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EXPERT SYSTEMS IN MEDICINE

Possible Future Effects

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INTRODUCTION

Medical expert systems can be described as computer software products with a medical data base that are designed to assist physicians and medical personnel in diagnosis, therapy, patient conduct, and related tasks in medical care. The use of medical expert systems is expected to produce tremendous changes in today's health care system. Some physicians and computer scientists anticipate that computers in medicine will drastically alter the role of physicians or even replace them, and affect the total structure, process, and outcome of medical care (13;18). The public and politicians have also become curious and anxious about the possible benefits and risks of this new technology (8).

In the Federal Republic of Germany, a recently established parlamentarian commission on "Technology Assessment" decided that expert systems should be among the first technologies whose impact on health care and society must be studied comprehensively and prospectively. This conclusion was based on the conviction that the application of powerful information technologies will inevitably produce some of the most important challenges for society in the near future. This paper summarizes some of the results of a subsequent study on the possible future effects of expert systems in medicine.

PURPOSE AND DESIGN OF THE STUDY

The purpose of the study was to assess the potential benefits as well as the risks of expert systems in medicine (ESM) in the next 10 to 15 years. The results of the assessment were intended to help identify lines of action that could enhance the benefits and prevent the disadvantages of medical expert systems.

When planning the study we had to assume that practical applications of ESM still are at an early stage (10). Few reports of empirical trials from outside of research establishments are available. As a result, investigating the present state of medical expert systems and their potential for diffusion into practical application had to precede the assessment of their potential future benefits and risks.

Moreover, as routine applications are still rare, it was impossible to base the technology assessment on published trials of effects and side effects. Instead, we relied on two samples of experts' opinions. First, in a survey mailed to developers and pioneer users of ESM, we gathered information about their stage of development, domains and functions, actual and potential settings of application, and potential for diffusion. Second, in personal interviews with developers, users, potential users, and people presumably affected by the application of ESM, we collected their opinions about the benefits and risks of the systems. Thirty-nine personal interviews were conducted with computer scientists (the majority of the interviewed persons), physicians, health care administrators, representatives of health insurance organizations, and trade unions. Except for the computer scientists, all interviewees came from the Federal Republic of Germany or were representatives of WHO. Computer scientists from other countries, mainly Austria and the United States, were also interviewed. Some of the "experts" who were not computer scientists, and therefore not familiar with ESM, were given a short briefing before the interviews, introducing five prominent expert systems, for example, ONCOCIN, MYCIN, and HELP. The interviews were guided by a pre-established thematic structure. The completed interviews were processed using content analysis.

The mailed survey was conducted from March to May 1986. The sampling of developers and pioneer users was not systematic according to the rules of sampling theory, as we contacted everyone known to us as developers or users of ESM, and all those who could be identified as such by a search of the literature (using MEDLARS) and by scanning lists of participants of scientific meetings. Consequently, persons with publications had a higher chance of being contacted, and the survey should not be considered representative of the whole field. Nevertheless, it is our personal impression that the results give a valid general picture for the purpose of our study.

Interviewees were asked to give standardized information about the "expert or consultation system" they had developed and/or applied. No further formal definition was offered. The survey included expert systems in a narrow sense, for example, INTERNIST-1 or ABEL, as well as "intelligent" components of information systems, for example, HELP or KLASSIK. The questionnaire permitted respondents to describe as many as three expert or consultation systems.

Forty-three persons from the Federal Republic of Germany, England, France, Italy, Austria, Switzerland, Japan, and the United States participated in the survey. Sixty-four expert and consultations systems were described. When evaluating the responses, the experts' opinions were compared as much as possible with published empirical experiences.

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DEVELOPMENTAL STAGES OF MEDICAL EXPERT AND CONSULTATION SYSTEMS

Questionnaire respondents were asked to evaluate the maturity of the systems by assigning them to one of six developmental stages ranging from "system's design" to "routine practical application" (Figure 1). The classification of the stages, which was a slightly modified version of Davis' approach (4), reflects the steps involved in the industrial engineering of systems. Some respondents judged the stages not to be completely appropriate for ESM as they are mainly designed for purposes of basic research (e.g., modeling of physicians' reasoning). Furthermore one should bear in mind that developers might overestimate the maturity of their systems (2).

In our survey, half of the systems had reached only the prototype stage (Figure 1). For reasons mentioned earlier, the actual number of systems being designed is much higher than indicated by the numbers on the graph. Only a few systems were described as being applied in routine practice. Among them are DIASPAR (6), the serumprotein diagnostic program SPE (19), and the automated MMPI interpreter (11). Other systems, such as HELP (17), should be regarded as components of sophisticated hospital information systems. It might be concluded that today most ESM are far from application in practice. Kingsland (10) and Buchanan (2) reached similar conclusions relying on other methodological approaches.

Next, we considered the settings in which the systems are applied. At present, ESM

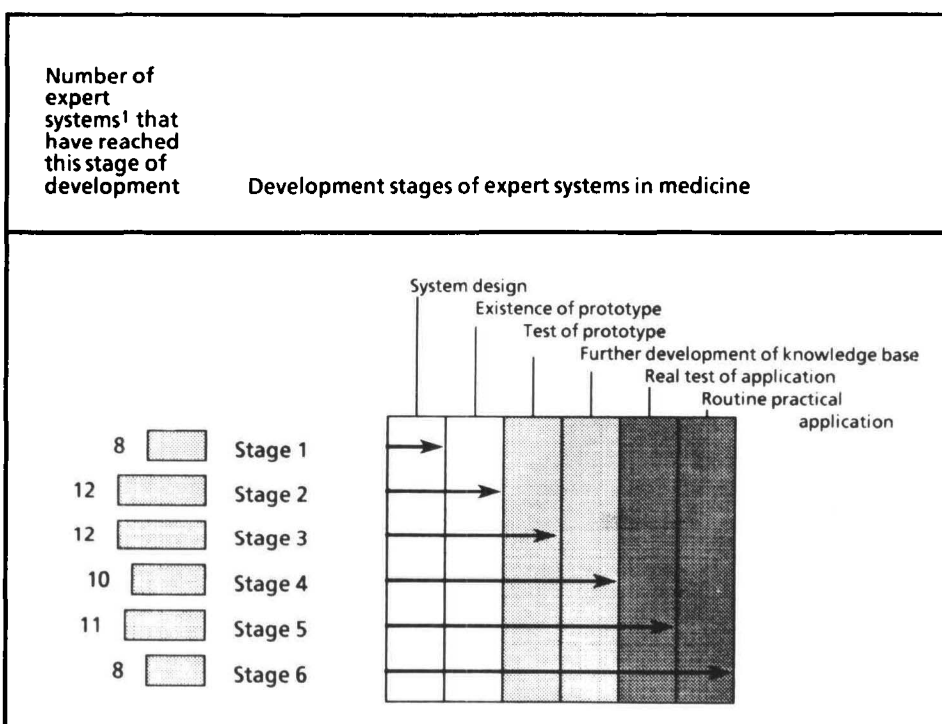

Figure 1. Maturity of expert systems in medicine (¹Number of systems studied (n = 64); 3 systems without checks of a development stage).

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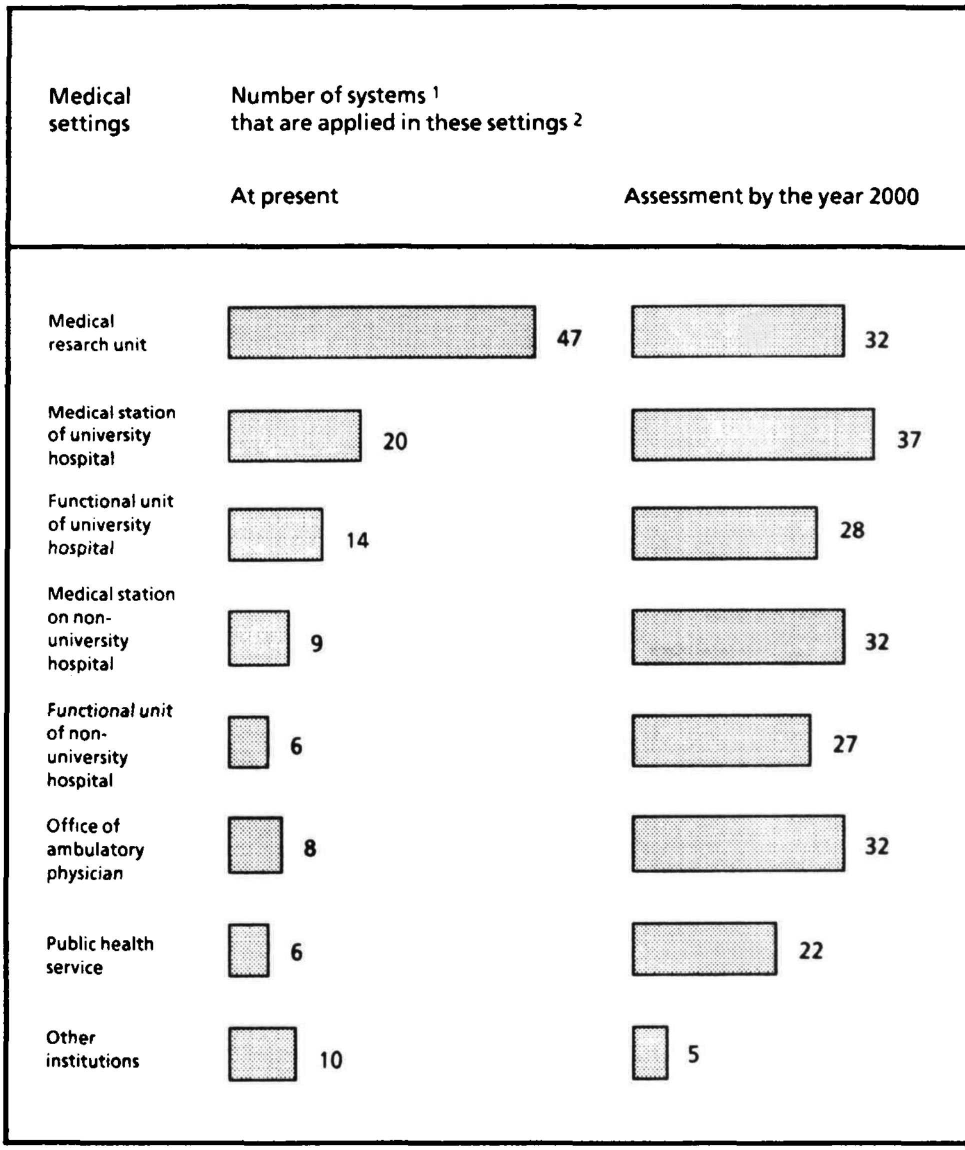

Figure 2. Settings in which expert systems in medicine are applied ([1]Number of systems studied (n = 64); [2]Multiple checks possible).

are used primarily in medical research institutions and university hospitals, that is, in environments where they are under the immediate control of their developers (Figure 2). Applications in doctors' offices and in non-university hospitals, the basis of the health care system, were mentioned only in a few cases. This may be due to the fact that only very few systems, such as AI/RHEUM (9), were designed for use in doctors' offices.

A further indication of the present systems' immaturity is their highly selective function. Most support diagnosis and only a few assist the physician in therapy deci-

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sions. Diagnostic support is available for highly structured tasks only. Solving complex problems is not possible in most cases. The speculation that computers can replace the reasoning of skilled physicians in the foreseeable future is obviously highly unrealistic.

CONDITIONS FOR AND PERSPECTIVES OF DIFFUSION

Following the opinions of the experts, as they were expressed in the questionnaires and in the personal interviews, the diffusion of ESM in medical practice will depend upon solving some technological problems. Prominent among them are the development of comfortable user interfaces, an acceptable relationship between the performance of the systems and price of acquiring and maintaining them, and an adaptation of the functions of the systems to the needs in medical practice, including the ability to handle complex problems.

A further essential condition of diffusion is the availability of computer hardware in health care facilities. Assuming that within the next 10 to 15 years most ESM in ambulatory doctors' offices will run on personal computers (PCs) or PC-like hardware, the diffusion of physicians' office computers is a relatively strict condition for the diffusion of ESM in this field. Following the indications of the Association of German Ambulatory Doctors (Kassenärztliche Bundesvereinigung) which observes the market for office computers carefully, computers were installed in 986 doctors' offices in 1985, or 1.6% of all office physicians (5). Furthermore, it is estimated that within the next five years no more than 3,000 office computers will be sold to physicians. Other experts have estimated that during the next 10 years no more than 5%–10% of ambulatory doctors' offices will be equipped with computers. Consequently, a widespread extent of ESM in doctors' offices cannot be expected in the time period under consideration.

Faster evolution will presumably take place in German hospitals. According to a study by Lordieck and Reichertz (12), the installation of mainframe computers in hospitals may reach up to 90% within the next 10 to 15 years. But experiences at one German university hospital show that the process of implementing data bases into hospital information systems can be a time-consuming endeavor. Medical computer scientists will take as much as 10 years before all hospital departments are linked to the HELP system (7).

ASSESSMENT OF THE POSSIBLE FUTURE EFFECTS OF ESM

Following the philosophy and methods of medical technology assessment discussed elsewhere (1;3), our study examined the effects of ESM in five areas:

- quality of care;
- costs of care;
- labor force and work structure;
- patient–physician interaction; and
- the organization of health care system.

Methodologically, reliable evaluations of effects should be based on controlled studies, for example, clinical trials for estimating effects on quality or cost-effectiveness analyses for economic considerations (16). However, as previously demonstrated, controlled applications of ESM in medical practice outside of research settings are few, and only a small number of related studies are published. Moreover, these studies do not cover all of the above-mentioned areas. What can be investigated at present are, with a few exceptions, estimates and anticipations of effects but not empirically supported assessments. Therefore we do not consider our study to be a definite evaluation of ESM, but an initial step towards an evaluation of its potential and risks, an evaluation that should continuously accompany subsequent technological development.

Detailed estimates of the possible future effects of ESM were predominantly identified from the personal interviews and the open-ended questions of the questionnaire. Additionally, the questionnaire contained some follow-up statements which give a global overview of the experts' opinions on the effects of ESM.

Experts' Opinions About Global Effects of ESM

An overview of the experts' reactions to seven propositions (rating them as "true" or "not true") on global effects of ESM is given in Table 1. Some statements were judged to be too complex for a simple "true–not true" evaluation, but in general clear answers were possible. The distributions of the responses indicate the degrees of agreement or disagreement about the items and should not be regarded as votes, implying that the majority has the "right" opinion. Most experts agreed that:

Table 1. Experts' Opinion about Benefits and Risks of Expert Systems in Medicine (ESM).

Impact on	*Answers*[a] *true*	*Answers*[a] *not true*
Quality of care		
Since ES set standards for medical care, the latter will become more transparent and controllable. In that way ES contribute to the increase of the quality of care.	35	7
Costs of care		
Since ES support the rationality of medical decisions they are apt to reduce the costs of medical care.	29	17
Physician–patient interaction		
As a consequence of the application of ES in medicine, the relationship between patient and physician will become more impersonal.	8	35
When citizens and patients can easily use ES on illness and disease by telecommunication, their competence vis-á-vis physicians will increase.	20	20
Health care system		
The ethical and juridical problems of the responsibility of physicians will be increased by the application of decision supporting ES in medicine.	28	17
The necessity to protect the privacy of personal data in ES is stronger compared e.g., to patient-data-banks or to computers in physicians' offices.	4	42
Independent audit commissions are necessary to control the quality and medical competence of ES.	36	4

[a] Number of respondents (n = 46); missing values are not quoted in the table.

- ESM will increase the quality of care;
- the relationship between physician and patient will *not* become more impersonal with ESM;
- the need to protect the privacy of data is *not* greater than with the office computers or patient-data-banks; and
- independent audit commissions are desirable to control the quality and medical competence of ESM.

There were conflicting opinions on whether:

- ESM will reduce the costs of care by supporting the rationality of medical decision making;
- ESM will increase patients' knowledge and competence if they are made available to them; and
- ESM will increase the ethical and legal problems of physician responsibility.

ESM and the Quality of Care

ESM are widely expected to improve the quality of medical care, but risks are anticipated too. In the interviews and in the open-ended parts of the questionnaire, an overwhelming number of effects on the quality of care were mentioned. After we had recorded them in detail, we put them together in "tables of chances and risks" (Tables 2–5). In these tables, some of the comments appear contradictory, but we refrained from balancing them. Whether positive expectations or negative apprehensions will be realized is not a matter of correct or incorrect prediction, but of the conscientious shaping of the technological development in the future.

Regarding the quality of care, the ability to double check medical decisions and optimize human cognitive functioning was mentioned most often. ESM can, above all, contribute to improved medical decisions by efficiently placing current experts' knowledge at the doctors' disposal and helping them to avoid errors caused by the imperfection of the human intellect. As one of the interviewees explained: "The main task of techniques of artificial intelligence is to overcome the weaknesses of the human intellect and its inconsistent working at different cognitive functions, for example, memory, information processing, reasoning."

There are some published evaluation studies in this area. The monitoring system CARE, for example, is part of a hospital information system. It contains 1,490 rules defining – according to medical expert knowledge – the medical or care-oriented actions that must be taken in light of specific clinical findings. If a patient's medical findings are introduced into the system, it produces one of 751 messages that recommend further actions to the physician; therefore it is called a data-driven system. In a trial with an experimental and a control group, that is, hospital physicians with and without the assistance of CARE, McDonald et al. (14) demonstrated that the physicians supported by CARE omitted significantly fewer "obligatory" actions than physicians working without CARE. The computer messages reduced the gap between the intent of a physician to undertake a determined action and the execution of this intent.

Another example is the system MEDICL which supports physicians when diagnosing acute abdominal pain. MEDICL compares the individual patient's findings with approximately 6,000 cases in a data bank and assigns a diagnosis to the patient applying a statistical classification algorithm (6). The impact of MEDICL on the reli-

Table 2. Possible Impact on Quality of Care

A. Quality of care

I. *Chances for quality of care*

1. Increase in quality of care by optimizing cognitive functions:
   errors in physicians' performance, information processing, iatrogenic failures in cases of rare diseases may be avoided;
   medical practice will be more standardized; decisions will be based on objective reasoning;
   diffusion of medical knowledge will proceed faster; and
   decision can be based on processing of complex knowledge and information.
2. Diagnoses will become more reliable; findings will be interpreted more precisely.
3. Therapy will be enhanced:
   therapy recommendations will be more specific; countereffects will be minimized;
   decisions about therapy will be reached faster;
   drug prescriptions will become more specific; and
   therapy and patient care will be more individualized.
4. General comments:
   quality of medical care will be enhanced;
   quality assurance may be facilitated; and
   physicians' performance will become easier to survey.

II. *Risks for quality of care*

1. Risks due to physicians' misuse of systems:
   physicians may become careless, lazy; may rely too much on the systems, over-estimate their reliability; and
   incompetent use of systems because of lack in education and training.
2. Risks due to unreliable systems:
   wrong diagnoses and therapy recommendations due to unreliable or out-of-date knowledge bases; and
   insufficient evaluation and validation of systems' performance; contradictions between systems.
3. Risks for the process of care:
   care will become more impersonal; loss of humanity
   over-diagnostics, over-therapy; and
   unquantifiable information about the patient, global aspects of human life will be neglected; care will become too technically oriented.

ability of diagnoses was demonstrated in a field trial in eight medical centers in Great Britain. The rate of correct diagnoses at admission to the hospital was increased from 45.6% to 65.3% (16,737 patients). The authors relate the improvement in part to the implementation of a standardized documentation of patient data, and in part to the computer-aided diagnosis (15).

The expectations of benefits in our survey were contrasted with the apprehension of risks for the quality of care (Table 2, Part II). The latter were attributed to the inappropriate use of the systems, to unreliable ESM, and to induced negative changes in the process of care (e.g., risks of over-diagnostics, over-therapy, too much technology in care). The public seems to be especially afraid of computers replacing the judgment of human physicians. The experts in our survey expressed concern that the physicians may become too careless and may rely too much on the recommendations of the ESM. In general, a thorough education in handling ESM was viewed as a shelter against this risk.

A second major risk mentioned was that ESM themselves may give wrong recommendations and lead to consequent suboptimal medical care because of unreliable or obsolete knowledge bases, insufficient evaluation, or premature practical application. As mentioned previously, a competent evaluation of systems' performance was requested to prevent this risk (16).

ESM and the Costs of Health Care

The costs of health care are another important dimension for the evaluation of ESM. The consequences of ESM application for costs were judged less consequential than the impacts on the quality of care by the experts interviewed. Whereas improved quality

Table 3. Possible Impact on Costs of Care

B. Costs of care

I. *Benefits for costs of care*

1. Costs will decrease, quality will be maintained.
2. Costs will decrease because of improving the quality of care:
   - because of more specific, faster, better diagnoses and therapy;
   - by specific and economical drug prescriptions;
   - by omitting iatrogenic diseases and their consequences;
   - by substituting in-patient by (more economical) out-patient (primary) care; and
   - by cutting down length of stay.
3. Cost will decrease because of optimizing the process of care:
   - by refraining from double examinations;
   - by making care more easy to survey;
   - by avoiding additional services from medical experts;
   - by better surveillance of legitimacy of claims of insured persons;
   - by more rational rationalized care in general; and
   - but decrease of costs will be possible in the long run only.

II. *Risks for costs of care*

1. Increase in costs:
   - because of necessary investments, overhead;
   - because of construction and maintenance of systems (including knowledge engineering);
   - because of over-diagnostics, over-therapy; and
   - because of improper allocation of systems.
2. Misuse of systems by administrations for the sake of over-rationalization.
3. Increase of costs in general.

and the more efficient work flow may cause a reduction in costs, it was feared on the other side that the expenditures for the development, acquisition, maintenance, and operation of the systems may increase the costs of care (see Table 3).

Nevertheless, DIASPAR was able to demonstrate in a field trial that its application to the treatment of about 17,000 hospital patients resulted in the saving of, on average, 8½ days of treatment per patient (15). The resulting savings for a German hospital would amount to 1.7 million Deutschmark. To what extent, however, such cutbacks of services are forwarded to the carriers of cost, for example, the health insurances, heavily depends on the specific financing systems of hospital care. It is our opinion that the influences of the health care systems on the effects of ESM must not be underestimated.

Table 4. Possible Impact on Labor Force and Work Structure

C. Labor force, work structure

I. *General comment*

It is too early to speculate about effects, but a considerable loss of jobs is not expected.

II. *Chances for labor force and work structures*

1. Development of new jobs and professions.
2. Enrichment of jobs:
   decrease of repetitive work load;
   more responsibility for paraprofessionals;
   growth of knowledge, input for reflection;
   more qualified jobs, enhancement of human performance;
   jobs become easier; and
   need for training can be identified by means of error-monitoring.
3. Improvement of work structures:
   better communication (more possibilities, more time);
   removal of hierarchical structures, of dominance of experts;
   reduction of experts' work load; and
   more efficient use of labor force in general.

III. *Risks for labor force and work structures*

1. Deterioration of jobs;
   dequalification, decrease of personal responsibility; and
   inefficient work load because of improper use of systems.
2. Deterioration of work structures:
   impoverishment of personal verbal communication;
   loss of authority for "computer physicians"; and
   misuse of systems for control of personnel.
3. Loss of jobs:
   isolated loss of jobs for physicians, nurses;
   threat of personnel at an advanced age or of less flexible persons; and
   rationalization in general.

Other Consequences of ESM

The possible future consequences of ESM in the other areas of evaluation are detailed in Tables 4 and 5. The most important expectations concerning work structure, patient-physician relationship, and structure of the health care system include that:

- except by representatives of trade unions, significant effects on the number of work places are, in general, not expected;
- at present, it is not conceivable whether the introduction of ESM into the interaction between physician and patient will result in a reduction of the doctors' more technical tasks and thus will enable a more personal relationship, or whether it will result in a depersonalization of medical care;
- special attention should be paid to data protection whereby less risk is seen in the abuse of the patients' data than in the danger that ESM messages could be misused for the purposes of personnel control;
- developers, medical expert societies, and users should strive after responsibility for effective forms of quality control of ESM; and
- the doctor's responsibility for consequences in the application of ESM requires clarification as regards legal duties and professional ethics.

Table 5. Possible Impacts on Physician–Patient Interaction and the Health Care System

D. Physician–Patient interaction

1. Expert and consultation systems meet the expectations of the patient for modern medical technology.
2. Physicians may have more time for personal interaction with patients when using the systems.
3. The application of the systems may lead to less personal contact and humanity in the physician-patient interaction.

E. Health care system

1. Effects on the structure of the health care system:
   more equity, reduction of regional disparities of supply of services;
   more local cooperation, coordination, continuity of care; and
   better chances for regulation in the health care system.
2. Effects on dominance of experts;
   reduction of institutional hierarchies;
   reduction of interprofessional dominance; and
   more competence and autonomy for patients.
3. Legal and regulatory implications:
   liability of physicians;
   need for quality assurance and evaluation of systems (including technology assessment); and
   protection of confidentiality of data (concerning patients as well as medical personnel).

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SUMMARY

It should be pointed out that during the interviews most of the experts had positive expectations of ESM. The developers are more generally enthusiastic than the prospective users and affected parties who, especially in respect of the diffusion of ESM into practical application, only show a limited optimism.

However, the representatives of the medical profession and the health insurance industry were convinced that ESM might contribute to cost-neutral increases of quality in out-patient and in-patient medicine. But we also understood them to say that they consider other developments in medicine to be overriding, for example, a tendency of general medicine towards a more family-oriented medicine and a reduced emphasis on technology-oriented medicine. In respect of the conception shared by developers as well as potential users that over-enthusiastic expectations should rather be restrained, we consider such a balanced expectation of positive effects of ESM to be adequate to the actual knowledge of the subject.

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