Medical Research and its Impact on Healthcare Design

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Throughout the developed world different healthcare systems are being challenged and undergo a turbulent period of intensive changes and development. The definition of a "hospital" is not obvious any more. We are gradually moving from traditional hospital-based healthcare systems to e-health. These changes are driven by many factors e. g.:

Socio-economic factors

- Rising costs for health care – "the tyranny of the bottom line"
- Demographic changes (increased number of elderly; increased average length of life; multicultural society; urbanisation and mobility)
- Patient empowerment – knowing more, demanding more

"Changes in lifestyle" factors

- The way we live (more one-person households; changes in indoor environment; fashion trends (piercing, tattoos)
- The way we eat (more prefabricated fast food; functional food)
- The way we work (increased mobility; specialization; teamwork; processes)
- The way we interact (mobile phones; e-mail; Internet; increased travelling)

Political factors

- Globalisation – disintegration of the national state
- Increased competition
- Increased consumer influence
- Environmental issues
- More complicated infrastructure
- *but also* Barriers of globalisation (new regulations; no acceptance of e-signatures; use of local names for drugs)

… but perhaps mostly by the force entailed with the rapid development of the medical research and information-communication technologies. The scientific advances in medicine have brought about new diagnostic and therapeutic methods based on new and partly different technological principles. Some of the most fundamental innovations have been made possible by the "molecular revolution", ushered in with the discovery of recombinant DNA techniques and the breakthrough in immunology (gene therapy; new types of vaccines; individually designed drugs; prevention based on molecular genetics

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etc) and the introduction of new biomaterials. Other very important contributions to the rapid development include minimal-invasive surgical techniques, high-technology methods for image-analysis (digital X-ray; MRT; ultrasound; CT; PET; MEG etc), epidemiology and molecular genetics, new methods in nursing care and an explosive development in information-communication technologies (convergence of media; wireless communication; the virtual workplace etc.) and its utilisation in the healthcare system. This in turn has put increased demands on the competence of individual members of the medical and nursing staff and demands on the healthcare organisation and hospital structure to adapt to these rapid changes.

Some of the consequences of this development can be envisioned as

- shortage of competent healthcare professionals – increased personnel mobility
- multiplicity of healthcare providers
- patients will not be a given asset
- competition between healthcare providers based on quality and patient satisfaction
- healthcare will be an international growth area.

The problems in the health care systems today include low efficiency, time-consuming, unclear leadership, few outcome measures, impersonal and poor coordination but also not patient-oriented, care based on episodes, limited choices for the patient and low level of service. When discussing health care design and hospital planning all these issues must be considered.

Some of healthcare trends today can be summarized as follows:

- Patient in focus – increased freedom of choice
- Transparency – patients; relatives; providers; media
- Focus on ethics and integrity
- Increased specialization, a powerful development towards high-technological diagnostics and therapeutics and an explosive development in health-care oriented information technology
- Shorter times of treatment and care
- Less hospitalised care – more patients are treated in primary care – fewer hospital beds needed
- The traditional borderlines between different medical disciplines are eliminated – formation of interdisciplinary centres and networks – virtual arenas of care – interactive learning
- Focus on quality and value-generating processes
- Increased demands for rationalisation in the health-care organisation
- Professionals transform into knowledge brookers
- Stronger international connection.

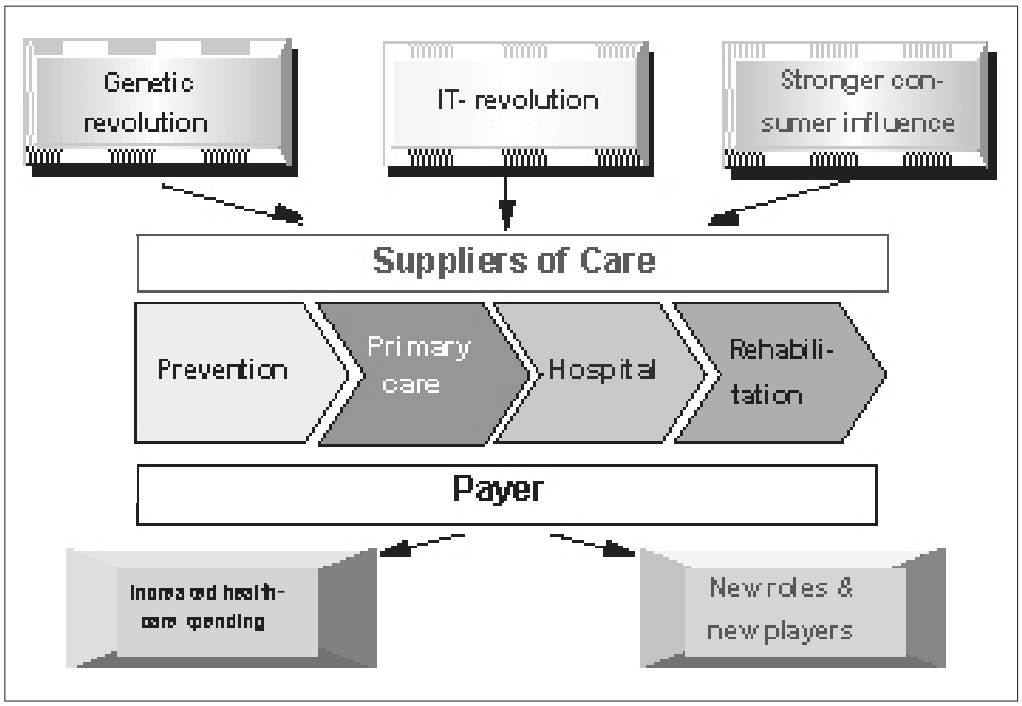
The driving forces in the health care system today are depicted in the figure below:

As stated above the rapid development in medical diagnostics and therapeutics will have a profound impact on the health care system. Below I will give a brief presentation of some of the most important achievements in this area, the expected development and their potential impact .

Image-based diagnostic methods

The extremely fast development in computer sciences has strongly contributed to the construction and development of a number of different technologies for image analyses, which are all based on physical methodology. If these methods are used in an optimal way they will give complementary diagnostic information on different types of diseases and will thereby improve the precision and fidelity in the diagnostic process. Some of the expected improvements are summarised below:

- *Computer tomography* – development of faster tomography
- *Magnetic Resonance Tomography (MRT)* will gradually replace traditional contrast-based X-ray. MR-morphology, MR-spectroscopy and PET will be used in combination to diagnose specialised metabolic disorders and to study



Health care trends.

patients with localised biochemical and other disturbances.

- *Ultrasound.* The development of two different lines of instruments can be seen. One simple and cheap instrument ("image stethoscope") and one advanced and expensive equipment, which can handle multiple planes of images.
- *Positron emission tomography (PET).* The resolution of the cameras used will increase. The method will be used to characterise the metabolism in the brain and to study the blood supply to and energy turn over in the heart and liver.
- *Magnet encephalography (MEG).* This technique will be used mostly to localise epileptic foci and be used in combination with the stereotactic radiation knife to eliminate such foci.
- *Nuclear medicine.* This discipline has seen a rather slow but steady progress. A handhold gamma camera has been developed. Furthermore the development of techniques for isotope diagnostics with labelled antibodies is in a steady progress. These techniques will be used in tumour and metastasis diagnosis.
- *Digital X-ray laboratories* and silver-free film will drastically change the conditions for archiving of radiological diagnostic data. It will also improve the local working environment.
- A fast development is presently taken place with regard to new morphological tomographs which are able to image e g temperature gradients or electron spin resonance in specific segments of the body. Such instruments will be used within 5 years and be important complements to the techniques described above.

Diagnostic methods based on molecular genetics and molecular biology

The molecular revolution has enabled scientists to make astonishing discoveries about the functions of genes and molecules. Large investments in the now completed HUGO-project

(HUman GenOm project) has resulted in a very rapid introduction of diagnostic methods based on molecular biology. Some trends in this development are listed below.

- *Identification of high-risk individuals* with molecular genetics will improve the possibilities for prevention. E.g. early diagnosis of predisposition for certain types of cancer; diabetes; heart-disease; allergy and autoimmune disorders will be possible.
- *Diagnostics of specific diseases:* 5% of the population will be stricken with illnesses which are completely or partly dependent on genetic factors. More than 50 monogenetic diseases have so far been mapped and can be diagnosed by molecular-genetic methodology e.g. Huntingtons chorea, cystic fibrosis, Duchennes muscular dystrophy, haemophilia, familiar hypercholesteraemia, phenylketonuria
- *Genetic diagnostics* will be developed further and refined and used to identify carriers of familiar forms of endocrine diseases (MEN). This will lead to an increased demand for prophylactic, elective surgery.
- *Preimplantatoric diagnostics* after *in vitro* fertilisation (IVF) create conditions to implant only healthy embryos

Diagnostic methods for cancer and other tumours

A steady increase in the frequency of different types of cancer has been shown during the last years:

– prostate cancer 1.4% /year
– lung cancer 2% (males) and 4% (females) per year
– malignant melanomas 4.5% per year.

The development of molecular biology and molecular genetics is continuously supplying the oncologists with a number of new tools for the diagnosis of both primary tumours and metastasis. Some examples are listed below.

- Genetically based diagnostics of several forms of cancer will be a very important tool in a close future, e g breast cancer, colon cancer and malignant melanoma.
- Improved diagnostic methods to identify micrometastasis
- Diagnostics based on molecular biology will make it possible to identify hormone-producing tumours at an earlier stage.

Diagnostic methods for diseases in the heart and blood vessels

Also regarding disorders of the heart and blood vessels the research within molecular biology and molecular genetics is of great importance and will strongly influence future diagnostic methodology. In the discipline of cardiology the achievements within the image-based technologies will have a very fast and profound impact in the future.

- The genetics behind and the mechanisms for different types of atherosclerosis is presently being solved. This will create possibilities to identify the high-risk groups on a genetic level which in turn will make it possible to apply selective prophylaxis, including changed eating behaviour or specific therapy.
- More exact, non-invasive and cheap image-based diagnostics (echocardiography with ultrasound, computerised tomography, MR scanner; digital storing and information transfer) are developed rapidly. These will make it possible to handle almost all types of diagnostic work in cardiology at the primary-care level.

Therapy in cancer and other tumours

The treatment of cancer will within the foreseeable future be dominated by traditional methods such as surgery, radiation therapy and cytotoxic drugs and steroids. These methods are undergoing continuous improvements with increased efficiency and precision and reduced side ef-

fects. Some new methods based on cell biological and immunological basic science can also be expected to be used in clinical trials within a close future.

- Surgery. No decrease can be seen. The reasons for this is mainly that the large groups of cancer in the ventricle, intestine and lung will be treated similarly as 30 years ago and no significant therapeutic progress is at sight.
- Radiation. A promising development of proton-radiation therapy is taking place.
- Cytotoxic drugs. The research studying the cellular factors of importance for the sensitivity of the drug is progressing rapidly. The results of this will make it possible to individualise therapy at different tumour conditions, which will give better therapeutic results and fewer side effects.
- Antibody therapy. The development of methods to interfere with adhesion molecules on the surface of the cancer cell will make it possible to create drugs that will slow down the progress of metastasis.
- Autologue and analogue bone-marrow transplantation. In combination with cytotoxic drugs this technique will be used for treatment of tumours which can't be cured today, e.g. malignant melanomas and solid tumours such as cancer of the colon and breast cancer.
- Gene therapy. Large investments are made to develop this technique for clinical purposes. It will be used on the one hand to replace a defect gene which will cause cancer, and on the other to modulate the expressing of onco-genes and supressor genes. The latter form of therapy means a new strategy for cancer prevention and treatment. Another promising form of therapy involves blocking of the angiogenesis.
- Substantial improvements in the therapy of different forms of cancer in children; cancer in the lymphatic system, testis cancer and cancer of the urinary bladder.

The new methods of tumour therapy will in the future have a profound impact on the structural changes of the systems for the care and nursing of patients suffering from cancer.

Therapy for diseases in the heart and blood vessels

Fundamental changes are taking place with regard to the treatment of different circulatory disorders. The new therapeutic methods will result in fewer inpatients at the hospitals and a better quality of life for a larger number of patients. Some trends are summarised below.

- Surgery of the heart and blood vessels. New less invasive technologies are developed. The "BIG" open surgery in the thorax and the brain will gradually be replaced by "catheter-based" techniques including PTCA in coronary vessels and introduction of "stents" in narrow vessels.
- Technologies for revascularisation will be improved (stents; ultrasound; laser, high-speed drills). Also more serious damages of the vessel or long-lasting occlusions will be treatable. Transplantation of endothelium will be used.
- Treatment of heart failure. A rapid development of new types of drugs is taking place (e.g. ACE inhibitors; peptide hormones). These new drugs will reduce the number of in patients.
- Treatment of stroke. The future will see less "classical" rehabilitation and more early, aggressive treatment with e.g. TPA and streptokinase after thrombosis and drugs that prevent the progress and expansion of the tissue damage after a haemorrhage. Acute neuroprotective treatment will include the use of calcium-channel antagonists; GABA antagonists and antagonists against glutamate.
- Methods to prolong the survival time for cells that have been exposed to hypoxia in the brain or the myocardium will be develo-

ped. This will create possibilities for reconstructive surgery or other invasive techniques to restore circulation before the damage becomes irreversible.
- Drugs with improved specificity and selectivity (receptor blockers) produced by biotechnology will make it possible to more efficiently treat several conditions without any side effects e.g. heart failure, arrhythmias, hypertonia and hyperlipidaemia.

Transplantation as therapeutic methods

The immunological research has resulted in new drugs which counteract the rejection/reaction during transplantation. Furthermore, it has created conditions which will make heterologous organ transplantation possible. Thus, the indications for organ transplantation as a therapeutic method will be broadened and the demands for surgical and nursing capacity increased. The present situation can be summarised as follows:
- Kidney, liver, heart, lungs and pancreas are transplanted practically on a routine basis at different centres specialising in transplantation
- Transplantation of the intestine is still at an initial stage
- Great efforts are made to develop methods which will make it possible to use animals as organ donors (xenotransplantation), particularly the pig. Furthermore, extensive research is carried out in order to solve the problems connected to the rejection of insulin-producing cells from pig pancreas.
- Transplantation of nerve cells (adrenal medullar cells and cells from brains of foetuses) is used in clinical trials to cure e. g. Parkinsons, Alzheimer, diabetes, epilepsy, damages of the spinal cord etc.

Surgical therapy – consequences of the scientific revolution

- "Classical" general surgery (ventricle, gall bladder, intestines etc.) will decrease, partly because of the development of new drugs and partly because of the introduction of new technologies (laparascopy). The remaining part will primarily consist of cancer surgery, trauma surgery and reconstructive surgery. This will result in a reduced number of in patients.
- Emergency surgery will decrease and be concentrated to fewer hospitals. This will mean the closing of smaller surgical clinics or turning them into elective units. Fewer and larger high-technology units with high emergency competence will be formed. These structural changes will be most pronounced in the densely populated areas whereas the thinly populated areas will be changed less.
- Orthopaedic surgery. This will increase because of the rapid development of new materials for prosthesis and new drugs, which will speed up the healing process of fractures and damages of the soft tissues. It is possible that cell transplantation will be a new method to treat damage of cartilage and bone. Improved methods to prevent and treat osteoporosis will be used.
- Laparascopic surgery will be used on widened indications. The results of the method will be improved which will bring about a more extensive use of this technique.
- Laser surgery will increase e.g. within gynaecology (early cancer in the cervix, vagina or labia); urology (tumours of the urinary bladder, especially condyloma); otorhinolaryngology (cancer of the vocal cords and certain cases of cancer of the pharynx and larynx); and surgery of the coronary vessels.

Therapy in psychiatric disorders

Concerning therapy of psychiatric disorders the development is mostly concentrated to a refinement of the psychopharmacological drugs that are used today. Increased knowledge of the transmission systems in the brain and the mode

of action of different drugs will make it possible to improve the therapeutic precision and efficiency.

- Selective drugs (serotonin inhibitors) with minimal side effects have been introduced and will be improved.
- New drugs are being designed which will affect the serotonin system according to a different mechanism of action. These drugs will also be effective against so called "therapy-resistant" conditions.
- The mode of action of lithium will be solved which will create a basis for the development of new substances with less toxicity.
- Development of more selective drugs with fewer side effects for the treatment of schizophrenia.
- New methods for the optimisation of the dose of neuroleptica based on PET studies of dopamine-receptor localisation.
- A breakthrough in the understanding of the pathogenesis of schizophrenia can be expected.

Therapy in the future – some speculations

- Production of new types of drugs and vaccines using biotechnology. E.g. TPA produced by biotechnological methods will be used in treatment of thrombosis in the brain and heart (acute myocardial infarction) and erythropoietin at anaemia caused by renal disorders. The genes coding for most of the lymphocytes have been sequenced which will make recombinant substances available for therapeutic use.
- Gene therapy will be possible for monogenetic diseases like Duchenne's muscular dystrophy, using adenovirus vectors.
- The etiological mechanisms behind the origin of immunologicalinflammatory diseases like diabetes type 1, multiple sclerosis, rheumatoid arthritis will be solved and make prevention possible.
- HIV and AIDS treatment will be improved by the introduction of new drugs. It is however doubtful whether it will be possible to create a vaccine against HIV.
- Vaccines against malaria, cholera and ordinary cold will be developed.

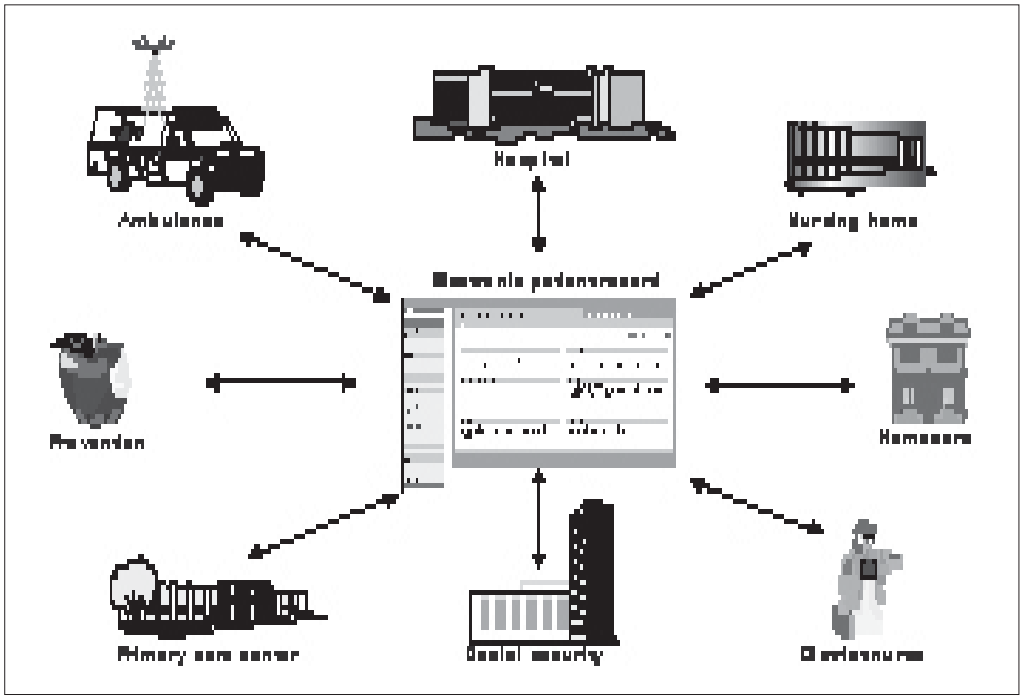
Healthcare development

The development in the healthcare organisation is directed towards a process-oriented system which honour keywords such as "patient orientation", "knowledge navigation", "coordination/feedback" and "benchmarking" and which ~~forms a logistic chain from "Social security system"~~ – "Prevention care" – "Primary medical care" – "Diagnostics" – "Therapeutics" – Rehabilitation" – "Work/retirement" to "Follow-up measures" and includes patient-centred hospitals. The evolution can be illustrated as follows

Today	Tomorrow
Fragmented services	Continuum of care
Treating illnesses	Managing health
Acute, inpatient care	Preventive/primary care
Institutional measures	Community measures
Perceived quality	Outcome measures, report cards
Individual IT systems	Integrated IT networks

This shift will most likely lead to a partial disintegration of the omnipotent "Mega-institutions", which try to cover everything in the medical area, and the formation of smaller customized and specialized units which will collaborate in an integrated network, much based on modern information-communication technologies. The healthcare system will gradually move from an "information hierarchy" to an "information hyperarchy". We will see the development of a health network which integrates the information flow related to the individual patient in the following way.

In this way it will be possible to integrate the



Healthcare system and information technology.

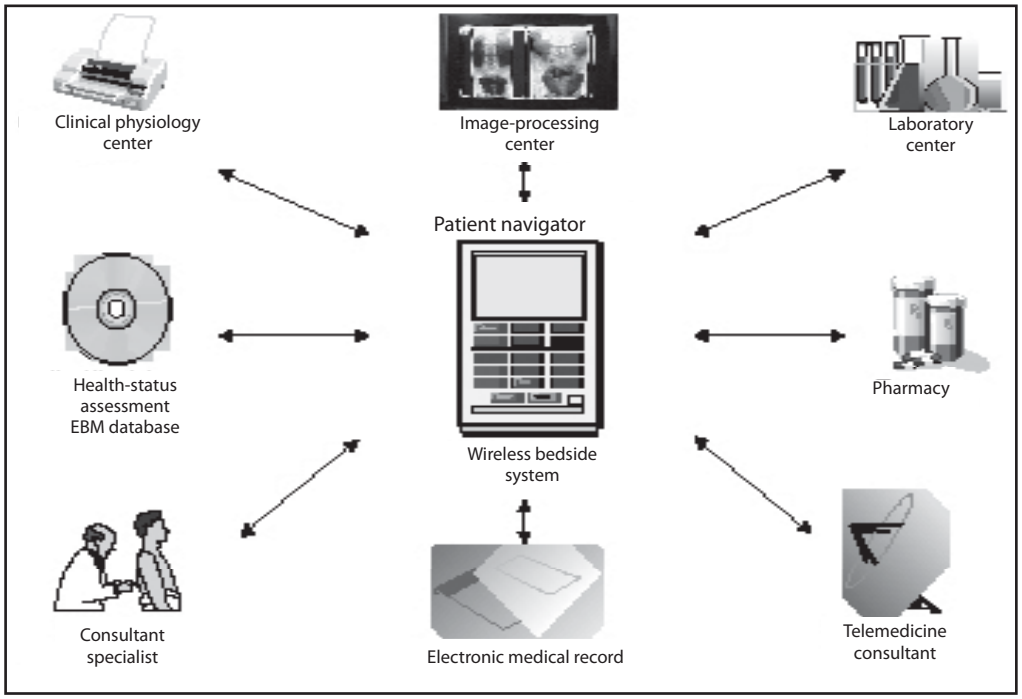
different components of the healthcare system from a patient perspective i.e.

- Rapid and easy access to primary care
- Services close to home
- Access to specialist consultants
- Medical records available at point of service
- Collaboration and consultation among care providers
- Coordination of care
- Clinical process improvement
- Continuous quality assessment of care
- Easy access to medical information.

Since these changes will have a fundamental impact on the way healthcare professionals will work together and with the patient, they will also strongly influence the demands on the architectural design of hospitals. Several service units which today constitute physical parts of the hospital building will in the future be localized outside the hospital and instead be accessed via IT networks. The figure below illustrates a possible future scenario in a hospital ward.

All information regarding each individual patient can displayed on a "patient navigator" connected to a wireless bedside information system which can access databases in different service disciplines such as clinical physiology, laboratory medicine, image-processing center and pharmacy. Furthermore, the doctor can consult both specialists via telemedicine and external health-status assessment databases online. After examination of and conversation with the patient, all anamnestic statements, ordered diagnostic tests and prescribed drugs are recorded in the patient's electronic record in the central medical record database via the patient navigator. This database can then be accessed by duly qualified personnel in e.g. the primary care center to which the patient is affiliated.

Thus the prerequisites for a development of "patient-centred care" are here and several key factors drive this evolution.



All information regarding each patient could displayed on a patientnavigator.

- The understanding of genetic predisposition. This will make it possible to predict health risks for individuals by establishing links between defect genes and specific diseases. Furthermore it will serve as the basis for individualized drug treatment.
- More readily available information. Through the Internet a whole new world of "Health portals" will be accessible. These will be anything from general health sites with medical and health news to highly specialized disease-specific sites aiming at selective groups of patients.
- More active and informed consumers. The patient educates her-/himself via chat groups and active patient groups on the Internet and via high-quality TV production in specific educational channels.
- Increasing responsibility of consumers. The patient will take active part in the diagnostic process e.g. by using "home diagnostics".

Visions of the future for the structure of the healthcare system

In a shorter perspective than 5 years it is not likely that the medical research and development will have any greater impact on the structure and function of hospitals and the health-care system than the one which is the result of already partly implemented, established new technologies as described above. The fast development in prevention, diagnostics, therapeutics and communication technologies will, however, create conditions for a society where most of the healthcare can be handled locally and close to the patient regardless where you live. The need for large hospitals will be reduced. The "hospital-free" society is coming closer. To bring this vision a step further let us first look on the present structure of the Swedish healthcare system. In that you can identify five distinct organisational levels. Three of these levels include different-sized hospitals, each with its own emergency ward and surgical department, which handles similar

types of medical disorders. This means e.g. that small numbers of difficult and advanced surgical operations are performed at a large number of smaller hospitals on the municipal level by surgeons with limited experience of that kind of surgery and that high-technology diagnostic and therapeutic techniques are introduced at high costs in hospitals where they will be used rarely by inexperienced personal.

In order to get a high quality in the utilisation of these new and advanced technologies they must be concentrated to larger centres of experts at the regional-/university-hospital level, where a large number of diagnostic examinations are performed and where R&D is a part of the daily use of these technologies. To these expert centres are concentrated diagnostic techniques requiring heavy, expensive high-technology equipment and a cadre of specially-trained physicians and nurses and therapeutic methods involving large, complicated operations and "aggressive" treatments. Since the classical borderlines between different diagnostic laboratory disciplines are gradually being more and more unsharp, conditions are created for diagnostic centres where radiology, clinical chemistry, histopathology, clinical physiology and clinical microbiology can be integrated. These hospitals should in turn serve as nodes in an integrated network of different hospitals, primary- care centres and nursing institutions which are localised close to the patients as outlined in the figure below.

By doing this problems with investments in new expensive equipment and personal competence, can be handled in a more cost-effective way.

The new possibilities to transfer large amounts of qualified information over long distances and analyse and store it on other places than where it was generated will have a great impact on the future structure of the healthcare organisation, since it will make it possible to move the desirable diagnostic and therapeutic competence to the patient instead of vice versa.

Conclusions

Thus, the scientific achievements in medicine and information technologies have created conditions for a new healthcare structure with: