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SPECIAL ISSUE: ASPECTS OF eHEALTH

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Erratum

There was an error in the format of the graphs in the article entitled "Land Area Requirements to Meet the Targets of the Renewable Energy policies in the European Union" by Boyan Kavalov (IPTS), which was published in issue 80 (December 2003). The corrected graphs are shown at the end of this issue.

4 Information and Communication Technology

The Challenges to the Medical Decision Making System posed by mHealth

Andrzej M. Skulimowski, *Progress & Business Foundation, Poland*

Issue: The classical medical paradigm assumes a personal relationship between patients and medical practitioners. This relationship is reflected in the way medical infrastructure has evolved to be tailored according to the availability of medical staff. Mobile health will have a twofold impact on health care: it will imply changes in the way healthcare is financed and a move towards unification between professional medical care and so-called "home medicine".

Relevance: mHealth will enable the number of medical readings taken at any one time to be increased considerably. This creates a need to integrate automated mobile medical systems into a new concept of healthcare policy and will have an impact on policy regarding medical insurance, medical liability and the funding and provision of medical care.

Introduction

MHealth (mobile health) is one of the major challenges being faced by both medical practice and healthcare policies. The impact of mHealth is likely to be more far-reaching than other developments such as nanomedicine and genetic therapy as it will create an urgent need to review the way healthcare is financed and blur the boundaries between professional medical help and so-called "do-it-yourself" medicine (i.e. minor treatment or self-medication without consulting a physician, but based on previous medical treatment experience, popular medical literature, or a pharmacist's advice). On current trends, mHealth systems will be more widely offered by mobile phone providers, and simple, yet important functions may even be offered as built-in features of mobile phones. This, in turn, will imply that technology providers account for a larger than ever share of the total value of medical services. Consequently, systems for the provision of medical care may have to accommodate new expenses, incurred by services from outside of the traditional healthcare system.

The classical paradigm of a one-to-one relationship between patients and doctors is likely to be challenged by the widespread adoption of mHealth

On the other hand, the classical medical paradigm assumes a one-to-one (or more) relationship between patients and medical practitioners when making a medical diagnosis or another relevant decision concerning therapy or prevention. This relationship has been reflected in the medical infrastructure, which is tailored according to the availability of medical staff. mHealth would make it possible to drastically increase the number of medical readings taken at any one time, as the patient is

The views expressed here are the author's and do not necessarily reflect those of the European Commission.

no longer bound by a direct link to a physician or nurse. It is expected that the number of persons using mHealth-based monitoring or therapy will soon exceed the number of medical personnel monitoring the use of mHealth equipment. This will create an urgent need to use automated medical diagnosis systems and to re-think the concept of physician-based healthcare. Furthermore, technological developments could make new policy measures necessary, especially regarding regulation of issues such as medical insurance and liability, and concerning the financing of medical services offered by electronic media providers.

While medical expert systems have been the subject of intensive R&D for several decades, they are still regarded as tools supporting decisions finally made by medical professionals. The large number of mHealth systems may mean that the number of decisions that needs to be made simultaneously far exceeds the capacity of existing medical procedures. This could lead to an incremental transfer of medical competencies to artificial-intelligence-based systems, starting with the simplest (or least controversial) decisions and eventually leading up to those involving processing large data sets and involving a degree of risk.

Although the ageing of European societies will lead to an increase in the absolute number of those needing continuous medical monitoring, older patients may, nevertheless, continue to show an above average resistance to "depersonalized" medicine. However, there is likely to be a tipping point some time in the future, after which development of automated medical decision-making systems will move much more quickly, thus changing the medical paradigms and influencing patients' habits and expectations. The corresponding scenarios, showing the possible future developments and bifurcation points in the future of European healthcare are discussed at the end of this article.

Mobile health: The present state-of-the-art, classification and current trends

The emergence of new medical technologies results in changes in medical terminology and may sometimes lead to confusion. In the older medical literature mHealth usually meant "mental health", sometimes "men's health". Today mHealth (or m-health) is widely accepted as an abbreviation used to mean "mobile health", which – in turn –usually means "medical services for a spatially unbound patient". Sometimes, especially in US sources, this notion is expanded to embrace the idea of a "spatially unbound physician (or other medical personnel)", e.g. a physician using a PDA to consult medical databases during the examination of a patient. For the sake of clarity, and to concentrate on the policy and social implications of mHealth, we will adopt here the first interpretation only.

Another medical term, which has acquired considerable popularity, is telemedicine. Despite the fact that it is often confused with, or used interchangeably with mHealth, its meaning is different as it focuses on the transfer of medical data, particularly medical images. While the use of telemedical technologies does not assume a moving or unbound patient, there is one important common point with mHealth, namely the fact that medical diagnosis takes place remotely. Conversely, virtually all mHealth applications involve the teletransmission of certain medical data, although one can also imagine autonomous mHealth systems, whereby a treatment decision follows an automated diagnosis, and the therapy or a preventive action is undertaken by an autonomous mobile medical system equipped with diagnostic devices serving as a source of data.

Based on the definitions given above, mHealth systems can be classified according to the characteristics of the source and destination of the medical information flow:

A rapid increase in the number of people whose health is being monitored by mHealth technologies is likely to lead to a gradual automation of many medical decision-making processes

mHealth is about monitoring the health status of, or providing treatment to, people who are on the move

- patient to (medical) supervisor,
- patient to physician,
- physician to physician,
- physician to expert system,
- patient to medical CRM system (management of patients and medical interventions).

Depending on the target group mHealth systems can be classified as follows:

- mHealth for hospital patients (i.e. moving within prescribed strict spatial limits),
- mHealth for healthy people (preventive mHealth),
- mHealth for the chronically ill or vulnerable individuals.

Early demand for mHealth will come from patients with conditions such as heart disease, diabetes and asthma

mHealth for medical personnel would fall outside of the above categories, but – as already mentioned – we will not study this case here, concentrating instead on the direct impact of new m-diagnosis and m-therapy technologies on patients.

Another classification, which derives from the technology used in mHealth systems is given in Table 1.

More technological details can be found on the numerous web sites devoted to mHealth[1]. A typical mHealth system, which is a subject of this paper is presented in Fig. 1.

Finally, the future development of mobile health will be driven by its ability to respond to the needs of the target groups, seeking location-independent diagnosis, monitoring or therapy. Priority for mHealth services is likely to be given to the following health conditions:

- cardiovascular system diseases, especially those at risk of a heart attack,
- diabetes,
- bronchial asthma, especially its acute forms.

Elderly people will generally need mHealth-based monitoring, even if their health is satisfactory, forming thus an intermediate group between mHealth focused on the sick, on the one hand, and preventive mHealth, on the other.

Preventive mHealth will address also healthy people at risk, such as:

- airline pilots and bus drivers,
- sportsmen,
- workers working in extreme or isolated environments (such as sailors),
- policemen and soldiers,
- public figures,
- prisoners,

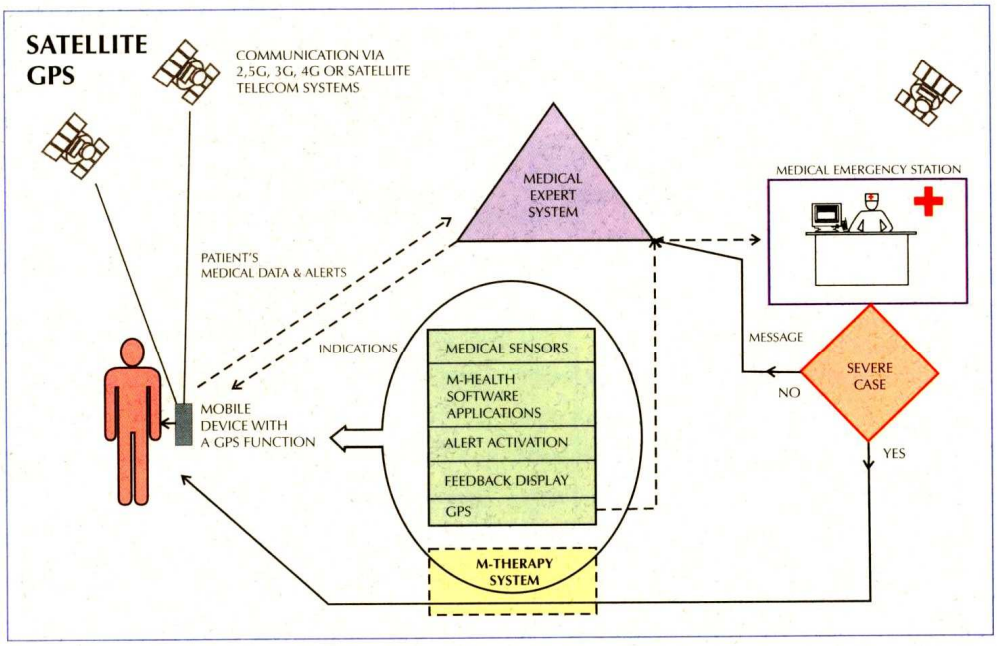
and other groups who face a subjective or objective sense of risk of injury or an acute disease.

Unlike mHealth systems targeted on the sick and elderly, preventive mHealth will focus on detecting injuries, accidents and heart attacks or strokes. Military mHealth applications are more specialized and therefore fall outside the scope of this article. Nevertheless, military mHealth techno-

Table 1. Classification of technologies currently used for mHealth

m-technology	transmission rate per mobile application			
No of applications served by m-device	local: Bluetooth	local to medium range: wLAN 802.11a/b	long range: GSM/GPRS, CDMA	long range: UMTS
single application	< 1 Mbaud	2 to 54 Mbaud	10 to 115 kbaud	0.144 to 2 Mbaud
multiple applications	< 1 Mbaud	1 to 27 Mbaud	< 10 kbaud (of guaranteed transmission capacity)	< 1 Mbaud

Figure 1. Patient-oriented mHealth system



logy will continue to play an important role, while civilian mHealth systems are being developed

Current mHealth devices are able to continuously monitor an individual's pulse and blood pressure, detect breathing abnormalities associated with bronchial asthma and other chronic respiratory system diseases. Sleep disorders also seem to be one of the main areas in which there is considerable experimentation with mHealth techniques. Home observations with mobile equipment are often the only practical approach that is convenient and acceptable for a large number (up to 40% of the European population suffer from some form of sleep and/or breathing disorder) of potential patients. Continuous monitoring of heart and brain functions (m-ECG and m-EEG) is possible from the technical point of view, yet difficult, due to the presence of so-called artefacts, i.e. various perturbing signals and noise. Therefore the appropriate signals are usually measured and transmitted at regular intervals instead. Similarly, monitoring blood content is both inconvenient and unnecessary, since it does not change rapidly under normal circumstances. For mHealth applications, e.g. those already widespread in diabetes, there are mobile devices allowing incidental blood analyses to be made and transmitting the results to the medical supervisor (a physician, a database, or an automated diagnosis system). Continuous blood content monitoring as well as real-time medical imaging may be useful in a hospital environment, especially when monitoring the impact of pharmacotherapy, pre- or post-operative patients and recovery processes without affecting the mobility of patients inside the hospital.

The rapid progress of telemedical systems and mHealth is a phenomenon of the last decade and it has no doubt not yet reached its culmination. Results achieved so far include the definition of a medical information transmission protocol (DICOM – Digital Image Communication) and the emergence of numerous professional telemedicine applications and the first large-scale public mobile systems offered by mobile telephony providers. The huge market for medical services, so far monopolized by incumbent healthcare organizations, will soon be invaded by low-price mobile medical services providers, using medical personnel only

Current mHealth devices are able to continuously monitor an individual's pulse and blood pressure and to detect breathing abnormalities

for operational and incidental tasks. The impact of this process on the European healthcare policy and social attitudes towards medicine will be outlined in the next section.

Mobile health: the future technology development and its implications on policies and social perception of health care

The implications of mHealth systems on health care are closely connected to the continuous evolution of medical techniques. They may be characterized by their shortening to a minimum the time taken to provide medical assistance to those in need. Currently, an m-diagnostic system with an alert function may make it possible for the device to call for medical aid sooner than the patient or his/her family or friends could. In many cases, especially when cardiovascular diseases are concerned, time is critical for the patient's survival. A more advanced system may be equipped with an autonomous m-therapy function, which could allow emergency action to be taken, such as delivering a nitro-glycerine injection, even before medical assistance arrives.

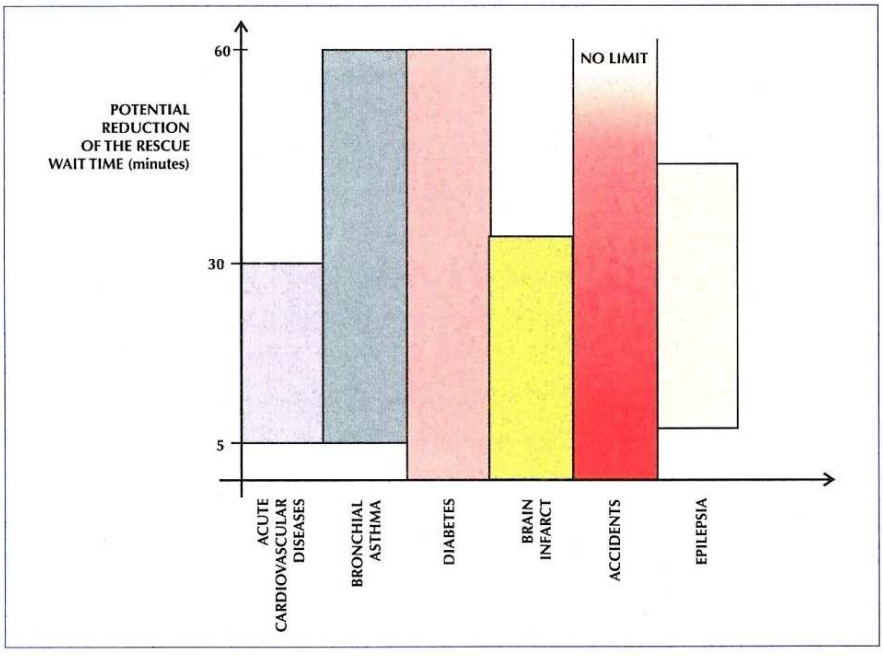
The next stage in the development of mHealth is likely to involve more widespread use of lower-cost systems with less direct involvement of medical practitioners

Figure 2 shows the estimated reduction in the expected time taken for assistance to arrive when using mobile diagnostic systems. The estimated increase in the survival rate for some major groups of patients when using m-diagnostic and m-therapeutic systems is shown in Fig.3.

The social acceptance of mHealth is rarely questioned, since the evidence gathered with existing telemedicine applications (Mair and Whitten, 2000) shows that patients appreciate the freedom of moving, the avoidance of time-consuming stationary medical examinations and the stress associated with them, and are convinced of the quality and timeliness of the mHealth systems. Existing applications, however, are dedicated to chronic diseases, whose symptoms and therapy are

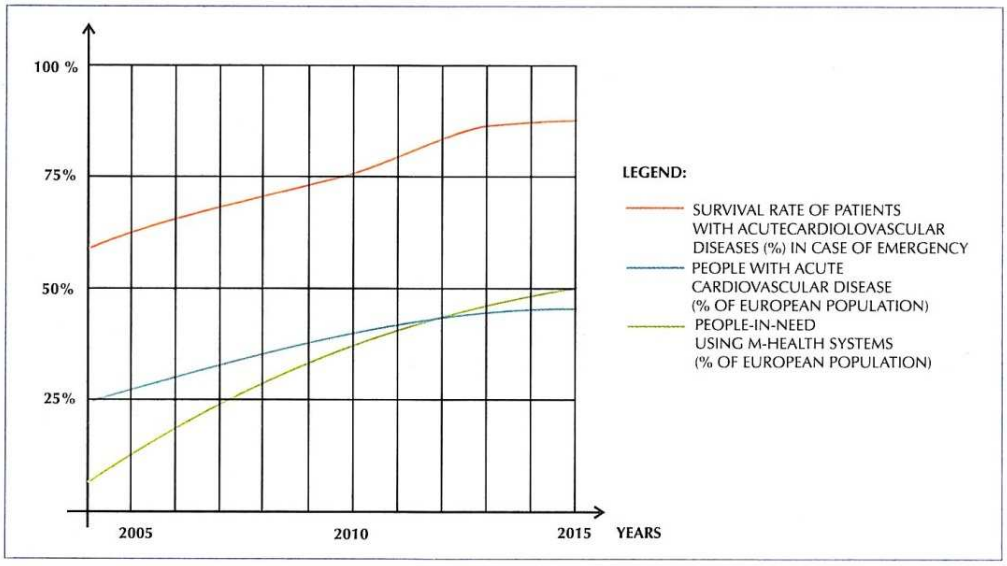
One of the key benefits of mHealth is its ability to shorten the time taken to identify and react to a medical emergency. More advanced systems may one day even be able to start initial treatment before medical assistance arrives

Figure 2. Reduction in rescue wait time for a randomly moving patient



Source: Author's estimates, 2003.

Figure 3. Survival rate as a function of time and the percentage of patients using mHealth systems



Source: Author's estimates, 2003.

very well known to sufferers, so the automatically generated treatment recommendations are repetitive and easily accepted. Thus, as a side effect of the expansion of mHealth systems one can expect growing acceptance of medicine without the presence of a physician, which may also manifest itself in increased self-medication (i.e. without a prescription), increased demand for medical literature and visits to medical web sites, and a growing resistance to "them and us" attitudes in medicine. Advanced medical applications available as a part of "do-it-yourself" medicine and access to medical expert systems may play a similar role as "user friendly" computer applications in the 80s, which made computing accessible to users without in-depth knowledge of programming techniques and digital electronics. It is also noteworthy that in poorer countries hopes of improving the overall quality of health care are often associated with eHealth and mHealth applications and these hopes prevail over any fears that may exist (see, for example, PRISMA Guideline 8).

Progress in this direction may be hindered by another possible future social phenomenon, however, namely the potentially growing fear that the excessive use of personal mobile electronic devices might lead to health risks. This would most likely also affect attitudes towards m-devices used for long-term health services. It cannot be ruled out that scientific evidence backing such a cautious attitude may be found in the future, which could affect the overall development of mobile technologies.

More sophisticated future mHealth applications will presumably be able to make less clear-cut decisions, based on the analysis of large data sets and associated with a certain degree of risk, thus indicating the need to make changes in the legislation concerning medical liability and data protection.

A set of procedures will be needed, backed by appropriate policy measures, which will guarantee that the risks associated with an action recommended by the autonomous mHealth system is controlled and that hard or doubtful cases will indeed be presented to a competent medical practitioner. The liability of the mobile technology provider, medical diagnostic software producer (if

Current mHealth users generally appreciate the freedom of movement it gives them and the fact that it allows them to avoid time-consuming and stressful medical examinations

As mHealth systems take on more decision-making functions, safeguards will need to be put in place to ensure that difficult decisions are in fact handled by qualified medical practitioners

As mobile communications operators come to handle larger volumes of medical data, information needs to be protected against incidental or deliberate disclosure to third parties

The widespread adoption of mHealth devices could also provide a much needed boost to Europe's mobile communications operators

different from the latter), the on-line medical team handling the hard and ambiguous cases, and patients themselves needs to be clearly demarcated.

Another issue is that - in addition to the information coming from phone calls - mobile communications providers will have access to personal medical data on mHealth system users. This information needs to be protected against incidental or deliberate disclosure to third parties, except the medical personnel directly involved in providing care. One can assume that the procedures supporting the use of mHealth systems will be outlined in the legislation and that they may become a part of the licences assigned to mHealth systems providers.

The next impact is the envisaged increase in the overall effectiveness of healthcare financing due to m-prevention, m-diagnostics, and m-therapy. It is a well known fact that spending on prevention is generally much more effective than paying for treatment once a disease has become apparent. However, often appropriate preventive programmes are not in place, or it is hard to convince some people to visit the doctor before the symptoms of disease emerge. mHealth can change this by providing easily accessible devices to perform diagnostics at home or on the move. Therefore, depending on the prevailing health care policy, the use of mHealth applications may enable better care to be provided more cost-effectively.

As exemplified by simple calculations and earlier studies (Bhargava et al., 2001), the social and economic justification of introducing mHealth systems into healthcare can be accomplished by the classic tools used for the evaluation of the healthcare policies, such as cost-benefit analysis (CBA) and cost-effectiveness analysis (CEA), which also often include an element of risk management. The diagnostic/therapeutic mHealth financing model should take into account the average price of traditional medical services, the population density, the costs of supplementary mHealth equipment and mHealth back-office support, the estimated number of patients or vulnerable individuals, and their distribution in the area under investigation. One can consider in the same model different mHealth applications, different equipment and types of support to elicit an optimum set of diseases to be covered by the mHealth system[2].

The cost-benefit analysis of preventive mHealth is even more straightforward, given the fact that prevention is cheaper in "traditional" medicine as well and that preventive mHealth applications can be more standardized and focused on non-intrusive data gathering.

Last, but not least, it is worth noting that mHealth applications may increase the potential market for 3G and 4G mobile communication systems. It may well turn out that mHealth features may be more attractive than the video transmission capability so often presented as the main appeal of 3G+ mobile phone systems, especially to older users. This could make the technology potentially good for the financial health of telecoms operators burdened by expensive 3G license fees too (in very sparsely populated areas the same argument may apply to satellite phone operators). In addition, mHealth creates another relevant field of applications for GPS/GSM systems, such as Galileo, whereby any perturbation in vital signs could be detected and reported by an mHealth application, then combined with a GPS localization function to optimize the rescue time (see the article on this topic by Rodríguez and Cabrera in this issue of the *IPTS Report*).

Conclusions

The overall development of mHealth can proceed according to an optimistic or a more pessimistic scenario, as outlined below. Depending on

the policy approach taken, mHealth could either be used to bolster the overall quality of healthcare by providing an immediate and reliable source of medical help, it could be used as a cheap surrogate for medical services, or it could be marketed as a value-added service paid for by mobile phone subscribers together with their monthly charges. Clearly, the approach taken will determine whether mHealth reduces inequalities of access to health care services by making services available remotely and free or at low cost, or whether it widens inequalities by being marketed as a luxury for people willing and able to pay for a potentially high-cost additional service.

Even if we assume that mHealth will supplement traditional healthcare by replacing just simple tasks or entering previously unexplored domains, the availability of mHealth services could result in a drop in demand for "stationary" (i.e. non-mobile) medical services, possibly leading the healthcare system reacting to defend its financial interests (healthcare consumes up to 20% of GDP in developed countries). Consequently, the development of mHealth will require harmonization with the overall evolution of health care.

Policy-makers need to frame regulations in such a way as to ensure equitable provision of mHealth services. Nevertheless, success of mHealth cannot be taken for granted without a positive social attitude, which may depend on a number of objective and subjective factors, some of which have been alluded to above.

Keywords
mobile health (mHealth), telemedicine, medical decision-making, foresight, health care policy.

Notes
1. See, for instance, **www.daou.com**
2. taking financial contributions from medical insurance, patients' fees, community and national contributions, as inputs, and using a multiple criteria decision model in which the quality of treatment is represented by medium-term (1-2 years) and long-term (5-15 years) health indicators, one can calculate a set of optimal financing policies, parameterized by the total healthcare expenses over unit of time.

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