Planning strategies for nosocomial infection control

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ABSTRACT: According to the American Centers for Disease Control and Prevention, 99,000 deaths per year in the United States are caused or impacted on by multiple hospital-acquired infections (HAIs), which are roughly estimated to be around 1.7 million cases. In Europe, there are 25,000 deaths per year from the same cause, 17.000 of which are linked to nosocomial infections. Patient safety is a core issue in today's health care settings. There is a growing consensus, supported by scientific investigation, that the role of the built environment is central towards minimizing and controlling the level of such infections.

The contribution of architectural solutions and planning choices becomes crucial at this stage. This paper outlines the most common measures to adopt at the architectural and planning level, to combat HAI, focusing on the most critical areas of the hospital: wards, intensive care units and operating theatres.

MRSA, methicilin-resistant *Staphylococcus aureus*, is only one of the so-called multidrug-resistant pathogens that characterize the spectrum of multidrug resistant organisms (MDROs), which are the origin of nosocomial infections. Recent findings depict a rather disturbing scenario on the rising level of risk factors for infections by MDROs in health care-associated infections. The initiation of the disease process regarding nosocomial infections is dependent upon the alteration of a weak equilibrium which lies between pathogens, patients and the environment. Whether hospital hygiene protocols are respected or not, there is an important role played by the way the hospital environment is physically shaped. The spread of infections and its control can, therefore, be influenced by hospital architecture.

Patient safety is a core issue for health care planners, policy-makers, and hospital managers nowadays. However, only a few hospitals in developing countries are designed on the basis of scientific evidence (edb). Linking hospital design and construction with the prevention of nosocomial infections becomes a challenge that can be won only through cooperation between hospital authorities and specialist design companies. The position of hand washing facilities, the right amount of space within a room, the division of septic and clean workflows, the use of sluices and the prevention of overcrowding in wards are only few of the spectrum of solutions that can be adopted in order to influence the control of hospital acquired infections. Figure 1, shows a recent survey conducted by the World Health Organization, on the percentage of new tuberculosis cases associated with MDR. This is rather shocking.

The same reaction could be provoked by analysing the map of the incidence of MRSA in human blood samples in European countries (Figure 2).

These data are the premises which motivate a common awareness of the importance of minimizing the effect of such infections within health care settings as seen from a safety perspective. But what can really be done by hospital planners and architects? Can architecture really support infection minimization? Despite all the national regulations and hygiene protocols, which are quite different from country to country, there are certain planning rules that health care architects follow during the design process. The control of nosocomial infections is an issue for the entire hospital building, but there are certain areas where a higher level of attention is required. Operating theatres (OT), intensive care units (ICU), central sterile supply departments (CSSD), the dietary laundry and laboratories are some of the most common areas where the attention of health care planners towards infection control are most needed. This paper, aims to outline the design strategies to adopt to reach a higher level of control of the development and spread of hospital-acquired infections.

Common planning guidelines

Health care facilities, and hospitals above all, are characterized by a varied population of users, each with a different health status. There are patients that need treatment, but also medical and service staff, visitors and other external parties that are healthy and have to work in an environment which has to be safe for them as well. Often some of these different categories of people share the same spaces and the potential risk of cross infections becomes relevant. The first basic challenge for health care planners becomes the avoidance of mixing of patient flows. This is achievable *in primis* by respecting a functional segregation of the macro areas of a hospital: outpatient departments (OPD), inpatient units, diagnostic and treatment (D&T) departments. Within these macro areas, the allocation of functional units, their proximity and adjacency, play an extremely important role which has to result in a smart zoning system, which is later supported by an efficient ventilation system.

FIGURE 1: THE PERCENTAGE OF NEW TB CASES ASSOCIATED WITH MDR

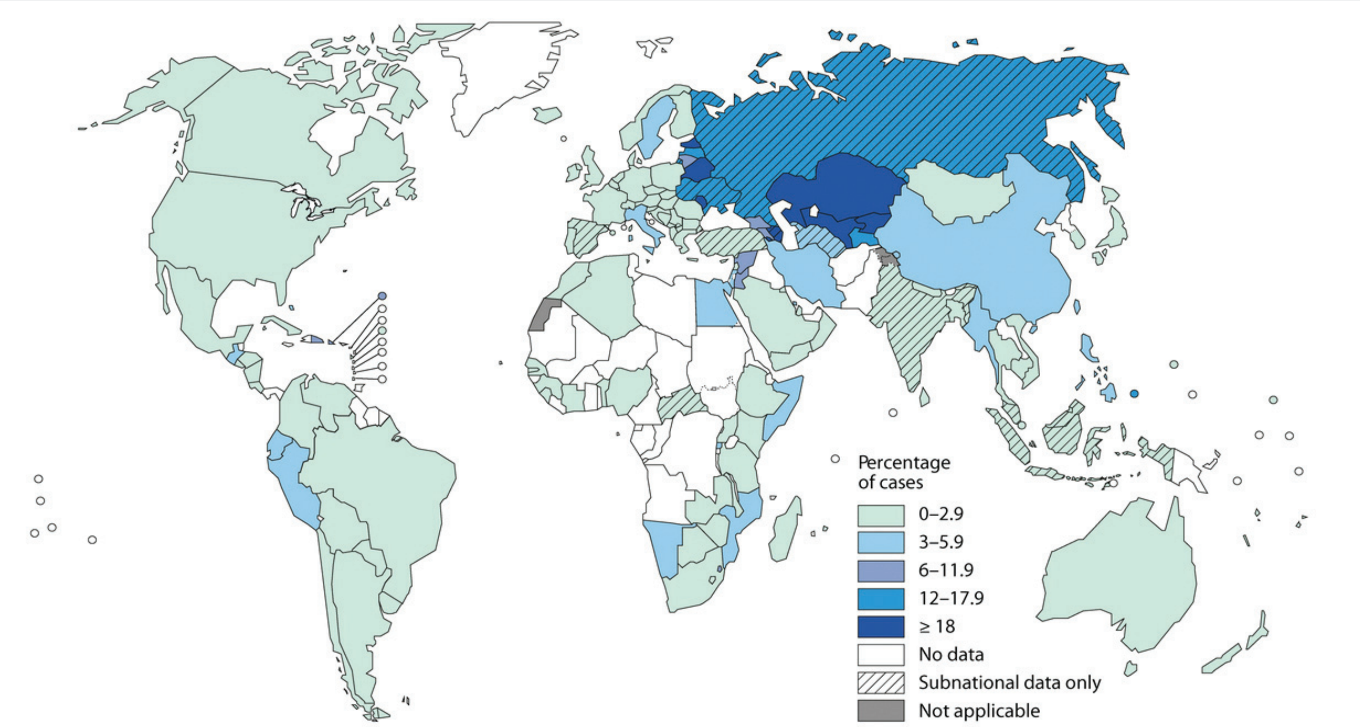
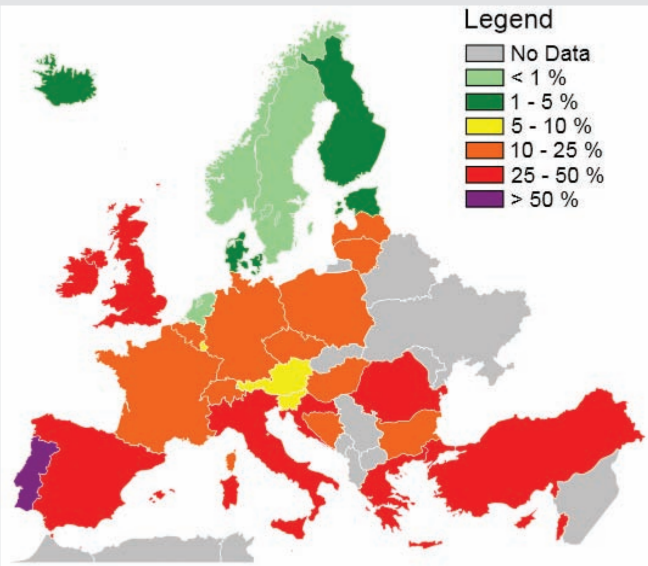


FIGURE 2: INCIDENCE OF MRSA IN HUMAN BLOOD SAMPLES



Applying a clear zoning structure can have a direct impact on the traffic division (soiled and clean, public and private) and on the consequent avoidance of congestion. These parameters are of paramount importance, for example, for the location of OTs and ICUs which have to be kept away from public traffic and air flows coming from other potentially infected areas such as laboratories and wards.

Usually a clear distinction among logistics, medical and public flows has to be embedded and clearly visible within the plan, so that soiled and clean workflows are located within specifically addressed corridors not adjacent to each other. Isolation wards have to be kept out of routine circulation, and the same has to be applicable to isolation rooms at ward level.

Experts often claim it is enough just to strictly respect hygiene protocols to control hospital infections. On one hand this is true; on the other hand, it is also true that a specific arrangement of the architectural layout can raise the probability that hygiene protocols are not neglected. Hand washing, for example, is the most basic and important step within hygiene protocols. A hospital's routines, stress and lack of time may result in neglect of such an important basic step. It is the responsibility of the health care architect to design a layout where the wash basins are visibly accessible to the medical staff.

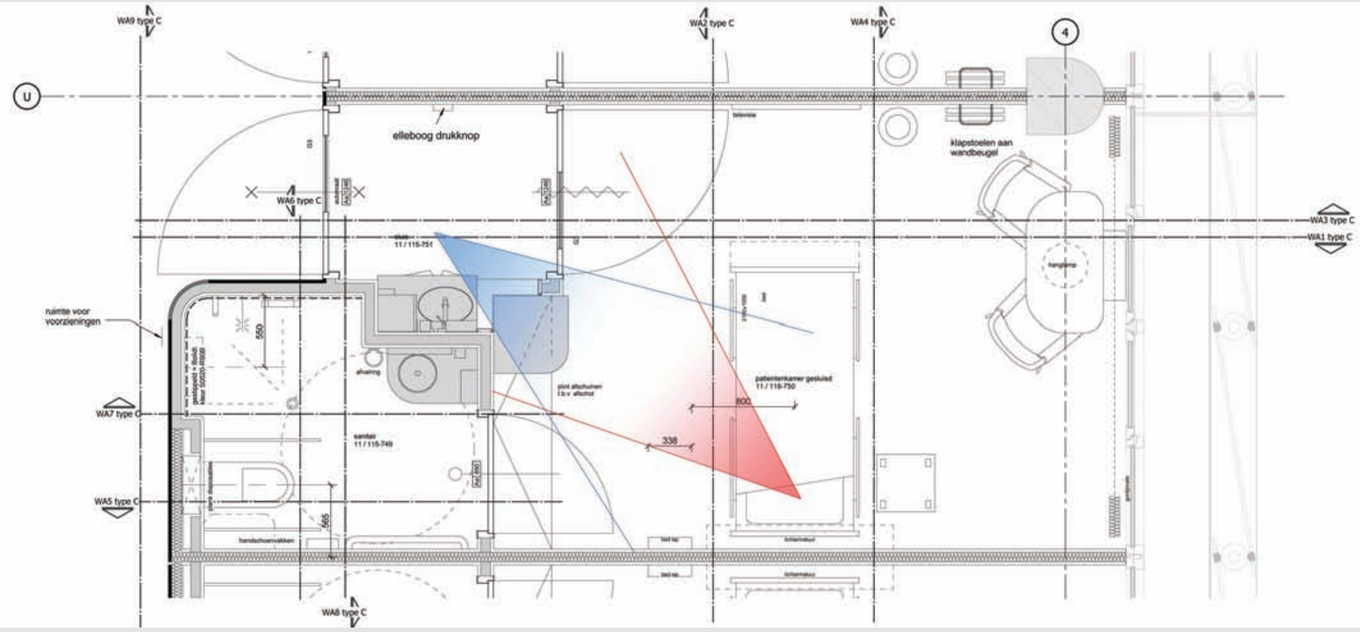
Air lock curtains and sluices are also often used to prevent the spread of nosocomial infections, especially in critical care areas where patients normally have a low immune defence system.

The new challenges for hospitals wards

The limits of hospital wards, and above all the acute wards, are continuously challenged as current debates testify. Comfort, patient support and safety are important keywords for these spaces. Safety also includes the risk of getting communicable diseases in health care settings. Principles of asepsis and hygiene protocols need to be constantly supported by design considerations.

As previously mentioned, the location and number of wash hand basins (WHB) can encourage medical staff to practice hand washing. It is important, therefore, that the WHB is the first element that the medical staff meet on their path when entering the patient bedroom. Moreover, in a patient supportive perspective, it is also important that patients themselves can directly watch the medical staff washing their hands before any procedure starts. This concept was applied to the new wards of the Erasmus Medical Center (EMC) in Rotterdam, a pioneering project in the European health care panorama designed according the latest ebd findings. The solution used for the new wards of the EMC proved very

Figure 3: The design for the new wards at the Erasmus Medical Center in Rotterdam, the Netherlands



successful both for patients and medical staff.

When planning hospital wards, it is also important to keep the number of multiple bedrooms to a minimum. The best situation would be to have an all single bedroom solution. Relevant previous studies have shown that increasing the number of beds in multibedrooms was associated with a significant increase in the nosocomial infection rate.

Ideally, each bedroom should be equipped with its own hand washing facility. However, to have wards consisting entirely of single bedrooms each with its own hand washing facilities is a solution not yet adopted even by some of the most developed countries in the world. This means that pavilion wards are still in use and the number of single bedrooms may be based on the number of other beds located in the pavilion itself. Certainly, when talking about pavilion wards we should not think to the number of beds which were present during Florence Nightingale's time. It might be better to simply call them multibedrooms with a maximum of 8–10 beds, which in some exceptional cases may be more.

An efficient air circulation system is also extremely important to prevent transferable diseases. HVAC systems are nowadays very efficient; however some experts support the use of clean natural air which is not mechanically controlled.

A recent survey by English researchers proved the significance of providing air circulation within the bedroom through opening simple windows. Providing air circulation through the natural ventilation system registered positive results in terms of reduction in the numbers of bacteria present in the bedroom environment. Therefore, equipping bedrooms with windows, which can be opened, is highly recommended. Isolation rooms, instead, should be planned to accommodate a sluice or air lock system which maintains a pressure difference between the two environments: the bedroom and the environment external to it.

The American Center for Disease Control and Prevention provided a checklist for planning isolation rooms. The checklist refers to three classes of isolation: S, N, P. The "S" class encompassed standard isolation conditions and is specifically focused on patients who require contact or droplet isolation. The "N" class, which stands for negative isolation, is focused on patients requiring airborne droplet nuclei isolation. The "P" class, positive isolation, is devised for deeply immunocompromised patients, such as oncology or transplant patients.

In this kind of special room a specific space should be provided to keep urine, stool samples of patients and also for disposal, washing and storage of contaminated materials such as soiled linen, as well as a place to mix disinfectant solution and place bedpans.

Planning critical spaces: The ICU

The last considerations on isolation rooms should concern the planning of ICUs.

More space per bed, more single bedrooms and better sanitary facilities are normally the aspects to consider when evaluating the impact of design solutions on hospital infection rates. In 1995, Vincent et al. reported that patients treated in ICUs with more than 11 beds had a higher risk of acquiring nosocomial infections than

Table 1: American Center for Disease Control and Prevention checklist

	Class "S"	Class "N"	Class "P"
Handwash basin room	Yes	Yes	Yes
Ensuite bathroom (shower, toilet, WHB)	Yes	Yes	Yes
Door with door closer	Yes	Yes	Yes
Airlock	–	Yes	Optional
Sealed room, door	–	Yes	Yes
Pan sanitizer (near room)	Optional	Optional	Optional
Independant exhasut	–	Yes	–
HEPA filters on supply		–	Yes
Air changes/hour	–	6–12	6–12

patients treated in ICUs with fewer than six beds. This stresses the importance of laying out ICUs on the basis of single bedrooms where possible. The impact of such a choice on decreasing nosocomial infections has already been statistically proved some time ago and it continues to be supported by recent studies.

The American Institute of Architects (AIA) sets the minimum number of hand washing facilities in ICUs for patients as one in the toilet room plus a sink in the patients' room.

Sinks need to be accessible and the surfaces made of nonporous materials in order to resist fungal growth. The use of copper has been recently proved to be exceptionally efficient against bacteria. However, costs considerations may prevent hospital managers from using large quantities of this expensive material.

Space beneath the WHB should not be used for storage because of the proximity to sanitary sewer connections and possible leaks. In the case of multibedroom ICUs, there is a common awareness among planners that there should be at least $14m^2$ of floor space per bed with adequate space for a head unit and sterile supplies. Isolation cubicles must be provided with self-closing doors and air locks.

The use of air locks and sluices are particularly relevant to create a protective barrier against the entrance and exit of contaminated air into the isolation cubicle where protective clothes can be worn without contamination prior to entering the room.

A15Pa positive pressure gradient between the isolation cubicles and the rest of the ICU environment is recommended by most common international standards, with 15 air changes per hour (five fresh and 10 re-circulations).

Not every country in the world agrees upon the use and net space needed for a sluice antebedroom.

Some western European countries, such as the Netherlands, require the sluice be measured on the basis of accommodating an entire bed plus medical personnel: 2.40 m is the average length of an air locked anteroom. If hand washing facilities are normally directly located in the bedroom just after the sluice, it is not uncommon to see in some pioneering projects the same facilities directly located within the anteroom. By doing so, the medical staff is already clean before they enter the core of the isolation cubicle. Furthermore, other kinds of air lock may be provided via so called air curtains. These systems consist of a downward-facing, blower fan mounted over a door, blowing air across the surface of the opening. This system, mostly used in United States, when applicable, can substantially reduce the amount of space normally needed for a common sluice.

However, there are several differences among countries when planning of ICUs which mostly belong to health care cultural approaches. These may result in a fragmented scenario for an external observer.

Planning OTs to reduce infection risk

Surgical departments and their operating rooms (OR) are supposed to be the cleanest and most isolated rooms in the hospital. The reasons are easily understandable because of the nature of the activities that normally are carried out in those spaces. The location and design of OTs, ventilation, temperature, hygiene protocols, the use of protective clothes and cleaning procedures are considered globally the most important factors affecting the outbreak of infections in operating settings. Also in planning operating theatres, there are several differences that arise from the health care culture background in different countries.

Normally, the entrance into a surgical department is marked by an air lock sluice that isolates the operating environment from the general one. Inside the surgical department, the location of the preparation rooms, of the OR, the position of hand washing facilities and the availability of soiled and clean corridors become crucially important. The room where the sterile material and tools are stored and unpacked before the operation starts is normally located in the middle of the surgical department, so that it can serve all the operating theatres from a centralized position. In this case, all the medical staff have a common entry point via the main entrance to the department. Some experts claim that in order to raise the level of infection prevention, the workflows of nurses, anesthesiologists and surgeons must be separated prior to entering the OR. Such views are directly linked to the way the operating settings are managed, which may differ from country to country. For example, in the Netherlands, it is common that one anaesthesiologist operates over two or more operating rooms.

By moving from one OR to another, the risk of bringing infection from that environment to another, is quite high. If this movement occurs through the central sterile hall, where the sterile material is unpacked, then there is a potential risk of spreading infection on the tools that will be used for the next operation. For this reason, some Dutch hospitals, such as the Jeroen Bosch in 's-Hertogenbosch, decided to adopt a particular design solution which took into account this potential risk from the mobility of medical staff within the surgical department. The architects who designed this modern hospital decided to relocate the space where the sterile material is unpacked to a specific room located between the two operating theatres. This special room has direct access to the OR, but it is filtered from the general departmental common corridor by a sluice room. This makes the procedure of unpacking the operating material and its room, the cleanest in the entire hospital environment and the most protected from potential risks due to the mobility of the medical staff.

This kind of solution also encompasses a division of workflows between the surgeons and other medical staff. In the Jeroen Bosch OR, the surgeon passes through a small room adjacent to the OT, specifically addressed to the hand washing procedures, before entering the operating theatre. This room is only intended to be used by surgeons. All the other medical staff, enter the operating theatre from the main access door.

There is a tendency, in countries like the Netherlands, to over use the space for sluices. This is obviously due to the way operation procedures and health care policies are conceived. In the Nordic European countries, such as Finland, every room has its own team including the anesthesiologist, who has no reason to move from one OR to another. Therefore, once the complete team is assembled within the OR, nobody moves from the OR until the operation is completed. In this kind of context, only the strict application of hygiene protocols is required to avoid the spread of acquired-hospital infections. Concerning corridors and their division in soiled and clean ones, there is an important consideration to bear in mind. Not all the hospitals have adopted this solution, and it is actually not true that unique corridors lessen the potential risk of the spread of infections. If waste or contaminated material is packed and sealed before leaving the OR, there is no need for an additional external corridor.

The American MASH (Mobile Army Surgery Hospital) model is still a perfect basic model to get inspiration from, above all in terms of protection against bacteria generated by the operating team and patients in the OR by using appropriate air volume changes and flows.

However there are common rules that planners observe worldwide for designing surgical departments. A sequence of increasingly clean zones from the entrance of the surgical department until the theatre are aimed at reaching absolute asepsis at the operating site is commonly planned.

The creation of an air flow pattern that carries contaminated air away from the operating table. The use of different air pressures as a tool to prevent less clean air entering the operating theatre. Moreover, no shelves should be present in the operating theatre and high attention has to be given to the choice of floor surface materials. Epoxy resin flooring is highly used, but in United States some hospital authorities have also recommended marble slabs with copper strips, since they have been found to be seamless, scratch proof, stain free and antistatic. Besides the OR and a separated sterile zone, one separate dedicated AHU aimed at maintaining a positive pressure gradient has to be taken into account.

Conclusions

The role of the physical environment in contributing to the minimization and control of nosocomial infections is still too often considered a minor factor among others that impact the hospital-acquired infections rates. This happens regardless of the availability of a strong and growing scientific evidence which supports the importance of environmental factors in the transmission of MRSOs.

Other factors, such as the adherence of medical staff to hygiene protocols and the vulnerability of the patients treated are thought to have a higher impact.

The differences of emphasis given to one factor rather than another is normally linked to the health care culture and the policy adopted. This might be due to the way operating procedures and teams are set up in different countries. The differences in planning surgical departments in the Netherlands and the Nordic countries are a clear proof of that.

This article has exposed some of the most common architectural measures used to contribute to hospital infection control in hospital wards, operating theatres and intensive care units.

More space for hospital beds, the choice of single bedrooms, the availability and position of hand washing facilities, HVAC systems and air lock solutions, and proper materials seem to be the most common, but not exhaustive, solutions implemented to impact on the control of nosocomial infections. However, relevant layout arrangements are also considered to be highly important in preventing the spread of MRSOs.

Differences between countries, beliefs and lack of scientific evidence in linking the built environment to the control of nosocomial infections, offer the possibility of exploring new frontiers in hospital design and management.

There is a need and a challenge to set-up further and systematic investigations aimed at strengthening the role of the physical environment in the minimization and prevention of hospital-acquired infections. ❏

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