Cutting costs with eHealth technology

Economic effects of permanently reducing the HbA_{1c} levels of patients suffering from diabetes mellitus

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Bibliography

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SUMMARY

Diabetes mellitus is a medical condition of enormous relevance when planning healthcare and social policies. According to the German Federal Statistics Office, the direct costs for treating patients with diabetes amounted to € 6.34 billion in 2008; these costs included medication, out-patient and in-patient treatment, care and rehabilitation services. This accounts for 2.5 % of all healthcare expenditure.

If the HbA_{1c} level can be permanently reduced – for example using a telemedical approach from 9.0 to 7.0 % -, average maximum savings of € 579.14 per patient and cycle based on a Markov model can be achieved for patients between the ages of 40 and 94. The savings reach their peak, however, for diabetes patients between the ages of 40 and 60: In this period, average savings of € 921.13 per patient and predefined cycle can be achieved if the HbA_{1c} level can be permanently reduced from 8.0 to 6.0 %. At higher ages, however, the cost curves between low and high HbA_{1c} levels increasingly converge. Since several diabetic complications and relevant cost factors are not included in the analyses due to limited availability of data, it is estimated that the calculated savings potential is lower than the actual savings that can be achieved.

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Diabetes mellitus is a medical condition of enormous relevance when planning healthcare and social policies. Undoubtedly one of the main reasons is the high prevalence of the illness among the population as a whole, another being the high mortality rate resulting from diabetes-related cardiovascular diseases. Furthermore, this metabolic disorder can lead to further complications involving, for example, loss of sight or conditions requiring dialysis or the amputation of limbs. This means that diabetes mellitus is a major factor in the increased utilisation of healthcare services [1].

Moreover, the incidence of diabetes mellitus increased by 38 % between 1998 and 2011 [2]. According to estimates drawn up by the "International Diabetes Federation" (IDF), 7.6 million people are suffering from diabetes mellitus throughout Germany. This estimate includes roughly 2 million cases of type 2 diabetes mellitus which remain unrecorded due to unspecific or total lack of symptoms [3].

A permanently elevated blood glucose level also results in severe damage to vessels and peripheral nerves. Such damage has a similarly high social-economic significance in terms of shortened life expectancy, reduced ability to work and reduced quality of life, as well as of healthcare expenditure for appropriate medical treatment. According to hospital statistics, the total number of in-patient cases of diabetes has remained largely constant: Between 2000 and 2009, the annual number of cases was around 210 000. Admittedly, official statistics often do not name diabetes as the reason for hospitalisation but one of its secondary conditions instead.

According to the German Federal Statistics Office, the total direct costs of treatment for diabetes patients in Germany, including medication, out-patient and in-patient treatment, care and rehabilitation services, amounted to € 6.34 billion in 2008. This accounts for 2.5 % of total healthcare expenditure [4].

Against this background, EMPERRA® GmbH E-Health Technologies has developed the telemedicine-based ESYSTA® system – a self-contained integrated diabetes self-management system. In the so-called S-T-A-R-T project, sustained improvement of the blood glucose metabolism conditions, measured on the basis of the HbA_{1c} level, was achieved using this system [5]: Patients managed to reduce their HbA_{1c} level by 0.7 ± 1.3 % [5]. On the basis of these results, a cost-efficiency analysis was carried out in order to obtain an estimate of the financial effect of permanently reducing the HbA_{1c} level to this extent.

Methods used

Time horizon and perspective

Since diabetes mellitus is a chronic condition, a time horizon ranging from 40 to 94 years of age was chosen for the model. In this way, all relevant medical and economic consequences occurring in the course of treating a patient with diabetes mellitus can be included.

The perspective of the statutory health insurance system was chosen for the health-economy analysis. In this way, the costs incurred by the statutory health insurance companies in connection with the treatment of diabetes mellitus and its associated diseases were identified, quantified and integrated into the model. Overall economic cost components (e. g. lost years of life, reduction in earning capacity) are therefore not included in the considerations.

Table 1 States and probabilities used in the Markov model

From	to	Range of transition probabilities according to the study situation
Diabetes mellitus without complications	Angina pectoris	0.031-0.0675
Angina pectoris	Myocardial infarction	0.055-0.078
Diabetes mellitus without complications	Nephropathy	0.001-0.075
Nephropathy	Terminal kidney failure	0.003-0.074
Diabetes mellitus without complications	Neuropathy	0.005-0.035
Diabetes mellitus without complications	Stroke	0.004
Neuropathy	Diabetic foot syndrome (DFS) with amputation	0.104-0.14
Neuropathy	Diabetic foot syndrome	0.042
Diabetes mellitus without complications	Retinopathy	0.0081-0.084
Retinopathy	Loss of eyesight	0.007-0.1065

Markov model (states and probabilities)

Markov models are particularly suitable for modelling recurring events or the progress of chronic illnesses with defined stages. Using such a model, the patients' conditions can be modelled as they progress through a finite number of disjunctive and exhaustive states of health. Here, the transition pathways indicate the possible events within a specific time period. This period is divided into discrete time intervals, in which transition probabilities between the individual states of health depend on the current state of health.

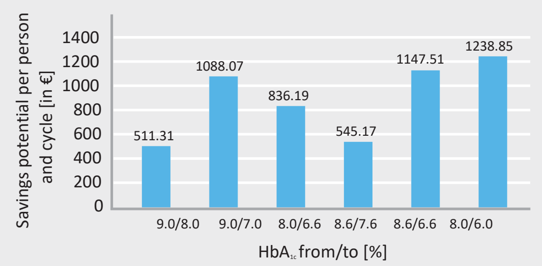
If longer time horizons are required for medical or economic reasons, the Markov model should be applied. This choice of model is justified, in particular, for the following 3 reasons [6]:

- time-varying costs or risks involve the problem of decision-making;
- the time when the event occurs plays a role;
- relevant events can occur several times over.

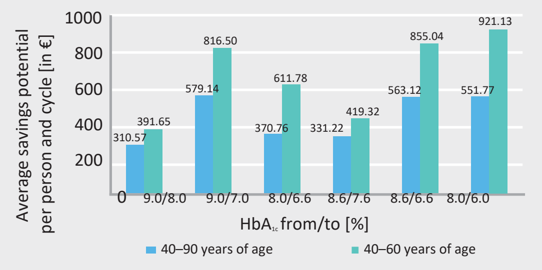
In order to take account of progress over a specific time period, this is divided up into consecutive cycles within which constant conditions are assumed. Once a cycle has elapsed, the patient's condition moves from the current state of health to that of the next cycle. The individual transition pathways with their accompanying transition probabilities between the individual states of health should be determined with this in mind. One of the special features of the Markov model is the assumption that the transition probabilities depend solely on the state of health of the current cycle and that, accordingly, the model has no memory of earlier states ("Markov assumption") [7].

▸ **Table 2** Cost data – depending on the state of health

Condition	per cycle	
	Basic costs	**High-price medicines**
Continuous diabetes mellitus	€ 542.00	–
Neuropathy	€ 2,312.17	–
Diabetic foot syndrome	€ 2,546.44	–
Diabetic foot syndrome with amputation	€ 6,068.85	–
Stroke	€ 4,720.80	€ 287.64
Nephropathy	€ 2,983.91	–
Terminal kidney failure	€ 22,984.00	included in basic costs
Retinopathy	€ 1,830.18	–
Loss of eyesight	€ 17,300.00	included in basic costs
Angina pectoris	€ 1,719.71	€ 287.64
Myocardial infarction	€ 4,609.62	€ 287.64



▸ **Fig. 1** Maximum savings potential per person and cycle (40 to 94 years of age)



▸ **Fig. 2** Average savings potential per person and cycle

Table 1 shows all the integrated states of health in the used Markov model, as well as the literature-based range [8] of respective associated transition probabilities. Two conditions – myocardial infarction and stroke – were not modelled in the study (UKPDS1) on which this calculation is based. For this reason, these two transition probabilities have been taken over from other studies that were identified in the course of bibliographical research [9, 10].

Cost data

All the relevant ICD10-GM-Codes for the determined states of health were determined using the 2014 version of the German coding index [11]. With the aid of the 2014 version of the technical specifications (Definitionshandbuch) of the German "Diagnosis Related Groups" (G-DRGs) [12], all relevant case groups can be identified by their respective ICD10-GM-Code. The basic monetary evaluation of inpatient services is determined from the basic case rate for the Federal State of Brandenburg in 2014, and weighting of the cost factors of the individual DRGs is determined from the number of billed cases of each respective state of health.

1 United Kingdom Prospective Diabetes Study

The 2015 consumer price index of 0.3 % has already been taken into account in the stated average costs. Outpatient dialysis costs for patients with terminal kidney failure have also been taken into account. In addition, ambulatory care costs have been assigned to the state of loss of sight. On the other hand, the costs of high-price medicines for the co-morbid conditions of angina pectoris, stroke and myocardial infarction have been additionally integrated into model calculations. (▸Table 2).

In the final Markov model, generalized hospitalisation rates of 50% have been assumed in order to model the inpatient cost developments over time approximately.

Results

Essentially, various scenarios of an HbA_{1c} reduction were considered when determining savings potential. The maximum possible savings that can be generated per person and cycle over the entire period of observation, i. e. from 40 to 94 years of age, is € 1,238.85 if the HbA_{1c} level is reduced from 8.0 to 6.0 % (▸Fig. 1). However, all maximum values theoretically occur between the age of 45 and 48.

Table 3 Savings index.

Savings	HbA1c from/to [%]					
	Scenario (40–94 years of age)					
	9.0/8.0	9.0/7.0	8.0/6.6	8.6/7.6	8.6/6.6	8.0/6.0
Minimum	€ 77.94	€ 138.91	€ 81.17	€ 68.43	€ 124.85	€ 106.54
Maximum	€ 511.31	€ 1,088.07	€ 836.19	€ 545.17	€ 1,147.51	€ 1,238.85
Mean value	€ 310.57	€ 579.14	€ 370.76	€ 331.22	€ 563.12	€ 551.77
Standard deviation	€ 92.27	€ 244.79	€ 235.58	€ 102.63	€ 292.42	€ 365.26
	Scenario (40-60 years of age)					
	9.0/8.0	9.0/7.0	8.0/6.6	8.6/7.6	8.6/6.6	8.0/6.0
Minimum	€ 77.94	€ 138.91	€ 81.17	€ 68.43	€ 124.85	€ 106.54
Maximum	€ 511.31	€ 1,088.07	€ 836.19	€ 545.17	€ 1,147.51	€ 1,238.85
Mean value	€ 391.65	€ 816.50	€ 611.78	€ 419.32	€ 855.04	€ 921.13
Standard deviation	€ 105.73	€ 242.89	€ 203.27	€ 119.35	€ 269.55	€ 308.96

If the HbA_{1c} level is reduced from 9.0 to 7.0 %, the maximum mean savings per person amounts to € 579,14 within the time period of 40 to 94 years of age. If one limits the observed age group to persons between 40 and 60 years of age, the maximum possible mean savings potential per person – in the case of HbA_{1c} reduction from 8.0 to 6.0 % – amounts to € 921,13 (▶ Fig. 2). Table 3 gives an overall view of the savings potential per person and cycle.

Discussion

Effectively, the savings potential changes in relation to the observed HbA_{1c} reductions and in relation to the different age groups. This results in a maximum possible savings potential of € 1,238.85 within one cycle if the HbA_{1c} level is reduced from 8.0 to 6.0 %. Taking the mean possible savings potential that can be achieved per person and cycle over the observation period 40 to 94 years of age, it can be seen that the highest possible savings potential is € 579.14 if the HbA_{1c} level is reduced from 9.0 to 7.0 %.

As opposed to this, between the age of 40 and 60 the mean maximum savings potential per person and cycle is € 921.13 – but only if the HbA_{1c} level is further reduced from 8.0 to 6.0 %. Generally speaking, the possible savings potential is highest within this age group. In comparison, the cost curves between low and high HbA_{1c} levels increasingly converge in the higher age groups.

Between the age of 40 and 94, a total of € 31,852.48 per patient can be saved if the HbA_{1c} level can be reduced from 9.0 to 7.0 %. 54 % of these possible savings – i. e. € 17,146.58 Euro – are achieved between the age of 40 and 60. A similar pattern can be observed if the HbA_{1c} level is reduced from 8.0 to 6.0 %. Here, a total savings potential of € 30,347.49 can be achieved per person between the age of 40 and 94, whereby € 19,343.79 (approx. 64 %) of these savings are attributable to the life span between the ages of 40 and 60.

The Markov model and its limitations

The Markov model models the transition of the medical condition of individuals included in a cohort from one state of health to the next. This modelling process is made possible using transition probabilities. These transition probabilities are calculated using logistic regression models in which risk profiles with variables such as HDL cholesterol values, smoker or non-smoker status, HbA_{1c} levels, blood pressure values and diabetes duration form the basis for calculation. The transition probabilities which have been obtained from studies identified in bibliographical research are the result of these calculations by the UKPDS.

In this Markov model, there is no modification of the probabilities with relation to HDL cholesterol values or risk factors other than the HbA_{1c} levels. The ceteris paribus clause applies. The result is a simplified model which represents and evaluates reality with regard to the effects of changes in the individual variables. In addition, this Markov model only models singular transitions between states, so that possible multi-morbidities are not considered. Similarly, increasing frequency of illnesses and possible progressive HbA_{1c} reductions over time are not considered, either.

Further limitations of cost calculations

A further limitation is that normally no data on the duration of a diabetes mellitus illness can be found in administrative datasets due to the gradual onset of this metabolic disorder, which is often not diagnosed until a later stage. For this reason, diabetes duration cannot be modelled in the Markov model.

The expenditure shown does not usually include costs for outpatient treatment or medication. Neither are the costs for therapeutic remedies and aids in the outpatient sector taken into account. Possible complications related to diabetes and the costs these involve are not accurately determined, either.

Speech problems and paralyses resulting from a stroke, for example, were not taken into account (no integration of the costs for physiotherapy, speech therapy or medical services related to these conditions). Psychological complications (e. g. diabetes-related depression) were also omitted. Also, the diagnosis of heart failure as a result of diabetes mellitus is not included in the model.

Last but not least, the assumed generalized hospitalisation rate of 50 %, particularly for cost-intensive health conditions (e. g. terminal kidney failure), seems to be very low. One can therefore assume that in view of the costs that have not been included and taking due consideration of existing inflation rates, the above-mentioned cost-saving effects on the healthcare system and/or the economy will tend to be even higher.

Conflicts of interest

The authors state that the study which they carried out at the Hochschule Niederrhein (university of applied sciences) on the cost efficiency of sustainable blood glucose reduction using a Markov model was commissioned by EMPERRA GmbH.

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