We are living in a paperless, digital age, and EHRs are becoming the standard of capturing patient related information. Understandably, the penetration of EHR systems is higher in developed compared to developing countries. Use of EHRs facilitates healthcare provider decisions resulting in better clinical care and improved patient outcomes.

Importance of introducing EHR in developing countries has been emphasized by the WHO almost 15 years ago, when the EHR Manual for developing countries was published [1]. Inadequate health information systems have been identified as a major challenge in the healthcare systems of many developing countries, and EHRs have not been widely implemented in those countries [1, 2].

Some of the reasons identified for inadequate use of EHRs in developing countries have been the high costs of procurement and maintenance of the EHR systems, lack of financial incentives and priorities, and inadequate internet connectivity [3].

It is important for lower resource countries to consider development of their own, national EHRs, instead of procuring global, costly EHR solutions. For that purpose they could use the expertise of other developing countries that are more advanced in the implementation of EHR. Such in-house solutions could be based on the open standards and open source software [4].

However, it is not enough just to have an EHR system capturing the medical information, including diabetes care parameters. The critical part of implementing EHR systems is to make them communicate with each other and provide interoperability, in order to share patient related information across the country. It is important that wherever the patient goes within a country, the healthcare providers have access to the patient’s medical history.

It is true nowadays that in most developed countries, such as the US, Germany or Sweden, patient related information is captured electronically in sophisticated EHR systems. However, interoperability of EHR systems is inadequate even in those developed countries, as the systems are not exchanging patient information with each other. It is great to have EHR systems, but if the records could not be easily
accessed by all the providers who need them and the patients themselves, then there is a lack of benefit of using such systems.

This is also relevant for the diabetes related information captured in EHRs of the most developed countries, if different systems are used in different hospitals. Hence, if a person with diabetes goes from one city or region to another within the same country, the healthcare providers would know nothing about its diabetes.

One striking example of a disastrous outcome due to non-integration of EHRs, even in the most developed healthcare systems such as Germany, was the case of Germanwings pilot Andreas Lubitz. He was unable to sleep because of what he believed were vision problems, and had consulted numerous doctors fearing he was going blind. Andreas Lubitz was taking prescription medicines and suffered from a psychosomatic illness, treated for suicidal tendencies, and was declared unfit to work by doctors, and absolutely unfit to operate an aircraft.

Andreas Lubitz should have never been allowed to be in control of an airplane. Nevertheless, medical secrecy requirements prevented above information to be available to Germanwings, and the doctors were not aware of the medical records of other doctors due to a missing interoperability of the different EHRs. It all ended up in catastrophe when Andreas Lubitz took over the control of Germanwings flight number 9525 from Barcelona to Dusseldorf, deliberately causing a crash on 24-March-2015, and killing all 144 passengers onboard. If the EHR systems of all the doctors he visited had been integrated, this tragedy could have probably been prevented.

Integration of the EHR systems should not only be between hospitals, but also between all relevant stakeholders across all layers of healthcare. All healthcare entities have to be integrated in a centralized, National e-Health System. Diabetes related information has to be a substantial part of the NeHS. In addition to improving the clinical care and patient outcomes, a centralized, integrated EHR system could serve as a database for healthcare authorities to perform numerous analyses at a national level, thus enabling the adequate management of medical conditions and available resources.

Although there are outstanding national registers in developed countries for certain conditions; the EHR systems in the majority of those countries are not centrally integrated. It is interesting that what is non-existent in the most developed countries is available in a developing, low-resource country, such as the Republic of North Macedonia. Accordingly, if it could have been implemented in a country like the Republic of North Macedonia, it would be possible to implement it in any developing country with limited resources.

Introduction of NeHS in the Republic of North Macedonia on 01-July-2013 was a revolutionary step in monitoring and improving the performance of national healthcare system. It was a domestically developed platform, created and tailored according to the instructions from the Ministry of Health. The comprehensive, national EHR system covered all citizens across the three healthcare levels: primary care provided by family physicians, secondary care provided by specialists in
general and regional hospitals, and tertiary care provided by university clinics. Implementation of the NeHS has been praised internationally as a key platform for improving the performance of the national healthcare system [5–7].

It is worth noting that the NeHS was domestically developed and the costs for development and maintenance have been a fraction of the costs of similar comprehensive, global e-Health solutions on the market. A dedicated Directorate for e-Health was formed within the Ministry of Health, responsible for maintaining and upgrading the NeHS, and reporting directly to the Minister of Health. The Directorate for e-Health has been closely cooperating with the healthcare authorities and the Institute of Public Health, as it has become possible to instantly generate and analyze numerous public healthcare data.

European Healthcare Consumer Index (EHCI) Report for 2014 stated that the Republic of North Macedonia has made the most remarkable advance in the EHCI scoring of any country in the history of the Index, from 27th to 16th place, largely due to eliminating waiting lists by implementing the real time e-Booking system (Fig. 7.1) [5–9].

The value of centralized, integrated EHR systems goes beyond the online appointments that have largely facilitated healthcare access for patients, including those with diabetes. It has been an online, cloud-based platform for EHRs of the entire population in the Republic of North Macedonia [5, 6, 8, 9]. Other countries have also expressed interest in providing the whole or elements of the NeHS in their national healthcare systems.

Since the beginning of 2015, the diabetes care module in the NeHS was upgraded with the possibility to record diabetes treatment, metabolic parameters and diabetes

![Fig. 7.1 National e-Health System in the Republic of North Macedonia [5–9]](image-url)
complications (Fig. 7.2a, b) [5–9]. In that way, the NeHS has provided endless possibilities for monitoring prevalence of morbidities and mortalities, prescribed medications, referrals across the system, metabolic control, and numerous other analyses in one of the worst hit populations in Europe [5–9].

Integration of diabetes related data in NeHS was one of the initiatives undertaken to manage the burden of diabetes in the Republic of North Macedonia (Fig. 7.3) [9–11]. Other initiatives included designating diabetes mellitus as a specific medical condition in the Law on Healthcare; adopting international guidelines as National Diabetes Care guidelines published in the Official Journal of Republic of North Macedonia, where laws are published, further emphasizing the importance of diabetes as a nationwide condition (Fig. 7.3) [9–11]. The National Diabetes Register was also created within the NeHS containing more detailed information about the people with diabetes (Fig. 7.3) [9–11].

Additional initiatives included formation of National Diabetes Committee according to the Law on Healthcare (Fig. 7.3) [9–11]. The National Diabetes Committee has been responsible for the development of National Diabetes Plan, implementation of the National Diabetes Care guidelines and monitoring of adherence to the guidelines.

Fig. 7.2 Integration of diabetes related data in NeHS (a) diabetes treatment (b) metabolic parameters and diabetes complications [5–9]
Fig. 7.2 (continued)
Introduction of the NeHS in the Republic of North Macedonia has provided the first opportunity to evaluate the prevalence of diagnosed diabetes cases, unlike the previous estimates based on extrapolations of high quality data from other countries in the region [6].

The IDF publications up to 2019 specified that there was no nationally reported data on the total prevalence for the Republic of North Macedonia, and the estimates were based on extrapolations. However, that has changed with the introduction of the NeHS [6, 12, 13]. Publication of the first stratified diabetes prevalence derived from the NeHS was considered for the country estimates in the latest edition of IDF Diabetes Atlas, confirming the value of the NeHS [6, 13].

The first stratified diabetes prevalence data for Republic of North Macedonia derived from the NeHS were key for the initiation of IDF regional project to evaluate the undiagnosed diabetes prevalence in Western Balkans countries (Albania, Bosnia and Herzegovina, Montenegro, Macedonia, Serbia), which if added to the diagnosed diabetes prevalence could result in a more precise estimate of the total diabetes prevalence.

The use of NeHS enables various stratification analyses in population with diabetes by age, gender, place of living, or comorbidities. Those analyses could help monitor diabetes prevalence, and evaluate the effectiveness of already introduced measures to curb the prevalence.

The NeHS has been an essential tool for the National Diabetes Committee. It has served as a platform for rationalization of diabetes treatment by monitoring prescribers’ adherence to the guidelines, thus being critical in managing the exponentially rising diabetes costs. Thanks to the NeHS, prescribers who were violating the guidelines were identified which played a crucial role in the rationalization of insulin treatment costs by almost 50% in 4 years, despite the cumulative annual growth of insulin volume by 5%, seven-fold increase in the free test strips, and introduction of novel diabetes treatment classes.

The NeHS has also served as a human resources management tool. Its use identified if additional human resources were needed in diabetes care, resulting in increased number of residencies and fellowships in Endocrinology and Diabetes.

Its value as a human resources tool has been critical as many physicians from the country have left their jobs in the Republic of North Macedonia, and moved to better paid jobs in developed European countries, leaving a gap in the national system. The migration of physicians is a huge problem for the other developing countries, as well. The problem is more complex as the ones who migrate are predominantly younger specialists and fellows, leaving the domestic system with the ageing physicians’ population.

By analyzing the workload of the remaining providers from the NeHS, such as the number of patients, visits, referrals, complexity of patients and other engagements of the providers, it was possible to reallocate the remaining resources or redistribute the workload to provide an adequate diabetes care.

Analysis of geographical distribution of diabetes population from the NeHS resulted in decisions to open additional Diabetes Centers and insulin pharmacies at locations where those were missing. As a result, in less than 2 years, 3 more Diabetes
Centers and insulin pharmacies were opened in the country, adding to the total number of 41 Diabetes Centers nationwide.

Furthermore, NeHS has become an essential platform for Predictive, Preventive and Personalized Medicine (PPPM) in people with diabetes. The concept of PPPM has emerged as the focal point of efforts in healthcare aimed at controlling the prevalence and management of NCDs, including diabetes [14–17].

The NeHS has been used as a platform for Predictive Diabetes Care, as it has enabled monitoring of metabolic control parameters and the associated predicted risk for diabetes complications. The NeHS could be used for monitoring of predicted diabetes risk and identifying high risk individuals for developing diabetes.

The NeHS has been a platform for Preventive Diabetes Care, as it has enabled monitoring of diabetes complications, and provides directions for preventive activities to avoid or delay diabetes complications. It also provides monitoring of modifiable risk factors for prevention of diabetes.

Finally, the NeHS has served as a platform for Personalized Diabetes Care, providing diabetes care based on individual glycaemic control and comorbidities. The NeHS data are available to care-givers across all healthcare levels and there is a potential of adding new scientifically sound and approved biomarkers to further personalize diabetes care in the future.

Taking into consideration that diabetes has been a huge healthcare and socio-economic burden for the country, the analysis of data on metabolic control in people with diabetes has been of utmost importance. A study was performed to analyze the metabolic control in insulin treated people with diabetes from the Republic of North Macedonia [18].

National e-Health System was searched for all insulin-treated people with data in their EHRs on any of the metabolic parameters. Analysis of the NeHS found that the insulin-treated people with diabetes in the Republic of North Macedonia had mean HbA1c of 7.8 ± 1.8%. It was found that 37.8% of the people with diabetes achieved target HbA1c ≤ 7%; whereas 25.9% had HbA1c >7% and ≤8%; and 36.3% had HbA1c >8% (Fig. 7.4) [18].

First metabolic control results in insulin-treated people with diabetes derived from the NeHS have reported that there is a need for improvement of glycaemic control, as 36.3% of subjects had poor glycaemic control (HbA1c > 8%) (Fig. 7.4) [18].

In addition, the need for improvement of weight management was identified, as mean BMI was 30.4 ± 5.2 kg/m² [18]. The need for improvement of lipid management was also reported as more than half of the subjects had total cholesterol and LDL above the recommended targets [18, 19]. Analysis discovered that only 16.8% of subjects had any metabolic data in their EHRs, so change from optional to mandatory recording of metabolic parameters was suggested as necessary to improve the individual and national metabolic control [18, 19].

If we compare the results of glycaemic control in the Republic of North Macedonia, where 37.8% of the people with diabetes were on target, with the glycaemic control from developed European countries, we could find it comparable to Italy (36% of cases on target), and the UK (39% of cases on target), whereas other developed
countries had better glycaemic control, including the Netherlands (71%), France (65%), Belgium (60%), Sweden (57%), Ireland (53%), and Germany (49%) [18, 20].

It is interesting that the study in the developed European countries was also conducted by using EHRs and it covered a total of 7,597 subjects from 8 developed European countries, compared to the study from NeHS in the small country of Republic of North Macedonia which analyzed 6,204 individuals, only confirming the power of centralized, integrated e-Health systems [18, 20].

Another interesting observation is that despite the reduction of penetration of insulin analogues, the achieved glycaemic control was comparable with some of the developed European countries, and improved compared to previous reports of glycaemic control in the country [21, 22].

The NeHS could also provide information on the percentage of people with diabetes achieving metabolic targets at the level of region, city, healthcare institution, or individual physician. In that way, it is possible to create benchmarks and identify the best and worst performers. Improvements in achieving targets at the physicians’ level contribute to the better national metabolic control. Those metrics could be defined for various processes, including achieving metabolic control, screening for complications, or cost-effective use of diabetes treatments. Institutions and physicians have to be incentivized to achieve better performance.

The NeHS was also used to evaluate the use of metformin in people with type 2 diabetes in the country. Surprisingly, it was found that metformin was not adequately titrated and the majority of people with diabetes were receiving suboptimal metformin doses. Similarly, it was identified that many patients were not receiving statin treatment for CVD prevention, although they were eligible for such treatment according to the National Diabetes Care guidelines.

It was already mentioned that Republic of North Macedonia is estimated to have one of the highest diabetes age-adjusted comparative prevalence in Europe, and is categorized as a very high risk country for CVD mortality, defined as CVD mortality >450/100,000 for men, and >350/100,000 for women [5, 6, 23].
By using the NeHS, for the first time it was possible to report the national prevalence of heart failure in people with type 2 diabetes in the Republic of North Macedonia, and their access to reimbursed treatment with SGLT2i or GLP-1RA after the initial treatment with metformin [24].

The national prevalence of heart failure in people with type 2 diabetes was found to be 12.0% [24]. Majority of the people with type 2 diabetes and heart failure were at the age of 60 years or above (92.5%) [24]. Only 0.5% of all people with type 2 diabetes and heart failure had access to fully reimbursed treatment with GLP-1RA or SGLT2i [24].

The first results of national prevalence of heart failure in people with type 2 diabetes derived from the NeHS suggested that despite the recent increase in the number of individuals with fully reimbursed treatment of SGLT2i or GLP-1RA, their access to those medications has still been very limited [24].

The access to NeHS is currently authorized only for various groups of healthcare providers with different rights. For example, physicians have full access, while nurses have limited access to the patient data. Citizens of the Republic of North Macedonia currently do not have access to their own EHRs, although such access has been enabled in certain developed countries. The next step should be to enable all citizens to have direct access to their own EHR data.

As we are moving from desktop to handheld devices, the next step in the improvement of NeHS would be to provide user friendly m-Health solution, or mobile app based platform. Such m-Health solutions are expected to have all the above mentioned functionalities, completely replacing the need of any paper documents in the healthcare processes.

It is interesting that developing countries might have an advantage in implementation of national, integrated EHR systems. Although it sounds paradoxical, many developed countries have EHR systems of different age and technology that are difficult to integrate on a national level. On the other hand, many developing countries are mainly EHR-naive, thus making the introduction of national, centralized, integrated systems much easier to implement. One such example has been the Republic of North Macedonia. But the explosion of mobile banking even in the less developed countries, reminds us that many other countries could easily benefit from the EHR systems as part of the m-Health solutions.

It would be beneficial if EHRs contain information on BMI, smoking status, and test score after SDEP; but also on physical activity, calories intake, and any novel biomarkers that might occur in the future. Individual EHRs could also include information from the glucose monitoring devices, such as BGMs and CGMs.

The NeHS could be used for monitoring the progression of subjects from prediabetes to type 2 diabetes. It could identify the people with prediabetes to focus preventive activities in this population. The NeHS could be used for monitoring of diabetes risk in people not diagnosed with diabetes.

The use of EHRs from NeHS has been crucial in performing telemedicine visits of people with diabetes in a time of a global infectious pandemic, such as the recent one with COVID-19. People with diabetes, as a high risk population for increased morbidity and mortality, have been strongly advised not to leave their homes. The role of telemedicine and NeHS in diabetes care will only increase in the future.
The NeHS has been valuable in times of natural disasters such as the floods in rural areas close to Skopje in 2016 when the people were stranded in their homes. The NeHS helped identify the people with diabetes in the affected area to facilitate the delivery of their medication.

It has to be considered that centralized, integrated e-Health systems would also be a target for breaching cyber security, exposing vital personal data from the medical histories. Efforts have to be made to protect the NeHS from data breaches through cyber-attacks.

The NeHS remains a key platform supporting the National Diabetes Committee activities in its main mission of improving glycaemic control in people with diabetes by adhering to National Diabetes Care guidelines, while preserving the sustainability of the health care system.

Finally, it needs to be mentioned that implementation of centralized, integrated NeHS in a developing country is not a smooth exercise. It has been met with strong resistance in the Republic of North Macedonia, since, suddenly, all the activities, workload and achievements of every physician, became very transparent.

However, the strong gains from the implementation of the NeHS justify the efforts to overcome all barriers that might appear on the way. In order to be successfully implemented, the NeHS requires strong political leadership and support from the medical community.

What could be the benefits from a centralized e-Health System in Diabetes Care?
Each developing country should...

• …have NeHS as a critical tool for Predictive, Preventive and Personalized diabetes care;
• …enable NeHS to include data on dietary pattern, physical activity, diabetes education, in addition to metabolic parameters in EHRs of people with diabetes;
• …consider integration of BGM and CGM data into the NeHS;
• …use analysis from the NeHS as a cornerstone for the national diabetes care policies;
• …provide its citizens with access to their own EHRs.

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