infect Dis J 2002; 21: 988-9.

47 Moran GJ, Amii RN, Abrahamian FM, Talan DA. Methicillin-resistant Staphylococcus aureus in community acquired skin infections. Emerg Infect Dis 2005; 11: 928-30.

48 Dietrich DW, Auld DB, Mermel LA. Community-acquired methicillin-resistant Staphylococcus aureus in Southern New England Children. Pediatrics 2004; 113: 347-52.

49 Suggs AH, Maranan MC, Boyle-Vavra S, Daum RS. Methicillin-resistant and borderline methicillin-resistant asymptomatic Staphylococcus aureus colonization in children without identifiable risk factors. Pediatr Infect Dis J 1999; 18: 410-4.

50 Nakamura MM, Rohling KL, Shashaty M, et al.. Prevalence of methicillin-resistant Staphylococcus aureus nasal carriage in the community pediatric population. Pediatr Infect Dis J 2002; 21: 917-21.

51 Salgado CD, Fan BM, Calfee DP. Community-acquired methicillin-resistant Staphylococcus aureus: a meta-analysis of prevalence and risk factors. Clin Infect Dis 2003, 36: 131-9.

52 Shopsin B, Mathema B, Martinez J, et al.. Prevalence of methicillin-resistant and methicillin-susceptible Staphylococcus aureus in the community. J Infect Dis 2000; 182: 359-62.

53 Kuehnert MJ, Kruszon-Moran D, Hill HA, et al.. Prevalence of Staphylococcus aureus nasal colonization in the United States, 2001-2002 J Infect Dis 2006; 193: 172-178

54 Nguyen DM, Mascola L, Bancroft E. Recurring methicillin-resistant Staphylococcus infections in a football team. Emerg Infect Dis 2005; 11: 526-32.

55 Fridkin SK, Hageman JC, Morrison M, et al.; Active Bacterial Core Surveillance Program of the Emerging Infections Program Network.. Methicillin-resistant S aureus disease in three communities. N Engl J Med 2005; 352: 1436-44.

56 Cefai C, Ashurst S, Owens C. Human carriage of methicillin-resistant Staphylococcus aureus linked with pet dog. Lancet 1994; 344: 539-40.

57 Manian FA. Asymptomatic nasal carriage of mupirocin resistant, methicillin-resistant Staphylococcus aureus (MRSA) in a pet dog associated with MRSA infection in household contacts. Clin Infect Dis 2003; 36: 26-8.

58 Rankin S, Roberts S, O'Shea K, Maloney D, Lorenzo M, Benson CE. Panton valentine leukocidin (PVL) toxin positive MRSA strains isolated from companion animals. Vet Microbiol 2005; 108: 145-8.

59 van Duijkeren E, Wolfhagen MJ, Box AT, et al.. Human-to-dog transmission of methicillin-resistant Staphylococcus aureus. Emerg Infect Dis 2004; 10: 2235-7.

60 Enoch DA, Karas JA, Slater JD, et al.. MRSA carriage in a pet therapy dog. J Hosp Infect 2005; 60: 186-8.

61 Loeffler A, Boag AK, Sung J, et al.. Prevalence of methicillin-resistant Staphylococcus aureus among staff and pets in a small animal referral hospital in the UK. J Antimicrob Chemother 2005; 56: 692-7.

62 Tackling MRSA in animals and humans. Veterinary Record 2005; 157: 671-2.

63 Solberg CO. Spread of Staphylococcus aureus in hospitals: causes and prevention. Scand J Infect Dis 2000; 32: 587-95.

64 Ayliffe GAJ, Collins BJ, Lowbury WJL, Babb JR, Lilly HA. Ward floors and other surfaces as reservoirs of hospital infection. J Hyg (Lond) 1967; 65: 515-36.

65 Scott EA, Bloomfield SF. The survival and transfer of microbial contamination via cloths, hands and utensils. J Appl Bacteriol 1990; 68: 271-8.

66 Oie S, Kamiya A. Survival of methicillin-resistant Staphylococcus aureus (MRSA) on naturally contaminated dry mops. J Hosp Infect 1996; 34: 145-9.

67 Wagenvoort JHT, Sluijsmans W, Penders RJR. Better environmental survival of outbreak vs. sporadic MRSA isolates. J Hosp Infect 2000; 45: 231-4.

68 Huws SA, Smith AW, Enright MC, Wood PJ, Brown MRW. Amoebae promote persistence of epidemic strains of MRSA. Environ Microbiol 2006; 8: 1130-3.

69 Reynolds K, Gerba C. Detection of MRSA in the domestic environment. IFH Newsheet 2006, http://www.ifh-homehygiene.org/2003/2newsletter/letter.htm.

70 Devine J, Cooke RPD, Wright EP. Is methicillin resistant Staphylococcus aureus (MRSA) contamination of ward-based computer terminals a surrogate marker for nosocomial MRSA transmission and handwashing compliance? J Hosp Infect 2001; 48: 72-5.

71 French G, Rayner D, Branson M, Walsh M. Contamination of doctors' and nurses' pens with nosocomial pathogens. Lancet 1998; 351: 213.

72 Stacey A, Burden P, Croton C, Jones E. Contamination of television sets by methicillin-resistant Staphylococcus aureus (MRSA). J Hosp Infect 1998; 39: 243-4.

73 Ndawua EM, Brown L. Mattresses as reservoirs of epidemic methicillin-resistant Staphylococcus aureus. Lancet 1991; 337: 488.

74 Oie S, Hosokawa I, Kamiya A. Contamination of room door handles by methicillin-sensitive/methicillin-resistant Staphylococcus aureus. J Hosp Infect 2002; 51: 140-3.

75 Blythe D, Keenlyside D, Dawson SJ, Galloway A. Environmental contamination due to methicillin resistant Staphylococcus aureus. J Hosp Infect 1998; 38: 67-70.

76 Rahman M. Epidemic methicillin resistant Staphylococcus aureus: experience of a health district in central England over 5 years. Postgrad Med J 1993; 69 (suppl 3): S126-9.

77 Moore EP, Williams EW. A maternity hospital outbreak of methicillin-resistant Staphylococcus aureus. J Hosp Infect 1991; 19: 5-16.

78 Rampling A, Wiseman S, Davis L, et al.. Evidence that hospital hygiene is important in the control of methicillin-resistant Staphylococcus aureus. J Hosp Infect 2001; 49: 109-16.

79 Sexton T, Clarke P, O'Neill E, Dillane T, Humphreys H. Environmental reservoirs of methicillin-resistant Staphylococcus aureus in isolation rooms: correlation with patient isolates and implications for hospital hygiene. J Hosp Infect 2006; 62: 187-94.

80 Duckworth GJ, Lothian JLE, Williams JD. Methicillin-resistant Staphylococcus aureus: report of an outbreak in a London teaching hospital. J Hosp Infect 1988; 11: 1-15.

81 Pearman TW, Christiansen KT, Annear DI, et al.. Control of methicillin-resistant Staphylococcus aureus (MRSA) in an Australian metropolitan teaching hospital complex. Med J Aust 1985; 142: 103-8.

82 Cogan TA, Bloomfield SF, Humphrey TJ. The effectiveness of hygiene procedures for the prevention of cross contamination from chicken carcasses in the domestic kitchen. Appl Microbiol 1999; 29: 354-8 (letter).

83 Cogan TA, Slader J, Bloomfield SF, Humphrey TJ. Achieving hygiene in the domestic kitchen: the effectiveness of commonly-used cleaning products. J Appl Microbiol 2002; 92: 885-92.

84 Barker J, Naeeni M, Bloomfield SF. The effects of cleaning and disinfection in reducing Salmonella contamination in a laboratory model kitchen. J Appl Microbiol 2003; 95: 1351-60.

85 Kusumaningrum H, Riboldi G, Hazeleger WC, Beumer RR. Survival of foodborne pathogens on stainless steel surfaces and cross-contamination to foods. Int J Food Microbiol 2003; 85: 227-36.

86 Rheinbaben FV, Schunemann S, Gross T, Wolff MH. Transmission of viruses via contact in a household setting: experiments using bacteriophage phiX174 as a model virus. J Hosp Infect 2000; 46: 61-6.

87 Curtis V, Biran A, Deverell K, Hughes C, Bellamy K, Drassar B. Hygiene in the home: relating bugs and behaviour. Soc Sci Med 2003: 57: 657-72.

88 Scott E, Bloomfield SF. The survival of microbial contamination on worksurfaces and cloths and its transfer via cloths hands and utensils. Environ Health 1990; 98: 34-47.

89 Exner M, Vacata V, Hornei B, Dietlein E, Gebel J. Household cleaning and surface disinfection: new insights and strategies. J Hosp Infect 2004; 56 (suppl 2): S70-5.

90 Neely AN, Maley MP. Survival of enterococci and Staphylococci on hospital fabrics and plastics. J Clin Microbiol 2000; 38: 724-6.

91 Sattar SA, Springthorpe S, Mani S, Gallant N, Nair RC, Scott E, Kain J. Transfer of bacteria from fabrics to hands: development and application of a quantitative method using Staphylococcus aureus as a model. J Appl Microbiol 2001; 90: 962-70.

92 Kundsin RB. Staphylococcal disease in the home. Clin Med 1966; 3: 27-9.

93 Shiomori T, Miyamotoy H, Makishima K, et al.. Evaluation of bedmaking-related airborne and surface methicillin-resistant Staphylococcus aureus contamination. J Hosp Infect 2002; 50: 30-5.

94 Masterton RG, Coia JE, Notman AW, Kempton-Smith L, Cookson BD. Refractory methicillin-resistant Staphylococcus aureus carriage associated with contamination of the home environment. J Hosp Infect 1995; 29: 318-9.

95 Allen KD, Anson JJ, Parsons LA, Frost NG. Staff carriage of methicillin-resistant Staphylococcus aureus (EMRSA 15) and the home environment: a case report. J Hosp Infect 1997; 35: 307-11.

96 Scott GM, Thomson R, Malone-Lee J, Ridgway GJ. Cross infection between animals and man: possible feline transmission of Staphylococcus aureus infection in humans? J Hosp Infect 1988; 12: 29-34.

97 Calfee DP, Durbin LJ, Germanson TP, et al.. Spread of methicillin-resistant Staphylococcus aureus (MRSA) among household contacts of individuals with nosocomially acquired MRSA. Infect Control Hosp Epidemiol 2003; 24: 422-6.

98 Kniehl E, Becker A, Forster DH. Bed, bath and beyond: pitfalls in prompt eradication of methicillin-resistant Staphylococcus aureus carrier status in healthcare workers. J Hosp Infect 2005; 59: 180-7.

99 Hollis R, Barr J, Doebbeling B, Pfaller M, Wenzel R. Familial carriage of methicillin-resistant Staphylococcus aureus and subsequent infection in a premature neonate. Clin Infect Dis 1995; 21: 328-32.

100 Hollyoak V, Gunn A. Methicillin-resistant Staphylococcus aureus (MRSA) in the community. Lancet 1995; 346: 513.

101 L'Heriteau F, Lucet J, Scanvic A, Bouvet E. Community-acquired methicillin-resistant Staphylococcus aureus and familial transmission. JAMA 1999; 282: 1038-9.

102 Shahin R, Johnson I, Tolkin J, Ford-Jones E, The Toronto Child Care Center Study Group. Methicillin-resistant Staphylococcus aureus carriage in a child care center following a case of disease. Arch Pediatr Adolesc Med 1999; 153: 864-8.

103 Turabelidze G, Lin M, Wolkoff B, Dodson D, Gladbach S, Zhu BP. Personal hygiene and methicillin-resistant Staphylococcus aureus infection. Emerg Infect Dis 2006; 12: 422-7.

104 Marples RR. Local infections experimental aspects. J Soc Cosmet Chem 1976; 27: 449-57.

105 Warry M, Pepin J, Fang A, et al.. Toxin production by an emerging strain of Clostridium difficile associated with outbreaks of sever disease in North America and Europe. Lancet 2005; 366: 1079-84.

106 Information about a new strain of C. difficile. Centers for Disease Control, July 2005 http://www.cdc.gov/http://www.cdc.gov/ncidod/dhqp/id_CdiffFAQ_newstrain.html.

107 Severe Clostridium difficile-associated disease in populations previously at low risk - four states, 2005. MMWR Morb Mortal Wkly Rep 2005; 54: 1201-5.

108 National Clostridium difficile Standards Group: Report to the Department of Health. J Hosp Infect 2004; 56: 1-38.

109 Results of the first year of mandatory Clostridium difficile reporting: January to December 2004. CDR Wkly 2005; 15: 1-3.

110 Burgner D, Siarakas S, Eagles G, McCarthy A, Bradbury R, Stevens M. A prospective study of Clostridium difficile infection and colonization in pediatric oncology patients. Pediatr Infect Dis J 1997; 16: 1131-4.

111 McFarland LV, Brandmarker SA, Guandalini S. Pediatric Clostridium difficile: a phantom menace or clinical reality? J Pediatr Gastroenterol Nutr 2000; 31: 220-31.

112 Knoop FC, Owens M, Crocker IC. Clostridium difficile clinical disease and diagnosis. Clin Microbiol Rev 1993; 6: 251-65.

113 Djuretic T, Wall PG, Brazier JS. Clostridium difficile: an update on its epidemiology and role in hospital outbreaks in England and Wales. J Hosp Infect 1999; 41: 213-8.

114 Walker KJ, Gilliland SS, Vance-Bryan K, et al.. Clostridium difficile colonisation in residents of long-term care facilities: prevalence and risk factors. J Am Geriatr Soc 1993; 41: 940-6.

115 Rudensky B, Rosner S, Sonnenblick M, van Dijk Y, Shapira E, Isaacsohn M. The prevalence and nosocomial acquisition of Clostridium difficile in elderly hospitalised patients. Postgrad Med J 1993; 69: 45-7.

116 Samore MH. Epidemiology of nosocomial Clostridium difficile infection. Compr Ther 1993; 19: 151-6.

117 McFarland LV, Mulligan ME, Kwok RYY, Stamm WE. Nosocomial acquisition of Clostridium difficile infection. N Engl J Med 1989; 320: 204-10.

118 Karlstrom O, Fryklund B, Tullus K, Burman LG. A prospective nationwide study of Clostridium difficile-associated diarrhea in Sweden. The Swedish C. difficile Study Group. Clin Infect Dis 1998; 26: 141-5.

119 Kyne L, Merry C, O'Connell B, Keane C, O'Neill D. Community-acquired Clostridium difficile infection. J Infect 1998; 36: 287-8.

120 Food Standards Agency. Report of the study of infectious intestinal disease in England. TSO 2000.

121 Wilcox MH, Bendall R, Settle CD, Fawley WN. Community Clostridium difficile infection. In: Abstracts of the 41st Interscience Conference on Antimicrobial Agents and Chemotherapy, 2001; 441.

122 Clostridium difficile colitis www.medicinenet.com/script/main/art.asp?articlekey=317&pf=3&page=1.

123 Lefebvrea SL, Waltner-Toewsa D, Peregrineb AS, et al.. Prevalence of zoonotic agents in dogs visiting hospitalized people in Ontario: implications for infection control. J Hosp Infect 2006; in press.

124 Borriello SP, Honour P, Turner T, et al.. Household pets as a potential reservoir for Clostridium difficile infection. J Clin Path 1983; 36: 84-7.

125 Al Saif N, Brazier JS. The distribution of Clostridium difficile in the environment of South Wales. J Med Microbiol 1996; 45: 133-7.

126 Wilcox MH. Gastrointestinal disorders and the critically ill. Clostridium difficile infection and pseudomembranous colitis. Best Pract Res Clin Gastroenterol 2003; 17: 475-93.

127 Freeman J, Wilcox MH. The effects of storage conditions on viability of Clostridium difficile vegetative cells and spores and toxin activity in human faeces. J Clin Pathol 2003; 56: 126-8.

128 Kim KH, Fekety R, Batts DH, et al.. Isolation of Clostridium difficile from the environment and contacts of patients with antibiotic-associated colitis. J Infect Dis 1981; 143: 42-50.

129 Mulligan ME, Roife RD, Finegold SM, George WL. Contamination of a hospital environment by Clostridium difficile. Curr Microbiol 1979; 3: 173-5.

130 Malamou-Ladas H, O'Farrell S, Nash JQ, Tabaqchali S. Isolation of Clostridium difficile from patients and the environment of hospital wards. J Clin Pathol 1983; 36: 88-92.

131 Kaatz GW, Gitlin SD, Schaberg DR, et al.. Acquisition of Clostridium difficile from the hospital environment. Am J Epidemiol 1988; 127: 1289-94.

132 Cartmill TD, Panigrahi H, Worsley MA, McCann DC, Nice CN, Keith E. Management and control (a large outbreak of diarrhoea due to Clostridium difficile). J Hosp Infect 1994; 27: 1-15.

133 Skoutelis At, Westenfelder GO, Beckerdite M, Phair JP. Hospital carpeting and epidemiology of Clostridium difficile. Am J Infect Control 1994; 22: 212-7.

134 Samore MH, Venkataraman L, DeGirolami PC, Arbeit RD, Karchmer AW. Clinical and molecular epidemiology of sporadic and clustered cases of nosocomial Clostridium difficile diarrhoea. Am J Med 1996; 100: 32-40.

135 Verity P, Wilcox MH, Fawley W, Parnell P. Prospective evaluation of environmental contamination by Clostridium difficile in isolation side rooms J Hosp Infect 2001; 49: 204-9.

136 Wilcox MH, Fawley WN, Wigglesworth N, Parnell P, Verity P, Freeman J. Comparison of the effect of detergent versus hypochlorite cleaning on environmental contamination and incidence of Clostridium difficile infection. J Hosp Infect 2003; 54: 109-14.

137 Fekety R, Kim KH, Brown D, Batts DH, Cudmore M, Silva J Jr. Epidemiology of antibiotic-associated colitis; isolation of Clostridium difficile from the hospital environment. Am J Med 1981; 70: 906-8.

138 Centers for Disease Control. Clostridium difficile: information for healthcare providers, CDC website.

139 HPA - Clostridium difficile frequently asked questions.

140 Cartwright CP, Stock F, Beekmann SE, Williams EC, Gill VJ. PCR amplification of rRNA intergenic spacer regions as a method for epidemiologic typing of Clostridium difficile. J Clin Microbiol 1995; 33: 184-7.

141 Chang VT, Nelson K. The role of physical proximity in nosocomial diarrhoea. Clin Infect Dis 2000; 31: 717-22.

142 AI-Saif NM, O'Neill GL, Magee JT, Brazier JS, Duerden BL. PCR-ribotyping and pyrolysis mass spectrometry fingerprinting of environmental and hospital isolates of Clostridium difficile. J Med Microbiol 1998; 47: 117-21

143 Costas M, Holmes B, Ganner M, et al.. Identification of outbreak-associated and other strains of Clostridium difficile by numerical analysis of SDS-PACE protein patterns. Epidemiol Infect 1994; 113: 1-12

144 Clabots CR, Johnson S, Olson MM, Peterson LR, Gerding DN. Acquisition of Clostridium difficile by hospitalized patients: evidence for colonized new admissions as a source of infection. J Infect 1992; 166: 561-7.

145 Bacon AE, Fekety R, Schaberg DR, Faix RC. Epidemiology of Clostridium difficile colonization newborns: results using a bacterlophage and bacteriocin typing system. J Infect Dis 1988; 15: 349-54.

146 Wilcox MH, Spencer RC. Clostridium difficile infection: responses, relapses and re-infections. J Hosp Infect 1992; 22: 85-92.

147 Wilcox MH, Fawley WN, Settle CD, Davidson A. Recurrence of symptoms in Clostridium difficile infection - relapse or reinfection? J Hosp Infect 1998; 38: 93-100.

148 Johnson S, Cording DN, Olson MM, Weiler MD, Hughes RA, Clabots CR, Peterson LR. Prospective, controlled study of vinyl glove use to interrupt Clostridium difficile nosocomial transmission. Am J Med 1990; 88: 137-40.

149 Larson HE, Borriello SP. Quantitative study of antibiotic-induced susceptibility to Clostridium difficile enterocecitis in hamsters. Antimicrob Agents Chemother 1990; 34: 1348-53.

150 Health Protection Agency. Investigations into multi-drug resistant ESBL-producing Escherichia coli strains causing infections in England. London: HPA, September 2005. http://www.hpa.org.uk/hpa/publications/esbl_report_05/7_bibliography.htm.

151 Woodford N, Ward ME, Kaufmann ME, et al.. Community and hospital spread of Escherichia coli producing CTX-M extended-spectrum ß-lactamases in the UK. J Antimicrob Chemother 2004; 54: 735-43.

152 Munday CJ, Whitehead GM, Todd NJ, Campbell M, Hawkey PM. Predominance and genetic diversity of community- and hospital-acquired CTX-M extended-spectrum ß-lactamases in York, UK. J Antimicrob Chemother 2004; 54: 625-33.

153 Livermore DM, Hawkey PM. CTX-M: changing the face of ESBLs in the UK. J Antimicrob Chemother 2005; 56: 451-4.

154 Valverde A, Coque TM, Sanchez-Moreno M, Rollan A, Baquero F, Canton R. Dramatic increase in prevalence of fecal carriage of extended-spectrum lactamase-producing enterobacteriaceae during nonoutbreak situations in Spain. J Clin Microbiol 2004; 42: 4769-75.

155 Parry SM, Salmon RL. Sporadic STEC 0157 infection: secondary household transmission in Wales. Emerg Infect Dis 1998; 4: 657-61.

156 Guidelines for prevention of infection and cross infection in the domestic environment. International Scientific Forum on Home Hygiene. Milan: Intramed Communications 1998.

157 Recommendations for selection of suitable hygiene procedures for use in the domestic environment. International Scientific Forum on Home Hygiene. Milan: Intramed Communications 2001.

158 Home Hygiene - prevention of infection at home: a training resource for carers and their trainers; http://www.ifh-homehygiene.org/2003/2public/2pub06.asp.

159 Bloomfield SF. Preventing infection in the home. British Journal of Infection Control J Infect Cont 2002; 3: 14-7.

160 Bloomfield SF, Scott EA. Cross-contamination and infection in the domestic environment and the role of chemical disinfectants. J Appl Microbiol 1997; 83: 1-9.

161 Barker J, Bloomfield SF. Survival of Salmonella in bathrooms and toilets in domestic homes following salmonellosis. J Appl Microbiol 2000; 89: 137-44.

162 Barker J, Jones MV. The potential spread of infection caused by aerosol contamination of surfaces after flushing a domestic toilet. J Appl Microbiol 2005; 99: 339-47.

163 Beumer R, Bloomfield SF, Exner M, Fara GM, Nath KJ, Scott E. The infection potential in the domestic setting and the role of hygiene practice in reducing infection. International Scientific Forum on Home Hygiene: http://www.ifh-homehygiene.org/2public/INFPOT2.pdf.

164 Barker J, Vipond IB, Bloomfield SF. The effects of cleaning and disinfection in reducing the spread of Norwalk-like virus contamination via environmental surfaces. J Hosp Infect 2004; 58: 42-9.

165 Kusumaningrum HD, Paltinaite R, Koomen AJ, Hazeleger WC, Rombouts FM, Beumer RR. Tolerance of Salmonella Enteritidis and Staphylococcus aureus to surface cleaning and household bleach. J Food Prot 2003; 2289-95.

166 Teare L, Cookson B, French G, et al.. Hand washing. A modest measure with big effects. BMJ 1999; 318: 686.

167 Boyce JM, Pittet D. Guideline for hand hygiene in heath care settings: Recommendations of the Healthcare Infection Control Practices Advisory Committee and the HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force. Infect Control Hosp Epidemiol 2003; 23(suppl): S1-40.

168 Curtis V, Cairncross S. Effect of washing hands with soap on diarrhoea risk in the community: a systematic review. Lancet Infect Dis 2003; 3: 275-81.

169 Aiello AE, Larson EL. What is the evidence for a causal link between hygiene and infections? Lancet Infect Dis 2002; 2: 103-10.

Ayliffe GAJ, Collins BJ, Lowbury WJL. Cleaning and disinfection of hospital floors. Br Med J 1966; 5511: 442-5.

171 Maki DG. Control of colonization and transmission of pathogenic bacteria in hospital. Ann Intern Med 1978; 89: 777-80.

172 McGowan JE. Environmental factors in nosocomial infection - A selective focus. Rev Infect Dis 1981; 3: 760-9.

173 Danforth D, Nicolle LE, Hume K, Alfieri N, Sims H. Nosocomial infections on nursing units with floors cleaned with a disinfectant compared with detergent. J Hosp Infect 1987; 10: 229-35.

174 Dharan S, Mourouga P, Copin P, Bessmer G, Tsanch B, Pittet D. Routine disinfection of patients' environmental surfaces. Myth or reality? J Hosp Infect 1999; 42: 113-7.

175 Dancer SJ. How do we assess hospital cleaning? A proposal for microbiological standards for surface hygiene in hospitals. J Hosp Infect 2004; 56: 10-5.

176 Guidance for the hospital management of methicillin resistant Staphylococcus aureus. Scottish Infection Standards and Strategy (SISS) Group of the Royal College of Physicians of Edinburgh and the Royal College of Physicians and Surgeons of Glasgow. March 2006.

177 Bhalla A, Pultz NJ, Gries DM, et al.. Acquisition of nosocomial pathogens on hands after contact with environmental surfaces near hospitalised patients. Infect Control Hosp Epidemiol 2004; 25: 164-7.

178 Loveday HP, Pellowe CM, Jones SRLJ, Pratt RJ. A systematic review of the evidence for interventions for the prevention and control of methicillin-resistant Staphylococcus aureus (1996-2004): report to the joint MRSA working party (subgroup A). J Hosp Infect 2006; 635 (suppl 1): S45-70.

179 French GL, Otter JA, Shannon KP, Adams NMT, Parks MJ, Watling D. Tackling contamination of the hospital environment by methicillin-resistant Staphylococcus aureus (MRSA): a comparison between conventional terminal cleaning and hydrogen peroxide vapour decontamination. J Hosp Infect 2004; 57: 31-7.

180 Griffith CJ, Obee P, Cooper RA, Lewis M. The effectiveness of existing and modified cleaning regimes in a Welsh hospital. J Hosp Infect. Submitted for publication, 2006.

181 Cooper RA, Griffith CJ, Malik RE, Obee P, Looker N. Monitoring the effectiveness of cleaning in four British hospitals. Am J Infect Control. Submitted for publication, 2006.

182 Byers KE, Durbin LJ, Simonton BM, et al.. Disinfection of hospital rooms contaminated with vancomycin-resistant Enterococcus faecium. Infect Control Hosp Epidemiol 1998; 19: 261-4.

183 Corcoran GD, Kirkwood EM. Revised guidelines for the control of methicillin-resistant Staphylococcus aureus infection in hospitals. J Hosp Infect 1999; 41: 72-4 (letter).

184 Dealler S. Methicillin-resistant Staphylococcus aureus infections and colonizations in an intensive care unit apparently stopped by environmental factors. J Hosp Infect 2004; 38: 238-43.

185 Mayfield JL, Leet T, Miller J, Mundy LM. Environmental control to reduce transmission of Clostridium difficile. Clin Infect Dis 2000; 31: 995-1000.

186 Streulens MJ, Maas A, Nonhoff C, Deplano A, Rost F, Serruys E. Control of nosocomial transmission of Clostridium difficile based on sporadic case surveillance. Am J Med 1991; 91 (suppl B): S138-44.

187 Zafar AB, Gaydos LA, Furlong WB, Nguyen MH, Mennonna PA. Effectiveness of infection control program in controlling nosocomial Clostridium difficile. Am J Infect Control 1998; 26: 588-93.

188 Larson E, Duarte CG. Home hygiene practices and infectious disease symptoms among household members. Public Health Nurs 2001; 18: 116-7.

189 The hygiene hypothesis and its implications for hygiene. The International Scientific Forum on Home Hygiene. http://www.ifh-homehygiene.org/2003/2hypothesis/hh.htm.

190 Bloomfield SF, Stanwell-Smith R, Crevel RWR, Pickup J. Too clean, or not too clean: the hygiene hypothesis and home hygiene. Clin Exp Allergy 2006; 36: 402-5.

APPENDIX 1 – BRIEFING DOCUMENT FOR HEALTH PROFESSIONALS

METHICILLIN RESISTANT *STAPHYLOCOCCUS AUREUS* (MRSA)

What is *Staphylococcus aureus*?

Staphylococcus aureus is a bacterium that can colonise and infect humans. It can be carried harmlessly in the nostrils, throat, and on the skin (particularly in areas such as the armpits and groin). About one third of the general population constantly carry *S. aureus*, and one third carry it on a transient basis. Carriers of *S. aureus* typically shed the organism from the skin's surface, most usually associated with skin scales, but whereas some people are extensive shedders, others are not.

Usually the individual is quite unharmed by colonisation. *S. aureus* can also rapidly colonise broken or abnormal skin such as superficial wounds, ulcers, psoriasis and eczema, often without any symptoms, but on occasion it may produce boils or, more seriously, it can enter the bladder or blood stream causing bacteraemia. *S. aureus* produces disease either by toxin production or by direct invasion and destruction of tissue. Any individual with "broken" (cuts, wounds, abrasions, etc.) skin is at risk of contracting *S. aureus* infection from another carrier or source of infection. Patients who carry *S. aureus* can also self-infect their own surgical or other wounds.

There are many different strains of *S. aureus* with different characteristics, all of which are constantly circulating in the community, which from time to time evolve into new strains. Most *S. aureus* infections heal spontaneously, or in response to antibiotic treatment, although in recent years there is increasing concern about the emergence of *S. aureus* strains that have developed resistance to multiple antibiotics.

What is methicillin resistant *Staphylococcus aureus*?

Antibiotic resistance first became apparent in *S. aureus* in the 1950s when strains of bacteria which acquired genes enabling them to produce penicillin-destroying ß-lactamase enzymes became widespread. This led to the development and use of semi-synthetic penicillins such as methicillin and flucloxacillin that were resistant to the penicillin-destroying enzymes produced by *S. aureus* and other bacteria. Methicillin resistant *Staphylococcus aureus* (MRSA) was first described in 1961, almost immediately after the agent was introduced into clinical practice. Widespread use of antibiotics throughout the 1970s led to the development of resistance, predominately in MRSA, to other antibiotics such as erythromycin, gentamicin and trimethoprim.

Hospital and community-acquired MRSA

S. aureus is an "opportunist pathogen", which primarily infects people whose immunity to infection is compromised. Not surprisingly therefore it is a common cause of hospital-acquired infections requiring antibiotic treatment. In the past 20 to 30 years, although the majority of *S. aureus* infections in hospitalised patients have remained sensitive to antibiotics, infections due to MRSA have evolved as a major cause of hospital-acquired infection. Methicillin resistance rates vary considerably between countries. In the USA and Southern Europe more than 40% of all *S. aureus* isolates from patients with bacteraemia are MRSA, whilst in Northern Europe MRSA isolates comprise <5% of isolates from patients with bacteraemia. It should be noted that there are several different MRSA strains present globally and that these also vary in their degree of antibiotic resistance.

Outside a hospital setting, *S. aureus* infections are quite common, but mostly go unrecorded unless the person develops a serious infection such as bacteraemia. Most of these infections are due to methicillin sensitive strains. In the past 10-15 years, however, it has become apparent that MRSA is by no means confined to the hospital setting. This has occurred for a number of reasons. Firstly, infected patients discharged from the hospital may continue to carry MRSA even after their infection has healed. In addition, new "community" strains of MRSA have emerged more recently. Experience now shows that these community-acquired strains, which first appeared in the late 1990s, are quite different from the strains that arose in hospitals and most probably evolved quite separately within the community, either associated with the widespread prescribing of methicillin in general practice, or by random evolution and subsequent spread

To distinguish between these two groups of MRSA strains, we will refer to them as "healthcare associated MRSA" (HCA-MRSA) and "community-acquired MRSA" (CA-MRSA). *S. aureus* strains not resistant to methicillin will be referred to as Methicillin sensitive *S. aureus* (MSSA). The situation is further confused, however, by the fact that some strains of *S. aureus* circulating in the community (mainly CA-MRSA but also MSSA) have acquired the ability to produce a potent tissue toxin called Panton-Valentine Leukocidin (PVL). The main characteristics of HCA and CA-MRSA can be summarised as follows:

Healthcare-associated MRSA

HCA-MRSA mostly affects frail and vulnerable individuals such as the elderly and the immunocompromised. Most infections arise in hospitals, but HCA-MRSA also has the same potential to affect the elderly and immunocompromised when they are cared for in the community and home. Patients with post-operative and other wounds that are cared for at home, and those that require invasive procedures such as urinary catheterisation, are particularly at risk. HCA-MRSA, like methicillin sensitive *Staphylococcus aureus* (MSSA), can rapidly colonise broken or abnormal skin such as superficial wounds, ulcers, psoriasis and eczema. Patients carrying both MSSA and HCA-MRSA can self-infect their own surgical or other wounds.

It is important to recognise that HCA-MRSA strains (like MSSA) do not generally represent a significant risk to healthy individuals. However, family members can also become colonised with MRSA in the same way that they can carry MSSA and can act as a source for spread to more vulnerable family members. MRSA may be transmitted from person to person by personal contact, or in contact via fomites. The most common form of transmission is via the hands.

Although HCA-MRSA inevitably attracts public attention, a key factor in communicating with the public is to reassure them that they are not more virulent than the parent strain. The term "superbug" refers to their ability to resist the action of many antibiotics. Skin infections associated with *S. aureus*, although unpleasant, are generally self-limiting. The major concern is that these strains are a source of genes that carry antibiotic resistance and as such, for someone infected with MRSA, the ability to treat the infection can be severely compromised.

Although HCA-MRSA are resistant to antibiotics, there is no evidence to suggest that they are resistant to disinfectants, antibacterials or antiseptics.

Community-acquired MRSA and PVL-producing MRSA

True community-acquired MRSA strains, which are now known to have emerged de novo from community-based *S. aureus* strains, have been known since the 1960s, but did not become a significant issue until the late 1990s. Although these CA-MRSA strains are of concern, at present infections from these strains are rare in the UK compared with other countries, particularly the USA, which have encountered more serious problems.

One of the key characteristics of CA-MRSA is that, in contrast with HCA-MRSA, it is more prevalent among children and young adults where they cause infections of cuts, wounds and abrasions. Another important characteristic is that CA-MRSA are resistant to fewer antibiotics than HCA-MRSA, with the consequence that these infections are readily treatable - provided doctors are aware that the patient might be carrying a CA-MRSA strain.

One of the main reasons for concern is that, unlike HCA-MRSA, some *S. aureus* strains circulating in the community (both CA-MRSA and MSSA) strains have acquired the ability to produce PVL toxin, which can lead to skin and soft tissue (sometimes necrotising) infections. In some cases these organisms can cause severe invasive infections such as septic arthritis, bacteraemia, or community-acquired necrotising pneumonia. An early skin infection often has the initial appearance of an insect bite. These infections often develop into cellulitis, furuncles, large boils or clusters of boils (up to 10cm in diameter in some cases) and deep-seated abscesses often in the thighs or buttocks. If the bacteria get into the lungs, fortunately a rare event, a devastating pneumonia that kills more than 40% of patients can result.

The PVL toxin was first reported in 1932 and is encoded by a mobile bacteriophage that can transfer the toxin to other strains. Current surveillance data do not give any clear indications of the proportion of *S. aureus* (or CA-MRSA) circulating in the UK community that are positive for PVL toxin; the bulk of the available data comes from MRSA reference laboratories, which means that only the rates of PVL-producing strains amongst those MRSA isolates that are referred to the laboratory are reported. For example, the MRSA Reference Laboratory in Ireland have reported that, of 1500 MRSA (hospital and community-acquired) isolates received, 28 were PVL-positive (2%). Of those isolates believed to be CA-MRSA, about 65% were found to be PVL-positive (Falkiner, personal communication). In England, there is no mandatory reporting system for cases of community PVL-producing strains of CA-MRSA, but infections associated with this organism are rare at present. The HPA have issued guidance on their treatment (http://www.dh.gov.uk/AboutUs/MinistersAndDepartmentLeaders/ChiefMedicalOfficer/Features/FeaturesArticle/fs/en?CONTENT_ID=4133761&chk=oW8s4w:). The Laboratory of Healthcare Associated Infection of the HPA are aware that PVL-positive *S. aureus* has been associated with the death of 27 individuals (17 males; 10 females) over 27 months (January 2004 to March 2006). During this period, 518 patient isolates of *S. aureus* referred to the SRU were identified as PVL-positive, suggesting a mortality rate of 5% (Cookson, personal communication).

In general, however, it is likely that the prevalence of PVL-producing *S. aureus* strains circulating in the general community in the UK is very small, but when it does occur, the majority are methicillin resistant.

Experience in the USA suggests that PVL-positive CA-MRSA are more virulent than MSSA strains. They are also easily transmissible not only within families, but also on a larger scale in community settings such as prisons, schools and sport teams. Skin-to-skin contact (including unabraided skin) and indirect contact with contaminated objects such as towels, sheets and sport equipment seem to represent the mode of transmission. Risk factors for spread of CA-MRSA are close skin-to-skin contact, cuts and abrasions, shared contaminated items or surfaces, intravenous drug use, poor hygiene and crowded living conditions.

There is concern that if the evolution of MRSA continues, community strains could become more like the hospital strains in terms of antibiotic resistance and thus become more difficult to treat; hospital strains could become more dangerous if they acquire toxin genes, and could cause serious disease in younger, healthier people.

How do you know if someone is carrying MRSA?

If someone is colonised with MRSA there is no way of knowing, unless they are tested.

For HCA-MRSA - At present the number of people who are carrying HCA-MRSA is relatively low, but with early discharge of patients and increased emphasis on community care, there are concerns that the number of carriers is likely to rise. Studies suggest that about 0.5 to 1.5% of the general population may be carrying HCA-MRSA, the majority of whom are 65 years or older or are healthcare workers who have cared for patients infected with MRSA. The risks for transmission of MRSA from an infected person to another family member will depend partly on the length of time the infected individual carries MRSA. In a recent study, 69% of carriers were still colonised with HCA-MRSA after four weeks following exposure.

For CA-MRSA – There are no data to indicate what proportion of the UK population may be carrying CA-MRSA as part of their normal body flora, but it is likely to be quite small.

Should we be concerned about CA-MRSA?

Whilst currently CA-MRSA infections are rare in the UK, experience in North America and several European countries demonstrate their potential for spread; CA-MRSA strains have been detected in the United States, France, Switzerland, Germany, Greece, the Nordic countries, Australasia, Netherlands and Latvia. In the United States, CA-MRSA is now a significant concern, although it is generally concluded that the rates of colonisation in the community remain low, but are likely to be on the rise. Whereas at the outset CA-MRSA was seen predominantly as an infection affecting children, a recent study in Minnesota found that the median age of patients with CA-MRSA was 23 years. In the USA it was concluded that the primary risk factors for CA-MRSA colonisation and infection are belonging to a minority group and low socioeconomic status. Underlying medical conditions do not appear to be a major risk factor, but intravenous drug use, gay massage parlours, incarceration, and close-contact sports such as rugby, football or wrestling. In these situations, skin abrasions are common and render individuals more prone to contracting CA-MRSA. The Health Protection Agency state, at least for UK reported cases of CA-MRSA, is unaware of any link to gyms or health clubs.

How do you know if someone is infected with MRSA?

HA-MRSA like MSSA can infect cuts, abrasions and other skin wounds. Infections of the skin are characterised by reddening of the skin, and the wound becomes hot and painful. If the inflamed area around the wound continues to increase it is important to consult a doctor.

CA-MRSA also infects cuts and abrasions on the skin surface, but unlike HCA-MRSA and most strains of MSSA, it can produce a dangerous toxin that infects the wound. An early skin infection often has the initial appearance of an insect bite and can easily go unnoticed. Skin and soft tissue infections may present as cellulitis, furuncles, large boils or clusters of boils (up to 10 cm in diameter in some cases) and deep-seated abscesses often in the thighs or buttocks. If untreated, the organisms can migrate to the blood stream and cause bacteraemia. If the bacteria get into the lungs, fortunately a rare event, a devastating pneumonia that kills more than 40% of patients can result[1].

Can pets and other animals carry MRSA?

Although little information is available on the prevalence of MRSA in domestic animals, isolation from household pets has been reported. In 1994 there was a case of a nurse who became colonised with MRSA; investigations showed that the likely source of the colonisation was a dog. It is possible that, in situations where a family member is shedding MRSA as skin scales, the skin fragments become trapped in the fur of the animal and might then be passed on to other family members.

How is MRSA transmitted in the home from one person to another?

When someone is colonised or infected with MRSA, they shed the organism, often in very large numbers, from the skin surface, usually associated with skin scales. The extent of shedding varies over time, but may increase when the carrier has a cold or is being treated with antibiotics. *S. aureus* is an organism that typically cannot grow and multiply in the environment outside a human or animal host. It is, however, relatively resistant to drying, and can survive on hands and environmental surfaces for several days or even longer.

A number of investigations show that, where there is someone living in the home who is infected or is a carrier, MRSA can be isolated from a variety of environmental surfaces including those frequently touched by hands. Since hands are an important route for transmission of MRSA, identification of MRSA on surfaces frequently touched by hands is particularly important. Hand contact and other surfaces from which MRSA has been isolated include computer keyboards, pens, television sets, clothing, mattresses, beds and chairs, baths and hand basins, dishcloths and door handles. When an infected or carrier person is present in the home, clothing and bed linens may become contaminated and promotes the risk of transfer to the hands of the person handling the soiled laundry or to other laundry.

The potential for MRSA transmission in the home, if good hygiene is not carried out, is demonstrated by a number of investigations of health care workers who became colonised whilst caring for infected patients in hospitals. For example, during a UK outbreak of MRSA, where a nurse was colonised, it was found that the patient's parents and fiancée, who shared the same house, were also colonised with the same strain. The family were treated with antimicrobial agents, although this failed to eradicate the MRSA. Investigation of their home environment revealed MRSA contamination on door handles, a computer desk and a computer joystick in the patient's bedroom. It was not until the home was thoroughly cleaned, all pillows and bedding were replaced, and the family again treated with antimicrobial, that the MRSA was eliminated. In another study MRSA was isolated from 25 out of 172 individuals who were the household/community contacts of 88 MRSA colonised patients discharged from a hospital. Household contacts that had close contact with the index patient were 7.5 times more likely to be colonised than those who had less frequent contact.

What are the risks associated with MRSA in the community?

Based on current evidence, it is generally concluded that the risks associated with CA- and HCA-MRSA transmission in the home and community are relatively small at present. Although up to 60% of us carry *S. aureus* as part of our normal skin flora, only a relatively small number of people actually carry HCA or CA-MRSA strains. However, although there is no particular cause for alarm, it is recognised that reducing the risks of transmission of MRSA in the home is important for a number of reasons.

In particular:

- When patients who are still infected or colonised with MRSA are discharged from the hospital, the organism may be transmitted to other family members or contacts, or can be disseminated into the home environment where it can survive for very significant periods. Although the patient may recover from the infection, they can become re-infected if they are again exposed to the organism either by another family member who has become colonised, or from surface contamination persisting in their home environment.

Although carriage of MRSA amongst healthy family members is not a risk in itself, there are a number of reasons why it makes sense to minimise dispersal of MRSA in the home environment and reduce opportunities for exposure amongst family members, which could lead to colonisation:

- When carriers of MRSA are admitted from home into hospital for surgery, there is significant risk of self–infection.
- When a family member who is a carrier of MRSA is admitted to hospital they represent a source of infection, which may be transmitted to other patients.
- When a family member who is a healthcare worker becomes colonised with MRSA at home, they may transmit the organism to patients in the healthcare setting where they are employed.
- For family members carrying PVL-producing strains of CA-MRSA, colonisation of cuts and abrasions may result in serious and potentially fatal skin and soft tissue infections.

Family members who are most likely to be colonised with MRSA include healthcare workers or those who work in healthcare settings where they may have acquired the organism from infected patients or their environment.

The risks from MRSA in the home are exacerbated by the fact that, if it is allowed to become "endemic" in the home environment, it can persist for very long periods of time and can be difficult to eradicate.

As far as public health authorities are concerned, persuading people to adopt good hygiene practices on a routine basis in the home, which will reduce the spread of these strains within the family, is key to controlling the spread of these strains in the community.

Reducing the opportunities for exposure amongst family members and domestic animals, which could lead to colonisation, depends on good day-to-day hygiene practice. Good daily hygiene means adopting the IFH targeted approach to home hygiene as outlined in the IFH Guidelines and Recommendations on home hygiene and the IFH Home Hygiene Training Resource. All individuals are at risk of exposure to MRSA during normal daily routines, but, unless there is someone at home who is known to be infected with MRSA, this mostly occurs without our awareness, which is why it is important to practice good hygiene on a constant basis.

There are, however, two situations where more specific support and advice can be given:
- To reduce the spread of MRSA in the home environment in situations where a family member is known to be infected.
- To specifically guard against the risks of CA-MRSA infection amongst family members.

The following are draft advice sheets for informing the public about these specific risks and provide practical advice.

Practical advice to guard against the risks of CA-MRSA infection amongst family members

At present the Health Protection Agency advises that since only a small number of CA-MRSA cases have been observed during the past three years, the risk of contracting this type of MRSA in the community remains extremely small. Those at greatest risk are young people, and the infection usually occurs via cuts and abrasions in the skin surface. Infection is transmitted from person to person. This occurs primarily via the hands, but can also occur via clothing, linens and facecloths, although hand and body contact surfaces such as baths and basins, shower trays and shower curtains might also be involved.

The most important measures for preventing transmission of CA-MRSA between family members at home or in the community are:
- Apply a topical antiseptic to cuts and abrasions and cover with an impermeable dressing. This is particularly important when taking part in contact sports.
- Keep an eye on cuts and abrasions, particularly those contracted during sports and other contact activities. If the wound becomes painful, or if the area of redness around the wound is increasing, consult a doctor immediately.
- Take care of sports clothing and equipment. Clothing and equipment such as towels should be laundered* after each use.
- Sheets and pillows should be laundered* regularly.
- Do not share towels, facecloths, toothbrushes, or other personal hygiene items with other family members.
- Hygienically clean surfaces in the bathroom and toilet, with particular attention to washbasins, baths and toilet seat and toilet handle. This can be achieved by cleaning with a detergent cleaner followed by thorough rinsing under running water, or where this is not possible e.g. for toilet seats, toilet flush handles etc., using a disinfectant cleaner.

Also:
- As far as possible keep hand contact surfaces clean (taps, door handles, telephones, computer keyboards, etc.). To make these surfaces hygienically clean you need to use a disinfectant cleaner.
- In a busy household it is not always possible to keep hand contact surfaces hygienically clean at all times. That is why it is important to wash hands as frequently as possible to break the chain of infection.

*For laundering of underclothing, sports clothing, towels and linen
- Wash at 40ºC using a bleach-containing laundry product

Or
- Wash at 60ºC or above (using any laundry product as heat will destroy MRSA)

Note: washing at 40ºC without the addition of bleach will not destroy MRSA

Practical advice to stop MRSA spreading when there is someone in the home who is infected or is carrying MRSA

If there is someone in the home who is known to be carrying or infected with MRSA, it is important to practice good hygiene in order to reduce the risks of spread to other family members who may then become colonised and pass the organism on to others. This is particularly important if there are family members who are healthcare providers who may come into contact with vulnerable groups during daily work. The risk of clinical infection in other "healthy" family members is small, but can still occur, particularly if cuts or abrasions are present. Those at higher risk of infection are family members who are "immunecompromised". This includes the elderly, those with underlying medical conditions or who are otherwise immunecompromised, e.g. undertaking drug therapy that reduces their resistance to infection. The organism is transmitted from person to person. This occurs primarily via the hands, but can also occur via clothing, linens and facecloths. Hand and body contact surfaces such as baths and basins, shower trays and curtains may also be involved as well as other environmental surfaces. The most "risky" surfaces are those that come into direct contact with the infected person and, when the patient is confined to bed, in their immediate vicinity, e.g. bedside tables, bed frames etc.

When an infected person is discharged from the hospital, family members may be concerned because of the strict precautions that were applied when the individual was hospitalised. It is important to make the family aware that these measures were aimed at preventing the spread of MRSA to other vulnerable patients in the hospital who were at particular risk because of their illness or surgery. At home the risks are reduced, even though it is important to continue good hygiene to prevent spread to other family members and the environment. Occasionally individuals can be cleared of infection only to become re-infected with MRSA from contaminated surfaces in the home.

The most important measures for preventing transmission of MRSA from an infected family member are:

For those caring for the infected person:

- Good hand washing practice is the single most important infection control measure. Caregivers should wash their hands with soap and water after contact with the infected or colonised person. If access to soap and running water is a problem, keep an alcohol hand rub by the patient's bedside.
- Disposable gloves should be worn if in contact with body fluids or dressings, and hands should be washed after removing gloves. Dispose of dressings safely**.
- Cover cuts and abrasions with an impermeable dressing.
- Clothing, sheets, pillows and linens from the infected patient (or carrier) should be kept separate from the rest of the family laundry and should be laundered in a manner that kills MRSA. This entails:
  - Washing at 40°C using a bleach-based laundry product

  Or
  - Washing at 60°C or above (using any laundry product that will destroy MRSA).

  Note: washing at 40°C without the addition of bleach will not destroy MRSA
- Do not share towels, facecloths, toothbrushes and other personal hygiene items with the infected or carrier person.
- Hygienically clean surfaces in the bathroom and toilet, with particular attention to washbasins, baths and toilet seat, toilet handles and showers. This can be achieved by cleaning with a detergent cleaner followed by thorough rinsing under running water, or when this is not possible, e.g. for toilet seats, toilet flush handles etc., using a disinfectant cleaner.
- Cleaning cloths can easily spread MRSA around the home. They should be hygienically cleaned after each use, particularly after use in the immediate area of the patient or the bathroom and toilet used by the patient. This can be done in any of the following ways:
  - wash in a washing machine at 60°C (hot wash)
  - clean with detergent and warm water, rinse and then immerse in hypochlorite disinfectant solution* for 20 minutes
  - clean with detergent and water then immerse in boiling water for 20 minutes.

  Alternatively use disposable cloths.

Also:

- Keep the patient's immediate environment hygienically clean. The most important surfaces are those which come into contact with the hands, e.g. door handles, telephones, bedside tables and bed frames. To make these surfaces hygienically clean you need to use a disinfectant product
- Clean floors, carpets and other surfaces daily using vacuum extraction, i.e. a vacuum cleaner
- In a busy household it is not always possible to keep hand contact surfaces hygienically clean. This is the reason why it is important to wash hands as frequently as possible to break the chain of infection.

For the infected person:

- Wash your hands frequently, particularly before touching anyone else – always be aware that you may have MRSA on your hands. Always wash your hands after blowing your nose and dispose of tissues. Do not leave them lying around for someone else to pick up.
- Keep wounds covered and avoid touching as far as possible. If you change a dressing, immediately wash your hands or use an alcohol hand rub**.
- Shower frequently.
- Do not share personal hygiene items such as towels, facecloths, toothbrushes with other family members.

** Dressings should be placed in a plastic bag. Tie the top of the bag before placing it in the general household waste.

Other considerations:

- The family must be aware that they should not deliver close personal care if they have an area of broken skin. MRSA carriers, or those with the infection, present a risk to adults or children with skin disorders such as psoriasis or eczema. In this case advice should be sought about whether the relative should continue to be cared for at home while colonised or infected with MRSA.
- Generally, pregnant women are fit and healthy and therefore at little risk from MRSA. Even if they become carriers, there is no risk to their baby during pregnancy. However, in a recent MRSA outbreak in a maternity hospital in Bristol, a woman became infected in the perineal area that had been damaged during childbirth. Transmission of the infection occurred not only because of inadequate hand washing by mothers and staff, but also inadequate hygiene in relation to fomites, including baths, bidets, toilet seats and mattresses.

Further reading

1. Guidelines for the control of meticillin-resistant *Staphylococcus aureus* (MRSA) in hospitals. Journal of Hospital Infection 2006; 635: S1-S44.
2. MRSA and other healthcare associated infections – information for visitors. Wipe it out: Royal College of Nursing campaign on MRSA. Royal College of Nursing. www.rcn/org.uk/mrsa
3. Information for patients - MRSA and other healthcare associated infections: how you can help stop the spread of infections and stay well. Wipe it out. Royal College of Nursing campaign on MRSA. Royal College of Nursing. www.rcn/org.uk/mrsa
4. Guidelines for prevention of infection and cross infection the domestic environment. http://www.ifh-homehygiene.org/2public/2pubgu00.htm
5. Recommendations for selection of suitable hygiene procedures for use in the domestic environment. http://www.ifh-homehygiene.org/2public/2pub04.htm
6. Home Hygiene - prevention of infection at home: a training resource for carers and their trainers. http://www.ifh-homehygiene.org/2003/2public/2pub06.asp

APPENDIX 2 – BRIEFING DOCUMENT FOR HEALTH PROFESSIONALS

CLOSTRIDIUM DIFFICILE

What is *Clostridium difficile*?

Clostridium difficile is a Gram-positive bacterium that was first described in 1935 as a component of the faecal flora in healthy babies. It was not recognised as a cause of disease until 1978. *C. difficile* can be present as one of the 'normal' bacteria in the gut.

C. difficile bacterium has two forms, an active, vegetative form that cannot survive in the environment for prolonged periods, but which causes disease, and a dormant spore form, that can survive in the environment for prolonged periods, but that does not cause disease. *C. difficile* is transmitted by the faecal-oral route. *C. difficile* colitis is a gastrointestinal disease that occurs primarily among individuals who have been using antibiotics. *C. difficile* colitis occurs when antibiotics disturb the equilibrium of bacteria in the gut. The antibiotic disrupts the other bacteria that are normally living in the colon and prevent *C. difficile* from transforming into its active, disease-causing form. When *C. difficile* transforms into its active form, some, but not all strains of *C. difficile* produce toxins that inflame and damage the colon causing diarrhoea of varying severity, which may resolve once antibiotic treatment is stopped, though severe inflammation of the bowel can sometimes be life threatening. Other symptoms can include fever, loss of appetite, nausea and abdominal pain or tenderness. This spectrum has come to be known as *Clostridium difficile*-associated disease (CDAD). CDAD may develop fairly rapidly in patients undergoing antibiotic treatment, although the period of susceptibility may continue for a considerable period such that CDAD may not develop until some time after the course of antibiotics has been completed.

While most *C. difficile* colitis is caused by antibiotics, *C. difficile* colitis can also occur in patients without such exposure. For example, patients with ulcerative colitis and Crohn's disease have been known to develop *C. difficile* colitis without exposure to antibiotics. In the USA, cases of CDAD have recently been reported in individuals in the community, where no predisposing factors were present.

As stated previously, many infants and young children, and even some adults, carry the organism in their colon. It is thought that *C. difficile* does not cause colitis in these individuals since the bacteria remain in the colon as non-active spores and individuals have developed antibodies that protect them against *C. difficile* toxins.

Hospital-acquired and community-acquired *C. difficile*

C. difficile has now been established as the leading cause of hospital-acquired infectious diarrhoea in adults. However, CDAD may also occur outside of hospitals in the community in individuals that carry the organism in their gut or become exposed to the organism in their home or community. As in the hospital setting, only certain people at home are at risk of developing CDAD. People most at risk include those which have undergone treatment that may impair or disrupt the microflora of the intestine, such as therapy with antibiotics, immunosuppressives, or antacids or surgery. Use of gastric acid suppressant drugs is a newly emerging risk factor. The elderly are particularly at risk and over 80% of cases are in the over-65 age group. Repeated enemas and/or gut surgery increase the risk of developing the disease. Multiple and severe underlying diseases and prolonged hospital stay are also risk factors. Although children under two years of age frequently carry *C. difficile*, they do not usually present with symptoms.

Recently a new type of *C. difficile* (type NAP1/027), closely related to one previously found in North America, has been detected in the UK, including at Stoke Mandeville Hospital. The new strain appears to be more virulent, with an ability to produce greater quantities of toxins. In addition, unlike many previous *C. difficile* strains, it is resistant to floroquinolone antibiotics. It is not possible to assess how prevalent this strain might be in the UK since sufficient data have not been collected to give us a true picture. However, it is known that type 027 now accounts for 28% of all isolates from hospital patients in England, which has risen from practically zero in the last two years. In the USA in 2005, a number of cases of community-acquired CDAD were reported in patients where there was minimal or no exposure to healthcare settings and no history of recent antibiotic prescribing. These various reports reflect the rapidly changing epidemiology that appears to be taking place with *C. difficile*.

How do you know if someone is carrying *C. difficile*?

If someone is harbouring *C. difficile* in their gut, there is no way of knowing. However, the presence of *C. difficile* in faeces can be demonstrated in up to 3% of healthy adults. The rates of colonisation and infection increase markedly beyond the age of 65, such that for England and Wales *C. difficile* is the predominant enteric pathogen among people in this age group.

During the first month of life up to two-thirds of infants become colonised with *C. difficile*. This probably reflects acquisition from the hospital environment, but for reasons that remain unclear most colonised neonates are asymptomatic carriers, even when toxin production can be demonstrated. During childhood, carriage rates decline to adult levels, while both sporadic and outbreak CDAD begin to appear.

How do you know if someone is infected with *C. difficile*?

The effects of *C. difficile* can vary from mild to sever diarrhoea. Other symptoms can include fever, loss of appetite, nausea and abdominal pain or tenderness. It most usually occurs in people who are elderly and/or have recently undergone a course of antibiotic treatment, and/or have recently been hospitalised.

Can pets and other animals carry *C. difficile*?

There are indications that *C. difficile* may be carried by domestic pets. A recent study in a group of 102 dogs from a variety of sources across Ontario, Canada showed that the most frequently isolated pathogen was *C. difficile* which was isolated from 58 (58%) faecal specimens. Seventy-one percent (41/58) of these isolates were toxigenic, i.e. disease-causing strains.

How is *C. difficile* spread in the home environment from one person to another?

C. difficile is transmitted from one person to another by the faecal-oral route by the ingestion of spores. The organism is shed in faeces from an infected person or someone (or a domestic animal) who is carrying the organisms in their gut. Release of spores is easily accomplished as *C. difficile* causes diarrhoea, which is often explosive. It has been estimated that infected patients excrete over 100 *C. difficile* per gram of faeces.

C. difficile is an organism that is very resistant to drying and can survive in the environment for long periods of time. Contamination of the environment is a major factor in the spread of the organism. One study reported that *C. difficile* spores can survive on hospital floors for at least five months, but other reports suggest that it may survive for much longer.

A number of investigations carried out in hospitals show that, where there is someone who is infected or is a carrier, *C. difficile* can be isolated from their hands, and the hands of carers, and from a range of environmental surfaces in their ward or room, including those frequently touched by hands. Since hands are known to be an important route for transmission of *C. difficile*, identification of *C. difficile* on surfaces frequently touched by hands is particularly important. Hand contact and other surfaces from which *C. difficile* has been isolated include items and/or surfaces such as bedpans, furniture, bed frames, bedding, floors, carpets, toilet seats, sinks and other bathroom sites, linens, telephones, fingernails, rings and floors and nappy buckets. It is known that *C. difficile* can be isolated from these surfaces even in places where infected patients were not known to have visited. Where an infected or carrier person is present in the home, clothing and linen (towels and bed clothing) may become contaminated and carries a risk of transfer to clean laundry during handling and the laundry process.

Since *C. difficile* is transmitted via the faecal-oral route, it is possible that it is also transmitted via food that is contaminated via the hands of the person preparing the food.

The potential for *C. difficile* transmission in the home if good basic hygiene is not carried out is borne out by a number of investigations demonstrating that introduction of hygiene measures in hospital areas where there were sporadic cases or outbreaks of CDAD resulted in a reduction in the number of cases or in termination of the outbreak.

What are the risks associated with *C. difficile* in the home and community?

Based on current evidence, the risks associated with transmission of *C. difficile* in the home and community are relatively small at present. Although *C. difficile* appears to be widespread in the general environment, and is frequently present in the gut flora of humans and animals, only a proportion of these strains are toxin producers, and gut carriage of these strains only causes CDAD in situations where the gut flora is disturbed, most usually as a result of taking antibiotics. However, although there is no particular cause for alarm, it is recognised that reducing the risks of transmission of *C. difficile* in the home is important for a number of reasons:

In particular:

- When patients who are still infected or colonised with *C. difficile* are discharged from hospital, the organism may be transmitted to other family members or contacts, or can be disseminated into the home environment where it can survive for significant periods. A patient may recover from a *C. difficile* infection, but can become re-infected if they are exposed to the organism either from another family member who has become colonised or from surface contamination persisting in their own home environment.

In addition, although carriage of *C. difficile* amongst healthy family members is not a risk in itself, there are a number of reasons why it makes sense to minimise dispersal of *C. difficile* in the home environment and reduce opportunities for exposure amongst family members, which could lead to colonisation:

- When someone in the home requires a course of antibiotic treatment, this person is at increased risk of developing CDAD if they are a carrier of *C. difficile* or are exposed to it via other family members or spores persisting in their home environment.
- When a family member who is a carrier of *C. difficile* is admitted to hospital they are at increased risk of developing CDAD in situations where they undergo antibiotic treatment, or treatments that destabilise the bowel.
- When a family member who is a carrier of *C. difficile* is admitted to hospital they represent a source of infection, which may be transmitted to other patients.
- When a family member who is a healthcare worker becomes colonised with *C. difficile* at home, they may transmit the organism to patients to the healthcare institution where they are employed.

Family members who are most likely to be colonised with *C. difficile* are those who are healthcare workers or work in healthcare settings where they may have acquired the organism from infected patients or their environment.

These risks are exacerbated by the fact that once it is allowed to become "endemic" in the home environment, *C. difficile* can persist for long periods of time and can be difficult to eradicate.

As far as public health authorities are concerned, persuading individuals to adopt hygiene practices on a routine basis in the home to reduce the spread of these strains within the family is key to controlling the spread of these strains in the community.

Reducing the opportunities for exposure amongst family members and domestic animals that could lead to colonisation depends on good day-to-day hygiene practice. Good daily hygiene means adopting the IFH targeted approach to home hygiene as outlined in the IFH Guidelines and Recommendations on home hygiene and the IFH Home Hygiene Training Resource. Everyone is at risk of exposure to *C. difficile* during our normal daily routine, but unless there is someone at home who is known to be infected with *C. difficile*, this mostly occurs without our awareness. Accordingly, it is always important to practice good hygiene.

However, in a situation where there is a family member who is known to be infected with or carrying *C. difficile*, there is some specific guidance that can be given. The following are draft advice sheets for informing the public about specific risks and giving practical advice.

Practical advice to prevent risks of spread of *C. difficile* in the home

If there is someone in the home who is known to be carrying *C. difficile*, it is important to practice good hygiene in order to reduce the risks of spread to other family members who are vulnerable to infection or who may become colonised and pass the infection on to others. This is particularly important if there are family members who are healthcare providers that may come into contact with vulnerable groups during daily activities. The risk of clinical infection in other "healthy" family members is very small, but can occur if they belong to a group that is at risk, i.e. over 65 years old, or are on a course of antibiotics. The infection is transmitted from person-to-person. This occurs primarily via hands, but can also occur via clothing, linens, facecloths etc. Hand and body contact surfaces such as baths and basins, shower trays and curtains may also be involved. Other environmental surfaces may also be involved. The most "risky" surfaces are those that come into direct contact with the infected person and, when the patient is bedridden, surfaces in their immediate vicinity e.g. bedside tables, bed frames etc.

When an infected person is discharged from hospital, the family may be concerned because of the strict precautions that were applied to them while they were in the hospital. It is important to make the family aware that these measures were aimed at preventing the spread of *C. difficile* to other vulnerable patients in the hospital who were at particular risk because of their illness or surgery. At home the risks are reduced, but it is important to continue good hygiene to prevent spread to other family members and the environment. Occasionally people can be cleared of infection, only to become re-infected from *C. difficile*, which has contaminated surfaces in the home.

The most important measures for preventing transmission of *C. difficile* from an infected family member are:

For those caring for the infected person:

- Good hand washing practice is the single most important infection control measure. Caregivers should wash their hands with soap and water after contact with the infected or colonised person or surfaces in their immediate environment (e.g. bedrails, bed cloths, bedside table etc). Alcohol hand rubs may be used in situations where there is no access to soap and running water, but there are indications that alcohol has limited disinfectant action against C. difficile spores, which means that hand washing should be the procedure of choice.

- Clothing, Sheets and pillows and linens from the infected patient (or carrier) should be kept separate from the rest of the family laundry and should be laundered in a manner which kills *C. difficile* spores. Either:
  - Wash at 40°C using a bleach-based laundry product.

  Or
  - Wash at 60°C or above (using any laundry product as heat will destroy *C. difficile*).

  Note: washing at 40°C without the addition of bleach will not destroy *C. difficile*
- Do not share towels, facecloths, toothbrushes and other personal hygiene items with the infected or carrier person.

- Wash hands thoroughly and hygienically clean kitchen surfaces using hypochlorite disinfectant cleaner before handing handling or preparing cooked or ready to eat foods.
- Hygienically clean surfaces in the bathroom and toilet, most particularly including washbasins, baths and toilet bowl, toilet seat and toilet handle using a hypochlorite disinfectant cleaner*
- Where floors or other surfaces** become contaminated with faeces or vomit, they should be hygienically cleaned at once:
  - Remove as much as possible of the excreta, from the surface using paper or a disposable cloth, then
  - Apply hypochlorite disinfectant cleaner to the surface using a fresh cloth or paper towel to remove residual dirt – then
  - Apply hypochlorite disinfectant cleaner to the surface a second time using a fresh cloth or paper towel to destroy any residual contamination
  - Disposable gloves should be worn if in contact with faeces, and hands should be washed after removing gloves.
- Cleaning cloths can easily spread *C. difficile* spores around the home. They should be hygienically cleaned after each use, particularly after use in the immediate area of the patient or the bathroom and toilet used by the patient. This can be done in any of the following ways:
  - wash in a washing machine at 60°C (hot wash)
  - clean with detergent and warm water, rinse and then immerse in hypochlorite disinfectant solution* for 20 minutes
  - clean with detergent and water then immerse in boiling water for 20 minutes.

  Alternatively use disposable cloths

Also:
- Keep the patient's immediate environment hygienically clean. The most important surfaces are those which come into contact with the hands e.g. door handles, telephones, bedside tables and bed frames. To make these surfaces hygienically clean you need to use a hypochlorite disinfectant cleaner.
- Clean floors, carpets and other surfaces daily using vacuum extraction.
- In a busy household it is not always possible to keep hand contact surfaces hygienically clean at all times. This is why it is so important to wash hands as frequently as possible to break the chain of infection.

For the infected person:
- Wash your hands frequently, particularly after visiting the toilet.
- Avoid preparing food for others. Wash hands before eating food.
- Shower frequently.
- If you have diarrhoea, clean and disinfect the toilet bowl and toilet seat and toilet flush handle using hypochlorite disinfectant cleaner after using the toilet.
- Do not share personal hygiene items such as towels, facecloths, and toothbrushes with other family members.

* Domestic hypochlorite bleach cleaners include the "thick bleaches" and "bleach spray surface cleaners". Domestic thick bleaches usually contain 50,000 ppm available chlorine and should be diluted 1:10 for hygienic cleaning of surfaces. Surface bleach spray cleaners usually contain a minimum of 5000 ppm. Bleaches tend to be inactivated by dirt and soil. For use on relatively clean surfaces such as toilet seats, baths and basins, this is not a problem. However, where there is heavy soiling, e.g. where floors or other surfaces are contaminated with faeces, it is necessary to first "clean" the surface by removing the soil (stage 1) and then apply the disinfectant cleaner (thick bleach or spray) to make the surface visibly clean (stage 2). This may, however, leave behind some residual contamination, so it is advisable to reapply the disinfectant cleaner a second time (stage 3) to ensure that the surface is "hygienically" clean, i.e. free from C. difficile. Detergent and hot water, followed by "thin bleach" can also be used for stages 2 and 3.

** Alternatively, carpets and furnishings can be hygienically cleaned by steam cleaning.

Further Reading

1. National *Clostridium difficile* Standards Group: Report to the Department of Health Journal of Hospital Infection 2004 56 1-38.
2. Information about a new strain of *C. difficile* CDC July 2005
http://www.cdc.gov/http://www.cdc.gov/ncidod/dhqp/id_CdiffFAQ_newstrain.html
3. Results of the first year of mandatory *Clostridium difficile* reporting: January to December 2004 CDR weekly vol 15 no 34, 2005, 1-3.
4. CDC. *Clostridium difficile* Information for Healthcare Providers (August 2004, Updated 9/23/04)
5. Health Protection Agency. Questions and Answers – *Clostridium difficile*
6. Guidelines for prevention of infection and cross infection the domestic environment. International Scientific Forum on Home Hygiene. http://www.ifh-homehygiene.org/2public/2pubgu00.htm
7. Recommendations for selection of suitable hygiene procedures for use in the domestic environment. International Scientific Forum on Home Hygiene http://www.ifh-homehygiene.org/2public/2pub04.htm
8. Home Hygiene - prevention of infection at home: a training resource for carers and their trainers. International Scientific Forum on Home Hygiene http://www.ifh-homehygiene.org/2003/2public/2pub06.asp

APPENDIX 3 – BRIEFING DOCUMENT FOR HEALTH PROFESSIONALS

EXTENDED-SPECTRUM ß-LACTAMASE-PRODUCING *ESCHERICHIA COLI* (ESBLS)

What is *Escherichia coli*?

Escherichia coli is a Gram-negative bacterium that is found in large numbers in the normal gut of all humans. There are many different strains of *E. coli* with different characteristics, all of which are constantly circulating in the community and evolving into new strains. *E. coli* can colonise the human gut without causing any symptoms, but is an opportunist pathogen and can cause disease in situations where it gains access, e.g. via the urinary tract to a susceptible person. *E. coli* is most frequently associated with bacterial sepsis (bacteraemia), neonatal meningitis, infections of the urinary tract and gastroenteritis in travellers to countries with poor hygiene. Most infections (with the exception of gastroenteritis) are endogenous and come from patients' own gut flora. Invasion of the urinary tract occurs by transfer from faeces (which may sometimes occur by cross infection as well as by self infection) and can lead to infection, which mainly occurs in people who are more vulnerable. *E. coli* is one of the most common bacteria causing gastrointestinal and urinary tract infections (UTIs) and can sometimes progress to cause more serious infections such as life-threatening bacteraemias. It is the most common agent causing urinary tract infections and the second most common agent causing bacteraemia. Strains of E.coli that cause gastroenteritis come from 4 groups, enterotoxigenic, enteroinvasive, enteropathogenic and enterohaemorrhagic. The strain known as *E. coli* O157:H7, which first became a concern some 10 years ago, belongs to the enterohaemorrhagic group. It is characterised by the ability to produce a verocytotoxin that causes severe abdominal pain and bloody diarrhoea.

What is extended-spectrum ß-lactamase-producing *E. coli*?

ESBL (extended-spectrum beta-lactamase) producing *E. coli* are antibiotic resistant strains. They are no different from other stains of *E. coli* in that they can be carried as part of the normal bowel flora and can cause urinary tract infections, bacteremia and meningitis in susceptible individuals. The key feature of these strains is that they are able to destroy a large number of common antibiotics, making infections very difficult to treat. In many instances, only two oral and a very limited group of intravenous antibiotics remain effective.

ESBL-producing strains of *E. coli* were first noted in 2003 when South East and West Midlands regions of England reported to the Health Protection Agency about the appearance of infections with highly cephalosporin-resistant strains of *E. coli*, some of which were thought to have arisen in the community.

The resistance of these bacteria is due to the fact that they have acquired genes that enable them to produce a particular class of extended-spectrum ß-lactamase enzymes (ESBLs) called CTX-M that attack and destroy the ß-lactam antibiotics (penicillins and cephalosporins), thereby making themselves resistant to their action. Most CTX-M-producing *E. coli* are exceptionally resistant to multiple antibiotics including ampicillin and the cephalosporins. They are often resistant to other antibiotics such as quinolones and trimethoprim, which are some of the most important and widely used classes of antibiotics. As a result, there are limited options for oral treatment of these infections.As stated above, UTIs and bacteraemia caused by *E. coli* can be life-threatening, which is why the emergence of the ESBL-producing strains is a serious concern. Early epidemiological studies revealed that a number of patients (often elderly and with serious illness) who became infected with CTX-M-producing *E. coli* subsequently died, although these were generally elderly patients with underlying health problems.

Hospital and community acquired ESBLs – who is at risk?

Of concern is the fact that CTX-M ESBL-producing *E. coli* strains have now become widespread in England, causing urinary tract infections and bacteraemia. Their emergence and spread has been rapid and recent. According to a recent HPA report, these strains were unrecorded in the UK prior to 2000, but have been subsequently increasing.

One of the concerns is that these strains are spreading not only in hospitals, but also in the community. A 2004 study showed that, of 291 isolates of ESBL-producing *E. coli* from infected patients sent to the UK Reference Laboratory, about 25% were from patients in the community. Most infections reported to GPs in the community, as in hospitals, were in elderly individuals or others with underlying medical conditions, most particularly those undergoing catheterisation. In some cases, patients were recently hospitalised, which means that the patient may have become colonised or infected whilst in hospital. For some community cases, however, there are no apparent risk factors.

There is evidence suggesting that ESBL-producing strains are carried in faeces, which in turn implies that these strains have now entered the food chain into the healthy community producing a reservoir of colonised healthy people in the community. This would therefore increase the risk of transmission to vulnerable groups. There has also been a report from Canada that domestic animals can carry these organisms in their gut and faeces.

Further research is needed to answer questions about the source of the current outbreak of ESBL-producing *E. coli*, in addition to why and how it has spread so rapidly, and why it sometimes affects patients in the community, without the usual risk factors. A case control study is currently underway in London and the South East regions to further investigate risk factors for community-acquired urinary tract infection with ESBL-producing *E. coli*, which hopefully will answer some of these questions.

Although emergent strains such as ESBLs inevitably attract public attention, a key factor in communicating with the public is to reassure them that they are not more virulent then the parent strain, i.e. they have the same ability as the parent strain in terms of colonisation of the human body and the ability to overcome host defences and cause infection. The term "superbug" refers to their ability to resist the action of many antibiotics. Urinary tract infections associated with *E. coli*, although unpleasant (and only occasionally life-threatening) are generally self-limiting. The main concern is that these strains are a source of genes that carry antibiotic resistance and that, for someone infected with an ESBL-producing strain, the ability to treat the infection can be severely compromised.

How are ESBL-producing *E. coli* spread from one person to another?

It is reasonable to assume that the chain of infection for ESBL-producing strains of *E. coli* is no different from that of the "parent" *E. coli* strains. Transfer of *E. coli* in these settings is most likely to occur via hands, but may also involve cleaning cloths and hand contact surfaces (e.g. door handles, tap handles, toilet seats), but as yet there is no data to confirm this. For those who carry *E. coli*, infection of the urinary tract may occur by self infection from their own faecal flora.

Surveillance data confirms that individuals who are infected with, or are carriers of, *E. coli* shed the organism in their faeces. *E. coli* is a species that typically cannot grow in the environment outside a human or animal host. It also has relatively limited ability to survive on hands and environmental surfaces, but organisms can survive for short periods on hands, cleaning cloths and surfaces in sufficient numbers to allow transmission of infection.

Colonisation of the healthy gut with *E. coli* involves transmission by the faecal-oral route, which can involve not only direct hand to mouth transfer, but also transfer via the food chain. Food can become contaminated either during handling by someone who is carrying the organism, or the organism can enter the food chain during food production. This is an area warranting further investigation, although there is little to indicate that ESBL-producing *E. coli* is prevalent in UK food animals at the present time. The major concern is that food can act as a vector to disseminate ESBL strains more widely in the community, thereby increasing the risk of infection with ESBL-producing strains for those people who belong to a vulnerable group.

What are the risks associated with ESBL-producing *E. coli* in the home and community?

In the home environment family members are only at risk of becoming colonised or infected with ESBL-producing *E. coli* strains in situations where there is another family member or a pet that is carrying the organism. Since the majority of urinary tract infections from *E. coli* involve self-infection from gut flora, the key to reducing the impact of ESBL-producing strains lies in reducing the circulation of these organisms within the healthy community. At the present time, there is relatively limited understanding about the origins and epidemiological properties of ESBL-producing strains of *E. coli* with which to formulate strategies for preventing spread, but it is reasonable to assume that, similar to *S. aureus* and *C. difficile* poor hygiene practice amongst family members in the home may have a significant role in facilitating the spread of these strains to both other family members and the immediate community.

Further Reading

1. Health Protection Agency. Extended-Spectrum Beta-Lactamase (ESBL) producing E. coli - questions and answers. http://www.hpa.org.uk/infections/topics_az/esbl/q_and_a.htm
2. Health Protection Agency. Investigations into multi-drug resistant ESBL-producing Escherichia coli strains causing Infections in England. London: HPA, September 2005. http://www.hpa.org.uk/hpa/publications/esbl_report_05/7_bibliography.htm
3. S.L. Lefebvrea, D. Waltner-Toewsa, A.S. Peregrineb, R. Reid-Smitha, L. Hodgec, L.G. Arroyod, J.S. Weesed Prevalence of zoonotic agents in dogs visiting hospitalised people in Ontario: implications for infection control. Journal of hospital Infection 2006 in press
4. Guidelines for prevention of infection and cross infection the domestic environment. International Scientific Forum on Home Hygiene http://www.ifh-homehygiene.org/2public/2pubgu00.htm
5. Recommendations for selection of suitable hygiene procedures for use in the domestic environment. International Scientific Forum on Home Hygiene http://www.ifh-homehygiene.org/2public/2pub04.htm
6. Home Hygiene - prevention of infection at home: a training resource for carers and their trainers. International Scientific Forum on Home Hygiene. http://www.ifh-homehygiene.org/2003/2public/2pub06.asp

www.ifh-homehygiene.org