A study into prevention of antibiotics resistance through enhanced building infrastructure design and management strategies

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A study into prevention of antibiotics resistance through enhanced building infrastructure design and management strategies

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Abstract: This study is part of a larger research project, which looks at how modern hospitals are built in Norway, and what can be done to make hospitals more user friendly and purpose built. It looks at how medical facilities can be made to encourage a quicker improvement in the patient's recovery, and what effect the way modern hospitals are being built and operated, has on the patients, the employees and to the visitors to the health facilities. A key focus of the research is to look at nosocomial infections (hospital-acquired infections) from medical care and to study the prevalence of antibiotic resistance at these facilities. The project aims to find conclusions and areas of improvement along larger parts of the hospital and patient chain. The greater research project aims to look at this scientific field through studies in 3 countries, in Northern Europe, Eastern Europe and Central Europe, to get an idea of the inter-European challenges in a very complicated scientific field, with different financial resources, cultures, focuses, and approaches to the frequency of use of antibiotics.

1. Introduction

This article is related to a larger research project ("Hygiene-Intensive Hospitals"), which looks at how modern hospitals are built in Norway, and what can be done to make hospitals more user friendly and purpose built. It touches on a few aspects which are relevant to the session topics for the International Scientific Conference. The articles main theme is a look at "New materials and technologies in building industry", in this case related to medical facilities. Additionally, it also touches on another important subject related to efficiency and technological improvements for medical facilities, which lies in the ventilation systems.

The greater research project has in its initial phase focused on Norwegian hospitals, but the intention is to look at challenges in Eastern Europe with our Romanian partners, and study the challenges faced in a third Central European country to be selected at a later stage. This approach has been chosen in an effort to get an idea of the inter-European challenges in a very complicated

scientific field, with different financial resources, cultures, focuses, and approaches to the frequency in use of antibiotics.

A key focus of the research is in nosocomial or hospital-acquired infections (HAI) from medical care, and to look at the prevalence of antibiotic resistance in medical facilities. This may seem like a broad field to approach, but it is the hypothesis of the research group that large benefits in reducing antibiotic resistance can be found in looking at the problem from a broad perspective. This will allow for identifying areas of improvement along larger parts of the hospital and patient treatment chain. The research project also has a key focus on how the building mass used for medical purposes, and the way modern hospitals are run, affect the patient's recovery, and the chance of survival. It looks at which improvements can be made to reduce infections, how to aid the quick and successful recovery of the patients, to improve the workdays for the staff, and to look at how improvements can benefit the hospitals and their operating economy.

2. The modern Norwegian medical facility building mass

For a greater overview of the building mass of Norwegian hospitals it is necessary to generalize a bit, and for the purposes of this article we will divide the medical facilities into 4 categories:

- general practitioner's facilities
- private and public health clinics
- smaller hospitals
- big hospitals

These facilities serve different purposes and their exposure to germs, viruses, microbes and bacteria, including antibiotic resistant strains, all differ to some degree. However, they all have a common enemy and interest in reducing the frequency of this exposure. In the Norwegian health system, the general practitioners are the front line of the medical treatment. The GP system is alongside the private and public health clinics the first medical professionals that patients turn to for non-emergency room treatment. These GP-facilities experience dealing with the full width of the population, germs and diseases. They serve the function for the health system as very important evaluation stations for the medical treatment chain, to assess the medical situation of the patients, and to determine whether the medical issues can be treated at their facilities by the general practitioners (GPs), or whether the patient needs to see a specialist or go to a hospital. Despite getting the broadest patient groups, and a broad exposure to medical issues and germs, sadly these general practitioner's offices are usually not built for the purpose they serve. They usually have the least specialized systems, assets and methods available to deal with the challenges. The general practitioners are in many cases able to determine whether the specialists or the hospitals need to take special measures during evaluations and treatments of patients, so they form an important line in the fight to protect the health system from extra complications. As for the building mass and equipment, it is difficult to keep non-purpose built buildings and equipment hygienic, and all indications are that there is ample scope for improvement of these medical facilities. Cleaning of them is limited to normal routine hygiene tasks, the ventilation systems are rarely dimensioned for the tasks, the facilities are never disinfected with pressurized droplet systems (aerosols), so that the disinfectant go in to the difficult to clean spots of rooms, technical installations, furniture and so on.

For many patients including immune suppressed patients the general practitioners office is a place of fear of what you may contract while waiting for the doctor, and it is a well-known fact that diseases spread easily at the doctor's office. The consequence is that you may come home with an additional problem to the one you went to the doctor with in the first place. In Norway like in many other countries the precautions one finds in hospital settings are usually only applied to GP offices during pandemic influenzas or when patients have been reporting with highly infectious diseases. In Canada the College of Family Physicians (CFPC) advised the GP or family doctors as they are referred to in the article to enforce tougher infection control guidelines to stop the pandemic outbreak of influenza. The article "Infectious risks in family doctor's offices" by Emily Senger advises that this practice

should be kept up, continuously [1]. Infectious diseases of course spread all year round, and they are not limited to when there are very easily transferred and contagious diseases like influenza.

The general practitioner system has limits in which medical cases it is able to treat, and how quickly it can provide access to doctors. Many doctors have 1250 to around 2000 patients on their patient list, which means that there can be significant waiting times. In many cases the patients will either evaluate the situation themselves and see that they need treatment that the GPs cannot provide, and that they need to go to emergency rooms at private or public health clinics. Alternatively, they will they choose to go to a GP or a specialist at a private health clinic instead of their assigned GP.

These health clinics face a wide array of possible infectious cases, and they may often be dealing with open fractures, open wounds, surgeries and other complicated cases where the risk of dangerous infections is considerable. The medical facilities are usually either purpose built, or have had alterations so that they have to a degree been designed for the purpose of being medical facilities. They usually have more advanced systems for hygiene and prevention of infections.

The next chains in the medical treatment line are the smaller and bigger hospitals. They face most of the same challenges, they are to a large degree purpose built, they have good systems in place, and usually knowledgeable staff who works to prevent infections. However, the age of the hospitals, the lack of financial resources to maintain and upgrade them, make individual hospitals very different between the best designed and the older and more average designed hospitals. As the hospitals handle the most seriously ill patients, the most complicated medical procedures, and has the patients under their intensive care for the longest period of time, they face complicated infections issues, and carry great risks for the transfer of secondary infections beyond the initial medical problem. In many cases it is close to impossible to do something about this, and certainly with the resources available. But it is the belief of medical professionals and researchers, that improvements can be made so that resources can be prioritized to minimize the risk of complicated and expensive medical problems that will have to be dealt with later. As it is, HAIs cost the health systems billions of Norwegian Kroner a year according to available research, but the general research data in this field for the Norwegian health system seems to be lacking significant parts of the greater picture. Some studies have been performed on what factors lead to HAIs, and both the building mass, the routines, methods, technical equipment and other factors all come into play. To the research group's knowledge there is room for a substantially improved research basis and data to find the differences, to find best practices, to find general improvements for all hospitals, and to find individual improvements for specific hospitals. Some researches indicate differences in the percentage prevalence of HAIs based on the size of the hospitals, and this is an interesting field that will be looked at, as there are many complicating factors involved [2].

The large numbers of hospital-acquired infections indicate that there should be significant room for reductions throughout the entire health system. There is a desire for this, but good intention, will and discussions must be follows by appropriate actions to make a change. This research project is working to engage all stakeholders in finding practical solutions to how we as a unified group can help each other reduce infection risks. We will make some proposals for improvements and solutions in the next part of this article.

3. Toilets / bathroom facilities

A general public health related weakness with buildings in society in general, are the restroom and bathroom facilities. In hospitals these facilities bring due to the accumulation of bacteria, viruses and germs a considerably greater chance of spreading diseases. Studies have shown that germs in feces can be propelled into the air when one flushes the toilet. Putting the lid down before one flush the toilet, leaving the bathroom stall where you have just flushed as quickly as possible, so that the amount of time you are exposed to germs is reduced [3]. Washing one's hands thoroughly for at least 20 seconds, and being careful with touching the sinks afterwards, are small and important steps that can be taken to reduce infection risk. Studies at the University of Arizona in Tucson found that "sinks are the greatest reservoir of germ colonies in restrooms, thanks in part to accumulations of water that become breeding grounds for tiny organisms" [3].

Research and interviews with medical professionals show that there is a great need for providing better education about bathroom hygiene in general. For hospitals it could be an idea to provide information material on how to take precautions to help the staff in their work, and to help society fight a common enemy.

For hospital wings, specifically for gastro-intestinal diseases, the use of toilets that flush and self-clean automatically, and faucets and showers that are triggered by motion sensors can be good uses of new building technologies. This could have a significantly positive effect in reducing nosocomial infections or hospital-acquired infections (HAI). These are simple and not too expensive improvements that can be utilized in large sectors of the building mass.

Better information material and education of general hygiene and health principles can greatly reduce the spread of infectious diseases. One area where improved education can quickly lead to reduced spreading is in prevention of urinary tract infections (UTI). According to Vyas et al. "Urinary tract infection (UTI) is the most common infection experienced by humans after respiratory and gastro-intestinal infections, and also the most common cause of nosocomial infections for patients admitted to hospitals indeed UTIs are the most frequent bacterial infection in women" [4].

Urinary tract infection (UTI) is one of the most important causes of morbidity in the general population and is the second most common cause of hospital visits [4].

This is an area where preventive measures can be made at any modern health and medical facility, and which in turn can lead to significant reductions in nosocomial infections, and financial expenses.

4. New building technological methods and materials

In addition to use of automatic faucets, toilets that can flush themselves, use of automatic doors, automatic soap and disinfectant dispensers and other simple measures, there are a number of changes that could be made when refitting or building new hospitals. Several hospitals in Norway use pneumatic tube postal systems to make sure blood tests, medicines, blood for operations and critical materials arrive quickly where they are needed. Although not a new technology, having been introduced in the 18th century, this efficient and time saving system is considered as a part of the modern automation of hospitals in Norway in the coming years. It is set to be included in the new hospital being built at Ulandhaug in Stavanger, Norway and is in use in at Ahus and Kalnes Hospital. Increased use of automation and robotics can allow for reduction in man hours required for internal transport, maintenance and operational tasks, freeing up employees to spend more time looking after the patients. Reducing the human handling of food, bed linen, dirty washing and waste can lead to the staff being less exposed to germs which they may bring with them throughout the hospital and into contact with patients.

Another key area for improvement is in the materials used for the various functions of the medical facility building mass. Most hospitals are built with significant weaknesses in the form of porous materials, and one should make more of an effort to reduce the amounts of hiding spaces and possible reservoirs for germs. This is a key area of the research, with the research and data collection in initial phases at the moment. Several research studies over decades have suggested that aesthetics can have positive health effects, and this study will look at the lessons learned and how this perspective can be applied in modern medical facilities. Many GP's offices, health clinics and hospitals have an eye to this field in their focus on art, gardens, plants (or plastic flowers) and so on, but a more holistic approach can probably be taken.

5. HVAC in medical facilities

Another key area of hospital design and operations is in the Heating, Ventilation and Air Conditioning Field (HVAC). As stated by major HVAC designers: "Hospitals are complex environments that require special HVAC system design, maintenance and repair considerations. HVAC systems are responsible for keeping indoor air quality (IAQ) high and providing a safe temperature for patients and staff" [5]. Furthermore: "Hospitals need a functional HVAC system to stay operational. This is especially true for places like a clean room or an operating room (OR)" [5].

The air quality in operating rooms, intensive care units, neonatal wards and isolation rooms etc. must meet several strict requirements. The air must ideally be free of pathogens and have a stable temperature and constant humidity. Furthermore, the air currents supplied by the ventilation system should have a sufficiently low velocity in order to avoid resuspension and recirculation of particles and microbes throughout a room [6]. In addition to the hygienic aspects, effective ventilation will provide a better working environment for the medical staff as well as aiding in the recovery of the patients. It is well documented that good in-door air quality has a positive effect on patient recovery time [7]. Hygiene guidelines for the planning, installation and operation of ventilation and air condition systems in health care facilities are found in the DIN 1946-4-12-2008 standard published by the German Society for Hospital Hygiene. In this guideline, the HVAC recommendations for different classes of rooms in medical facilities are given.

As previously stated, proper ventilation and temperature control is of vital importance in medical facilities. To prevent the spread of airborne microorganisms and pathogens, efficient air filtration systems must be in place. These systems must be able to filter out microscopic particulates and aerosols that may otherwise cause contamination to aseptic areas and/or compromise the recovery of patients. For vulnerable patient groups, like immunosuppressed patients, exposure to airborne viral or bacterial pathogens may result in life threatening complications. High efficiency particulate filters for use in medical facilities and clean rooms are classified according to the EN 1822 standard (EPA, HEPA or UPLA filters) [7]. For medical facilities, choosing the appropriate filter class to ensure enough filtering efficiency and minimal filter penetration and by-pass is essential in preventing the spread of airborne pathogens and other contaminants.

Attention should also be paid to air current patterns and air current velocities within a room. Ventilation systems supplying high velocity air currents may cause settled dust particles and microorganisms on surfaces to be whirled up and resuspended in the air. This will cause a recirculation of pathogens within the room, exposing patients to new infection hazards.

Temperature control is important for the comfort of both the hospital staff and patients. Controlled room temperatures will aid patient recovery and provide a safer working environment for the staff. Furthermore, modern medical equipment and instrumentation require efficient temperature control within certain limits to function optimally. As an alternative to ventilation systems based on conventional HVAC principles, we propose the use of thermal heating and cooling systems. While air condition and other systems using heavy duty fans may produce strong drafts and uneven temperature distributions, thermal systems can produce a more stable and evenly distributed heating/cooling effect in a room. Heating and cooling may be based on radiant heat panels (i.e. heat exchangers), where the heat can be supplied by the circulation of warm water from solar thermal collectors [REF needed]. Cooling is achieved by injection of cold water into the circulating water to give temperatures above 15-16 °C.

There are many ways of incorporating thermal heating and cooling devices structurally into a building. In several countries, like Spain, Australia and the UK, active chilled beams HVAC systems are in use [7]. Other technical solutions may be based on waterborne ceiling, wall or underfloor heating. In general, the use of solar thermal collectors and waterborne heating/cooling devices will provide significant savings in total energy costs compared to conventional HVAC systems. An attractive alternative to systems based on solar thermal collectors is geothermal heating and cooling. In Switzerland and Sweden 75% of new homes have geothermal heating and cooling installed [8]. Geothermal energy can generate energy cost savings up to 72% compared to conventional electric resistance heaters [9]. Local climate factors will of course be a deciding factor in which technical solution that is most suited

Finally, we must stress the importance of properly implemented maintenance and cleaning routines of HVAC systems to prevent system hazards and spreading of pathogens. Changing air filters regularly, cleaning coils, fluid reservoirs and piping when necessary and implementing suitable cooling tower maintenance procedures are all vital parts of the running maintenance. Along with

precise air quality monitoring systems, this will ensure that the HVAC system is geared towards achieving optimal hospital hygiene, staff and patient comfort [10].

6. Aims and goals of the research project

The research output aims to come up with proposals for improvements in health care and draw conclusions on how we can reduce the number of nosocomial infections and reduce the risk of antibiotics resistance in our hospitals and medical facilities. The goal is to work with the hospitals, the medical staff, the regional and national health authorities, the patient interest organizations and the patients themselves to come up with concrete proposals for reducing the cases of hospital infections. It is a key hypothesis of the researchers that the current building mass plays a significant role in the problem, and we will aim to make suggestions and concrete proposals for improvement in this. BIM, CAD and computer modeling alongside non-invasive and minimal invasive analysis techniques will play a key part of the research.

7. Conclusion

For this article we will focus on the conclusions to date of the research related to the topic sessions which are:

Improve the access to information materials and improve the health education and increase hygiene awareness in the medical and general communities. This is a simple, highly efficient and cost-effective way of reducing nosocomial infections at medical and health facilities. This method can be utilized at any modern facility and is easily implemented in the prevention chain.

The use for new technologies like motion sensors for faucets, automatic doors, automatic soap dispensers can reduce the transfer of germs. Robotic technology, pneumatic tube systems, more appropriate materials to fight germs, or to deny them hiding spaces are important ways in which modern hospitals can fight nosocomial infections. The use of new building materials with non-porous surfaces may reduce hiding spaces for bacteria, and can help in preventing resistance in hospital settings. The need for appropriate HVAC solutions is important in reducing spreading of germs and bacteria and has potential for considerable reductions in suffering and expenses.

Making sure that the quality of the ventilated air is appropriate, and performing systematic maintenance of the HVAC system is another area where the spread of diseases can be reduced compared to more traditional hospitals and medical facilities.

The authors believe that there are substantial steps that can be made to prevent the spread of antibiotic resistant bacterial strains and other pathogens throughout the hospital facilities. It is the opinion of the authors that several of these improvements can result in both significantly reduced medical complications, suffering of patients and in operating costs for running the medical facilities.

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