MEDICAL AND ECONOMIC BURDEN OF HYPERTENSION ASSESSED BY MODELLING AND SIMULATION

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Abstract

Hypertension is the most common chronic condition in humans and should be considered a major risk factor for cardiovascular and related diseases. Because of its high prevalence, long-term consequences and lifelong treatment, hypertension is a heavy burden for the healthcare systems and the society.
The aim of this study was to demonstrate clinical and economic effects of untreated versus ideally treated hypertension in a population of all hypertensive patients in Slovenia, with particular attention to congestive heart failure, stroke and myocardial infarction. The course of hypertension and the costs of its management were simulated for a period covering the total lifetime of the patients.
The highest treatment costs were associated with medications, followed by sick leave. According to the modelling results, hypertension practically begins at the age of 30 and its prevalence increases with age.
Severe complicating diseases were shown to occur after the age of 60, mainly after the age of 70.
A favourable cost-effectiveness of antihypertensive treatment became apparent after 12 years of treatment in the prevention of myocardial infarction and after 15 years of treatment if congestive heart failure and stroke were considered.

Keywords: burden of hypertension, modelling and simulation

Author's biography

Martin Bruderman graduated in 2004 from the Faculty of Pharmacy, University of Ljubljana, Slovenia. He is employed in the Sales Division of the company Krka, d. d.

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1. Introduction

Hypertension or abnormally high arterial blood pressure is a condition, not a disease. A generally accepted conceptual definition of hypertension is »that level of blood pressure at which the benefits (minus risk and costs) of action exceed the risk and costs (minus the benefits) of inaction. [1]

The prevalence of hypertension is substantial. In Slovenia, like in the United States, hypertension is found in 15–25% of adults. Its prevalence increases progressively with age. [2,3]

Hypertension should be considered a major risk factor for cardiovascular and related diseases as well as for diseases leading to a marked increase in cardiovascular risk. The total cardiovascular risk is stratified according to blood pressure but also gender, age and other risk factors. [4]

Hypertension significantly accelerates the development of atherosclerosis. This is manifested as an increased incidence of stroke, myocardial infarction, congestive heart failure, peripheral arterial disease, and hypertensive nephrosclerosis. [5]

Treatment of hypertension includes lifestyle modifications. These include change to a healthy diet, normalisation of body weight, alcohol reduction when needed, and regular exercise. However, the cornerstone of the treatment of hypertension is medication. Choosing the appropriate medication depends primarily upon the patient's co-morbid conditions and habits. [6]

Numerous prospective clinical trials and several meta-analyses have documented that effective antihypertensive treatment is associated with a major reduction in the risk of stroke (by about 30–40%), but that coronary events are reduced to a lesser degree (by about 20%). The treatment appears to lead to a larger reduction in the incidence of heart failure. [4]

The aim of this study was to demonstrate clinical and economic effects of untreated versus ideally treated hypertension in a population of all Slovenian hypertensive patients.

Special attention was paid to congestive heart failure, stroke, and myocardial infarction as consequences of hypertension. Using all the available epidemiological data, we modelled the course of the disease and the costs of its management for a period covering the total lifetime of the patients.

2. Methods

2.1 Epidemiology and economics of the disease

Epidemiological data were collected from international medical statistics, most frequently from the USA [7]. Some data were available in Slovenia [8] and from prospective clinical studies (included in reference 9).

Data on the costs of treatment of hypertensive patients were obtained from the Health Insurance Institute of Slovenia. [9,10].

The algorithm of the management of patients with hypertension was developed according to the European guidelines [4] with the help of a Slovenian expert (Prof. Rok Accetto). This algorithm is presented in Fig. 1.

2.2 Mathematical modelling and simulation of dynamic systems

We described the changes in observed dynamic processes with a multitude of differential equations. We determined their structure and parameter values by adjustment to baseline data. We built the mathematical model using the Matlab software [11] which is intended for scientific calculations. It includes several toolboxes for rapid problem solving. In particular, Simulink [12] should be mentioned, a general simulation tool suitable for solving simple differential equations.

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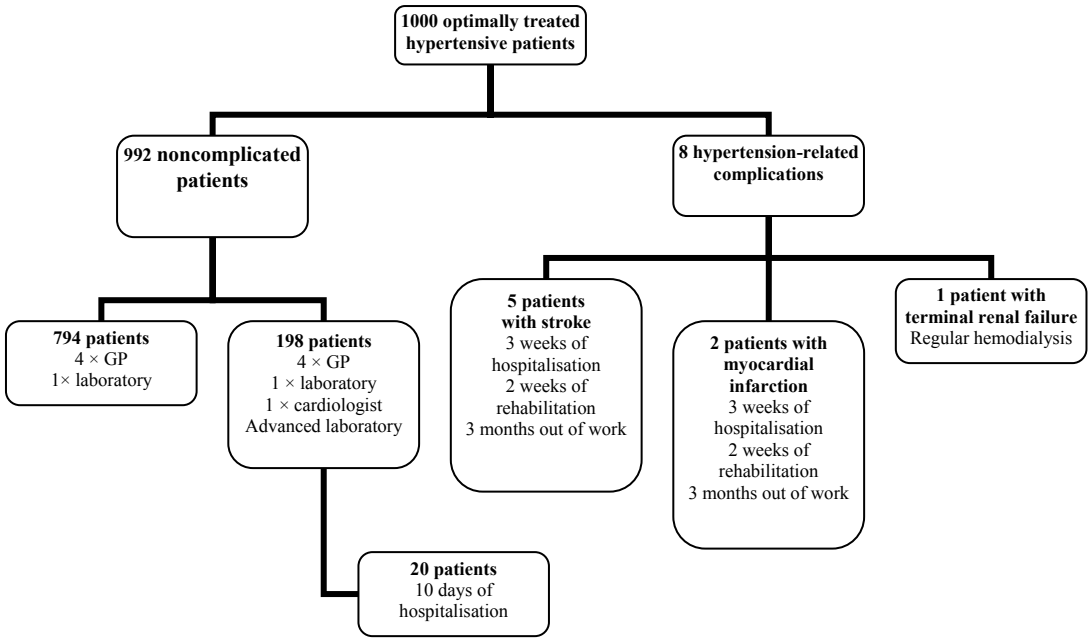

Fig. 1. Algorithm of the management of 1000 ideally treated hypertensive patients in Slovenia in one year

3. Results

3.1 Results of analysis of disease economics

Based on the algorithm of optimal management and on epidemiological data and data on medication prices and healthcare services, we calculated the costs of an optimal management of 1000 hypertensive patients in Slovenia over a period of one year. The highest costs were associated with medication (27.9%), sick leave (20.5%) and family physician visits (18.2%). The costs and cost distribution are shown in Tab. 1.

Tab. 1. Final distribution of costs of one-year optimal treatment of 1000 hypertensive patients in Slovenia

TYPE OF COSTS	Healthcare service	COSTS [€]	SHARE IN TOTAL COSTS [%]
DIRECT MEDICAL	Family physician visits	121,228.8	18,2
	Specialist visits	12,875.0	1.9
	Laboratory examinations	33,267.0	5.0
	Hemodialysis	18,778.2	2.8
	Rehabilitation	7,602.9	1.1
	Hospitalisation	78,081.3	11.7
	Medications	185,560.0	27.9
	Total	**457,393.5**	**69.8**
DIRECT NONMEDICAL	**Travel expenses**	**43,761.0**	**6.6**
	Total	**43,761.0**	**6.6**
INDIRECT	**Sick leave**	**136,686.0**	**20.5**
	Disability retirement	**27,360.0**	**4.1**
	Total	**164,046.0**	**24.6**
Total		**665,200.5**	**100.00**

Direct medical costs of therapy have a 69.8% share in the total costs, direct nonmedical costs have a 6.6% share in the total costs, and indirect costs have a 24.6% share in the total costs (Fig. 2).

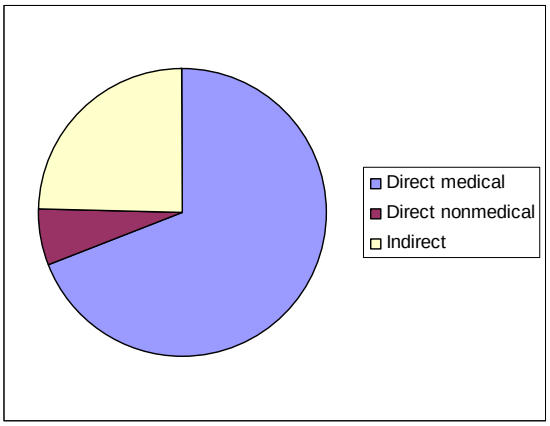

Fig. 2. Shares of total costs of optimal therapy of 1000 hypertensive patients

3.2 Results of mathematical modelling and simulation of dynamic systems

Based on initial assumptions and epidemiological data, we demonstrated the effect of hypertension on the course of cardiovascular complications. The models were updated with reliable and newer epidemiological data published in the literature. We demonstrated the time course of the development of individual complications in untreated persons and the effect of treatment. Hypertension occurs very rarely until the age of 30. We assumed that the studied population, despite having hypertension, was not receiving treatment for 25 years. At the age of 55 optimal antihypertensive therapy was initiated. The treatment led to a reduction in the share of complications. Clearly, we must not neglect single complications in normotensive persons, who do not receive treatment but contribute to the total share of persons with a specific disease.

Fig. 3 shows the incidence of congestive heart failure in persons with normal blood pressure and in those with untreated or ideally treated hypertension.

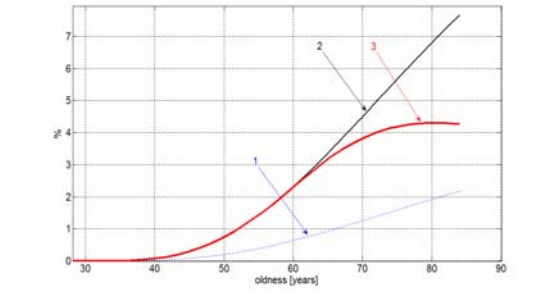

Fig. 3. Incidence of congestive heart failure in normotensive persons (1) and in untreated (2) or ideally treated (3) hypertensive patients

Fig. 4 shows the costs of antihypertensive treatment and hypertension-induced congestive heart failure.

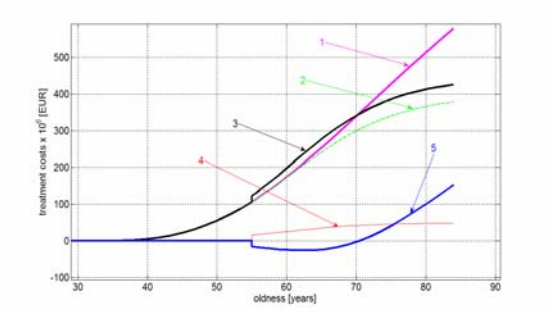

Fig. 4. Costs of treatment of congestive heart failure in patients with untreated hypertension (1), costs of treatment of congestive heart failure in patients with treated hypertension (2), costs of treatment of congestive heart failure and hypertension (3), costs of treatment of hypertension (4), and the difference in the costs of treatment between treated and untreated hypertensive patients (5)

The difference in the costs of treatment between treated and untreated hypertension becomes cost-effective after 15 years of treatment.

Fig. 5 shows the incidence of stroke in normotensive persons and in untreated or ideally treated hypertensive patients.

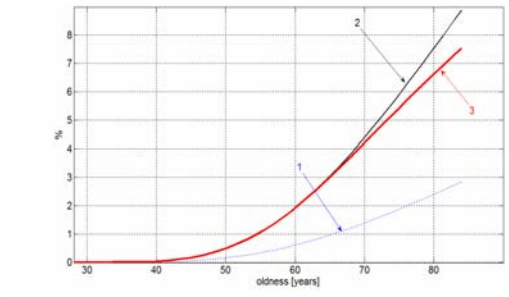

Fig. 5. Incidence of stroke in normotensive patients (1) and in untreated (2) or ideally treated (3) hypertensive patients

The costs of treatment of stroke in hypertensive patients are shown in Fig. 6.

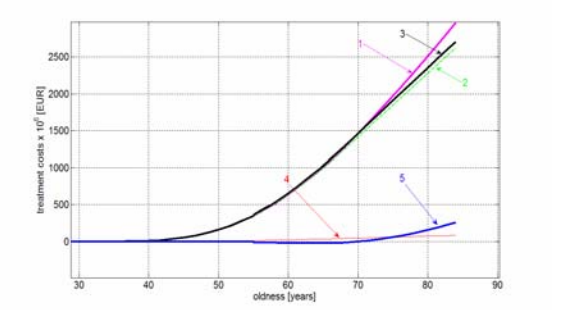

Fig. 6. Costs of treatment of hypertension-induced stroke in untreated hypertensive patients (1), costs of treatment of stroke in treated hypertensive patients (2), total costs of treatment of stroke and hypertension (3), costs of antihypertensive treatment (4), and the difference in the costs of treated and untreated hypertension (5)

The difference in the costs of treatment between treated and untreated hypertension becomes cost-effective after 15 years of treatment.

The incidence of myocardial infarction in normotensive patients and in untreated or ideally treated hypertensive patients is shown in Fig. 7.

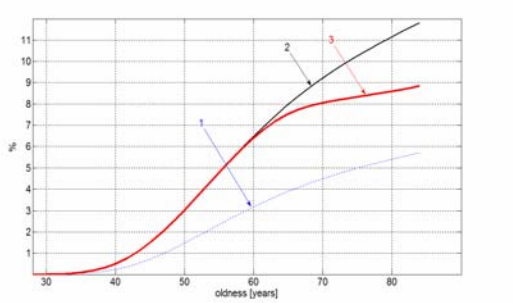

Fig. 7. Incidence of myocardial infarction in normotensive patients (1) and in untreated (2) or ideally treated (3) hypertensive patients.

Costs of treatment of myocardial infarction in hypertensive patients are shown in Fig.8.

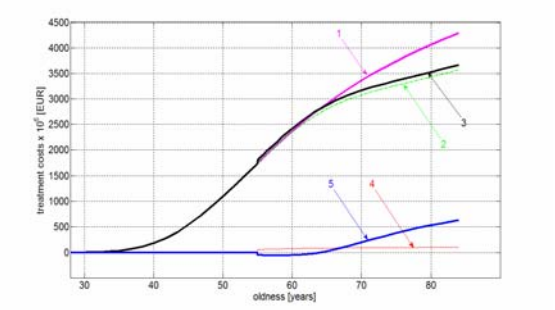

Fig. 8. Costs of treatment of hypertension-induced myocardial infarction in untreated hypertensive patients (1), costs of treatment of myocardial infarction in patients with treated hypertension (2), total costs of treatment of myocardial infarction and hypertension (3), costs of treatment of hypertension (4), and the difference in the costs of treated and untreated hypertension (5)

The difference in the costs of treatment of treated and untreated hypertension becomes cost-effective after 12 years of treatment.

4. Conclusions and discussion

Hypertension is the most common chronic disease and its prevalence continues to increase with aging of the population.

It is possible to prevent about 50% of congestive heart failure cases, 35% of stroke cases and 20% of myocardial infarction cases if hypertension is treated. [1]
However, it is necessary to treat hypertensive patients for a long time, for 10, 20, or even 40 years. This is demanding for patients and a great burden for the society. There are various reasons why in most patients the management of hypertension is suboptimal.

Our data show that complications of hypertension begin to occur after the age of 60, in most of the patients after the age of 70.

Myocardial infarction occurs earlier than stroke and congestive heart failure. Therefore, antihypertensive treatment is more cost-effective in the prevention of myocardial infarction than in stroke and congestive heart failure.
By simulating hypertension and complicating diseases, we can demonstrate the most probable epidemiological situations and calculate the social burden of these conditions.

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