Ventilation Concepts in Operating Rooms An Innovative Research Project

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SUMMARY

The current state of building services engineering in the healthcare sector is characterized by ambiguity and prejudice. There is a conflict, with inadequate knowledge of the necessity and effectiveness of ventilation-based protection concepts on the one hand – with the associated investment and operating costs if an integral view is adopted – and the economics of antibiotic prophylaxis and infection treatment costs on the other.

Keywords: HVAC systems in hospital, engineering in health facilities, operating room
Category: Innovative technologies and solutions / Innovative research project

INTRODUCTION

The "GiG" building services engineering in healthcare project is an interdisciplinary research and development project. The cost transparency and lump compensations per treatment unit required by healthcare policies are giving rise to new strategies and new cost/benefit considerations. Having to treat customers (i.e. patients) for as short a time as possible is becoming an increasingly attractive proposition. In order to achieve this, building services equipment as a whole must comply with requirements on hygiene.

The continuing spread of multi-resistant pathogens and the corresponding rise in the use of increasingly expensive antibiotics in hospitals and other healthcare facilities must be sustainably reduced.

This project will make contributions to building services engineering research and development with the aim of reducing both healthcare and building services costs in Switzerland by CHF 24 MN per annum. It is a project of international consequence in terms of private enterprise, research and health policy.

The major foreign research partners are represented by Prof. Dr. Ing. Rüdiger Külpmann, TFH Berlin and Dr. med. habil. Peter Lüderitz, AYSID Hygiene-Institut, Berlin. The main domestic partner is the Innovation Promotion Agency KTI/CTI of the Swiss Confederation, which is providing half of the project financing.

Surgical procedures make the highest demands on the sterility of the air in operating rooms, but not in the anterooms. Today we concentrate on creating the best possible conditions (asepsis) for the operating team in the vicinity of the operative field and instrument tables.

Heating, ventilation and air-conditioning systems are necessary for reasons of
- physiology / physical comfort (wellbeing)
- hospital-specific indoor air hygiene (infection prophylaxis),
- the technical process (functionality and safety requirements).

The primary purpose of air-conditioning is to ensure optimal conditions in terms of physiology and occupational health. The latter will require increasing attention in future. Bearing in mind all the routes to infection, the current expense in terms of ventilation technology to reduce the germ number of the indoor air outside the operating room appears excessively high, especially with regard to investment costs and ongoing maintenance costs.

New air-conditioning technology concepts can also be put to meaningful use in healthcare facilities. The basis is provided by requirements for hygienic air quality in hospitals as reformulated by hygienists, and the associated simplification for ventilation and air-conditioning technology from the point of view of hospital hygiene. High demands on the sterility and protective action of the air pertain only to the immediate vicinity of invasive procedures, to the care of immunosuppressed patients, to handling of hazardous airborne materials, and to isolation care. Therefore, interest in highly sterile air or directed airflows focuses on precisely defined areas in modern hospital hygiene. Requirements are function-specific, and they differ from room to room.
In the characterization of the necessary air treatment equipment, therefore, it seems useful to make a distinction according to characteristics of physical comfort and infection prophylaxis.

Assuming that, downstream of the upright filters, the supply air entering the conditioned space is sterile, the operating team, the nurses and the patient must be considered to be the primary emitters of microbes. Medical equipment and furnishings mainly represent thermal loads. Air treatment systems must also meet "normal" requirements in addition to hospital-specific requirements.

Evaluations, student dissertations and laboratory tests have revealed that existing concepts have clearly lacked an overall approach. Results and measurements are unsatisfactory in all respects.

Status of our own research

Development activities, and the resultant new Swiss SWKI 99-3 directive, represent the philosophy that air hygiene should concentrate only on areas where there is a risk to patients, instead of operating aseptically in all areas.

This philosophy has two important goals: to provide the best possible patient protection with the least possible energy expenditure and, at the same time, to make an intensive effort to get under control the costs of treating the infections and the problems of antibiotic resistance occurring in hospitals.

The basic idea of OR ventilation promoted by the new Swiss SWKI 99-3 directive stems from the experience that a very wide variety of procedures are performed in many hospitals – from urological procedures, which are of lesser significance in terms of air hygiene, to the highly demanding implantation of prosthetic joints. On the basis of numerous publications, the conviction has become prevalent that only a large LAF (Laminar Air Flow) ceiling panel with very good shielding effect is suitable for demanding procedures. On that basis, there are no

resultant special requirements for the other areas of the OR and even in the environment of the LAF field itself in terms of ventilation technology. Consequently, activities with increased hygienic requirements must only be performed in the OR, specifically in the LAF zone only.

Until now, independent technical and/or hygienic investigations have been performed in different ways, with different task definitions and according to different procedures (mainly in specific, already completed and no longer modifiable clinical operating rooms, under time pressure and only if the clinic was kind enough to grant access to the room during off-peak hours). Therefore, the individual investigations are barely comparable with each other. Clinical issues always took precedence, and structural or technical changes were barely possible. The results of investigations performed so far in the development departments of LAF outlet manufacturers, for example, are not generally available for scientific evaluation and use, with the exception that the influence of structural factors or of OR lighting was taken into account in those investigations.

Within the hospitals section of the Swiss administration's Energie 2000 program, memoranda generated during the operational optimization phases of the hospitals clearly reflect the unsatisfactory state of hygiene-relevant spaces.

This means that, although some development has taken place, there has as yet been no systematic and comprehensive, application-oriented research using exact and reproducible scientific methods.

State of the art (national, international)

The national situation is reflected directly at the international level. German, Austrian and Swiss hygienists and engineers have been working together for some time to discuss requirements and technical possibilities, at least in the German-speaking region.

Additionally, the Swiss standardization body for the construction sector, SIA, has expressed willingness to intensively support the standardization efforts of CEN (based on Switzerland and Germany). The German Association of Engineers, VDI, took over the current version of SWKI 99-3 and published it in Germany in 2004 as the applicable directive for hospitals and building services engineering (draft VDI 2167).

Since 2003/04, therefore, there has been a single directive that is able to reflect the present and future state of the art. The blanket deployment of this instrument/knowledge is to be accomplished via the network/center of competence of HTA Lucerne and the Berlin University of Applied Science TFH as well as the project partners from the industry.

An ad hoc CEN meeting took place in March 2004 to discuss the question of research and standardization of building services engineering in hospitals. The European CEN partners that attended were unanimous: today's knowledge is somewhere between imprecise and incorrect, and must be urgently revised. Working Group WG 13 of Technical Committee TC 156 officially began its work in November 2004. The convenor of the WG is the author of this document.

RESEARCH GOALS

The research goal is to analyze the contamination paths of airborne germs (particles) and to eliminate them via new and innovative ventilation concepts. Since ventilation investigations

for operating rooms cannot be done in scale model environments, and there are no simulation tools today that deliver sufficiently precise results, it is clear that today's OR ventilation technology must be investigated in the laboratory.

Investigations (among others in 2003/2004 term papers and dissertations of the HVAC/S department of HTA Lucerne) have shown that new systems with laminar flow ceilings do not always function as desired. OR lighting, for example, can cause undesirable mixing. Therefore, research and development work is needed.

Ventilation and measurement methods should be developed further, and not only theoretical but also experimental work is necessary.

There is no laboratory test facility for OR ventilation in Europe today. Professional associations, the industry, hospitals and German institutes are interested in our OR ventilation laboratory test facility.

The hospital hygiene project is of far-reaching international significance, since most hospitals (over 500 in Switzerland alone) are entering the renovation phase of their life cycles, and new, focused standards of hygiene need to be reviewed and developed further. Complementary work is required in the research sector. Airborne contamination paths and the ingress of germs attached to airborne particles must be investigated. Initial investigations have shown that insufficient attention has been paid to particle ingress from the sides and to contamination of the operating table from below, and that such ingress is being found to be considerable.

For this purpose, a test facility for OR ventilation is being set up to facilitate work in the field of OR qualification, hygiene, airflow investigations and metrology.

We have divided the overall project into five sub-projects:

Sub-project 1: heating and ventilation engineering concepts
Sub-project 2: OR lighting (flow optimization, new development)
Sub-project 3: measuring methods (quality controlling, quality assurance)
Sub-project 4: CFD (flow simulations as a supporting resource)
Sub-project 5: knowledge transfer and implementation

In addition to these research and development activities, an accreditation center for measurement of operating rooms or for companies providing such services is to be established at HTA Lucerne in cooperation with TFH Berlin.

NEW PERSPECTIVES

The current state and understanding of building services engineering in the healthcare sector is characterized by ambiguity and prejudice. There is a conflict, with inadequate knowledge of the necessity and effectiveness of ventilation-based protection concepts on the one hand – with the associated investment and operating costs if an integral view is adopted – and the economics of antibiotic prophylaxis and infection treatment costs on the other.
The research project is intended to contribute to the objectification and clarification of the situation.

What is new is above all the possibility to perform systematic investigations in a realistic operating room without the constraints on time and scope that real operating rooms impose. This alone makes it possible for the first time to perform comprehensive scientific investigations. Also new is the aspect that the investigations include the entirety of the OR equipment instead of individual aspects with findings that are not transferable to actual practice.

Therefore, the desire for an overall view of building services engineering and hygiene, and with it the desire for a functioning OR unit, also becomes the assignment. How can a concept be developed that meets both the needs of hygiene and the usual requirements on building services equipment? What will the future protection concept for hygiene and building services be like in order to achieve the defined characteristic values?

The goals have been divided into the five sub-projects described above for better understanding and simpler coordination. They will be accomplished individually and integrated at a higher, interdisciplinary level.

ALL PARTICIPANTS ARE WINNERS

Contribution to healthcare

Cost savings for health insurance providers and premium payers, as well as a reduction in patient suffering due to:

Infections: prevention of hospital acquired infections.
Hospitalization times: patients will spend less time in hospital.
Treatment: patients will not always require additional treatment with expensive antibiotics, and staff can concentrate on treating the basic condition.

Hospital and healthcare cost reduction:

Hygiene: Concentration on (in future, verifiably effective) hygienic protection concepts where there is a real risk. Cost reduction through reduced use of antibiotics, which is also appropriate in the light of the antibiotic resistance problem. (MRSA – multiresistant staphylococcus aureus, which occurs in hospitals in particular, is a serious problem, since these bacteria are resistant to most antibiotics)

Energy: avoiding needless asepsis in all areas means reduced air volume and less expense for hygiene in no-risk areas in the vicinity of invasive procedures (i.e. asepsis in the OR only, and not in the entire green zone).

Investment: The enclosed space (building investment) for central building services and ventilation shafts will be reduced. The outdoor air treatment equipment will be reduced to the dimensions necessary to meet the actual requirements for hygienic ventilation. Relatively little space is required between or above the conditioned spaces for the air circulation equipment and the necessary silencers (but it must be considered by the architects!). The ventilation equipment can be optimized selectively. Less investment expense will be necessary on average. Simplifications in the concepts will be possible.
Operating costs: Energy savings with local air recirculation instead of vast volumes of outdoor air that require constant heating or cooling. Reduced expense of preventive and corrective maintenance.

Medical product liability: Room air treatment systems make an important contribution in the field of medical product liability.
The sterility chain must be assured via organizational measures and improvements in ventilation. Sterile items must be protected against contamination, from unpacking to readying on instruments tables to use.
Lump compensations will necessitate a philosophical change in healthcare that will make investments in correct building services inevitable. If doctors are no longer paid according to hours worked but according to lump sums for each service provided (e.g. hip replacement) it will become economically relevant if a patent acquires an infection or can be discharged a few days earlier.

Goal = benefit for industry partners:

The goal of the industry partners is to optimize or redesign their products according to the redefined building services engineering requirements, i.e. taking the aspects of hygiene-relevance into account.

This will help them to achieve or maintain competitiveness, and create sustainable jobs in the healthcare supply sector while also reducing costs.

Goals from the hospitals' perspective:

Cost reductions are to be achieved in the OR area due to a highly sterile environment (reduced use of antibiotics) as well as energy savings on OR ventilation.

In the coming years, more than 600 operating rooms will be due for renovation in Switzerland alone; over 8'000 in the whole of Europe. The ongoing costs, which have until now been caused by poor hygiene, partially due to building services equipment, could be reduced in this context.

Direct cost reduction:

We have estimated the cost reduction in Switzerland and Germany based on reports from the statistical authorities in both countries as well as on statistics from the Energie 2000 program and dissertations from HTA Lucerne and TFH Berlin. With optimal use of building services equipment, i.e. through optimization and deployment of new products, costs could be reduced by an amount in excess of CHF 12 MN (a factor of 10 more than that in Germany, i.e. CHF 240 MN) per annum.

Benefit from economic recovery:

As a result of the new SWKI 99-3 directive for hospitals, which has been applicable in Switzerland since 11/2003 (VDI draft 2167), products are being withdrawn from the market and replaced with new developments (e.g. OR lamps, LAF outlets, media supply units, etc.).

The inevitable result is better and cheaper medical care for our population. This benefit is naturally also transferable to surgical day hospitals and outpatient surgeries.