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APPLICATION OF MEDICAL INFORMATION SYSTEMS IN EDUCATION AND RESEARCH IN MEDICINE

Dragan Janković, Petar Rajković, Tatjana Stanković, Aleksandar Milenković and Ivana Kocić

This paper presents medical information systems (MIS) as a powerful source for education and research in modern medicine. Paper gives an overview of functionalities of MIS system, emphasizing reporting and data analysis techniques as basic knowledge extracting methods. These two are considered as the most important functionalities for successful use of data from medical information systems in medical education and research processes. Also, general remarks on other possible usage of MIS in education and research in medicine are presented here and illustrated with examples from MEDIS. NET information system, developed in Laboratory for Medical Informatics of Faculty of Electronic Engineering in Niš. *Acta Medica Medianae 2012; 51(1):73-80.*

Key words: *medical information systems (MIS), research, education*

University of Niš,, Faculty of Electronic Engineering, Niš, Serbia

Contact: Dragan Janković
Aleksandra Medvedeva 14
18000 Niš, Srbija
E-mail: Dragan.Jankovic@elfak.ni.ac.rs

Introduction

The level of application of information technologies in modern healthcare systems continuously grows worldwide. Even though medical information systems are not something new from the technological point of view, the trend of their effective and massive use lasts only for the last ten to fifteen years. Medical information systems (MIS) significantly improve the work of healthcare institutions and professionals through efficiency increase, reduced scope of work with paper documents, automatic registration of data that follows every segment of healthcare, etc. However, besides its basic role in a healthcare, properly designed and implemented MIS should also contribute to significant improvement of education and research. This aspect of MIS is less exploited, but equally important as well as aspects of resource management within healthcare institution and support to basic health care delivery. Therefore, this paper discusses the position and role of MIS in education and research and gives some solutions realized within the projects TR 1.047 and TR13015 supported by the Ministry of Science and Technological Development of the Republic of Serbia.

Education of medical students, as well as continuous education of doctors is characterized with great complexity, huge amount of data and constant improvements. Leaning on classic ways of education with preferred ex-cathedra lectures and practical exercises with patients is less and less able to fulfill increasing demands and scope of medical education. Therefore, all additional forms of education in medicine became very significant. Important role in this process could be played by medical information systems if they are designed and realized properly and if they provide necessary functionalities which are widening the traditional set of options offered by medical information systems, previously focused on administrative data related to patients and provision of healthcare services.

Modern researches in the field of medicine are very often based on huge amount of information that could be collected specifically for the needs of certain research, or data that already exist within medical information systems. The advantage of using MIS is in the fact that specific collection of data usually cannot be measured by the scope and quality with data collected in MIS for many years. All these facts support the claim that MIS, which is installed and actively used in certain healthcare institution, presents an excellent educational and research database and pre-condition for efficient education and successful research.

MIS

Basically, medical information systems with realized Electronic Patient Record (EPR) (1) or Electronic Health Record (EHR) enable the following functionalities:

- electronic input and update of data related to provided healthcare services;
- work with medical, financial and technical documentation,
- connection with specialized information systems, such as laboratory or radiology information system;

- connection with diagnostic medical devices such as X-ray machine, electrocardiogram (ECG), laboratory analyzers, etc;
- review of all gathered medical data and possibility of following the history of disease;
- support to medical staff in decision making in real time.

In general, medical information systems contain detailed information on almost all daily activities and therefore are of great value in medical, financial and administrative sense. Lately, people employed in healthcare institutions understand the advantages and possibilities offered by these systems and therefore are interested in analysis of huge amount of data which follows everyday activities in order to get answers for many questions and efficient solutions. This fact, as well as the situation where healthcare funds are significantly supported by information systems is credited for wider use of medical information systems in the last decade.

Standard MIS functionalities

Generally, medical information systems, as one complete software solution, should realize support for (2):

- basic (medical) activity;
- related business processes (administrative and accountancy mainly);
- planning and management;
- improvement of market position for targeted medical institution;
- more efficient education, and
- scientific and research work.

Effects realized by implementation of properly designed, realized and exploited medical information system are multiple and some of them are:

- Increase of treatment efficiency by decreasing the average time of treatment, i.e. reducing the time of service provision by decreasing the time necessary for related administrative procedures (this efficiency is full when it is legally allowed that only electronic version of most documents exists, not parallel existence of paper documentation which is typical for transition regimes like currently in the Republic of Serbia);
- Higher level of resources usage (capacities, equipment, human resources) based on planning and appointments;
- Supporting both insurance and cost based billing systems for realized medical services;
- Efficient record keeping on provided medical services;
- Efficient control of supplies (medicaments and other medical supplies);
- Systematic and simple work planning;
- Increase of quality work for medical and non-medical staff;
- Efficient and wider implementation of the health care programme;
- Current information on the situation related to work processes;
- Creation of basis for quality education of all medical workers, as well as healthcare service beneficiaries;
- More qualitative and wider elements for scientific and research work.

Integration and collaboration of MIS

Looking through the wider perspective, in the field of healthcare, there are different healthcare institutions, insurance funds, as well as pharmaceutical companies and producers of medical devices. All these participants have the need to exchange data in order to provide patient with best possible care in the critical moment. Having in mind this and significantly increased population mobility, it can be concluded that medical information systems of closed type (isolated from other systems, with no data synchronization features) lose their significance since they are not able to provide information exchange with other similar systems. The existence of independent information systems within certain healthcare institutions or just within some of institutions does not meet the growing needs for information exchange. Therefore, two processes are rising up as an imperative: process of integration and process of collaboration (9). These processes are not simple, especially when single MIS are heterogeneous. In order to have integration, i.e. collaboration it is necessary that all MIS meet certain standards (for example MKB10 (11), openEHR, HL7 (12), DICOM, etc.).

Ways to achieve integration and collaboration of information systems in medical institutions will surely for a longer period remain an open problem, due to the constant advancement in the field of information technologies and complex and non-unique structure and organization of medical institutions. Within one country, this big step is not possible without strong support of ministries and institutions, especially considering standards for information exchange between the systems of one healthcare level, or between the levels. On wider international level this is even harder since the efficient exchange between large number of countries means that all of them support the same standards, and nowadays, unfortunately, this is not the case.

This paper demonstrates the basic elements of medical information systems through the system MEDIS.NET (developed within the Laboratory for Medical Informatics of the Faculty of Electronic Engineering in Niš) which is based on electronic health record and related with the patients' personal health record in digital form. Realized health record follows some of the previously mentioned standards, mainly openEHR for internal system organization and HL7 for data exchange. HL7 is related to the context of integration and collaboration of the information systems in healthcare institutions, since all healthcare institutions in the country represent the parts of the system, where more or less cooperation between certain medical institutions is inevitable.

Reporting and analysis in MIS as basis for the research

After certain period of functioning and use in real-time environment medical information systems gather huge amount of data in their databases. Speaking of huge amount of data, in the sense of information technologies, it is related to the number of records within objects of MIS database, and it means there could be few dozen-hundred thousand, or million composites, depending on size of the healthcare institution. From the medical point of view, it means that the number of patients' visits to doctor, i.e. number of prescribed medicaments, spent medical supplies and similar, is few hundred thousand (or few million) during one year.

As an illustration, Table 1 is given, which shows the number of patients' visits to doctor during one year, only for the Department of General Practice in the Health Care Center in Niš (3). The Health Care Center Niš is the central ambulatory outpatient institution for the City of Niš (approx. 250000 inhabitants), and also institution where people from the region of South Serbia come for specific examinations (in total around 1.3 million people).

The table shows that number of visits to doctor during one year is almost one million, and just for the Department of General Practice which is in charge for primary health care of the adult population. Usually, during first visit to a doctor patient gets certain therapy or medical referral, as well as diagnosis or recommendation from the specialist doctor. Therefore, on every input about visits in database come few more composites considering provided healthcare services, receipts, referrals, spent medical supplies, diagnoses or even results related to the laboratory diagnostics.

All of this, together with other services could be ten or more million records in one year related to the electronic patient record in database. Beside the report demanded by the Serbian National Health Insurance Fund, one question is asked: in which way this amount of data could be used, and in the interest of patients, medical staff, management of the healthcare institutions, and at the end (which is the topic of this paper), in the favor of education and research in the various branches of medicine?

All participants that figure in one information system, no matter if it is business, financial or medical, from the IT point of view, are entities linked with certain actions presented as interactions with other entities, i.e. relations in electronic databases. More concrete, in medical information systems, these are medical service providers, organizational units (departments) which provide medical services, medicaments, medical supplies, and many others.

Reports on medical data have the goal to present certain units (such as numbers, prices, some dates, etc.) through entities and their mutual relations in a way that is clear to the end-users of MIS, and grouped in some logical total. To make it more clear: Table 1 in this chapter presents the report which gives number (amount) of visits (entity) during one year (grouped by year), by the type of visit (entity) by the doctor (entity), and for the department of general practice (entity). Relations between hereby used entities would be doctor-department (doctor is employed at the department), visit-year (patients' visit to doctor happened in year), visit-type of visit (home visit, office visit). In other words, all of these entities and links could be called the parameters of one report.

First type of report within MIS is related to the reports that are necessary for everyday functioning of the healthcare institutions (4). There is a strong need for periodical reports (such as one regulated by the Republican Institute for Health Insurance) both in primary and secondary healthcare in our country. Some of these reports (5) are the following:

- Monthly reports of chosen doctors on the level of healthcare institutions and departments;
- Monthly reports on provided healthcare services;
- Regular examinations of school children in the public healthcare;
- Provided emergency services, and many other.

Modern MIS implies the existence of this type of reporting. Main characteristic of classic reports is that their parameters are defined in advance, i.e. assigned through MIS by the final user. Also their appearance is predefined and the final user cannot affect it through MIS functionalities. One such report, taken from Medis. NET MIS is presented in the Figure 1. It presents provided healthcare services for the period of time assigned by the Medis.NET users, by departments and doctor employed in named department.

Users of statistical reports in healthcare are mainly professionals and managers from departments where many different types of medical examinations are supported – such are cardiology, neurology and other specialist and sub-specialist departments. Also, users of these reports could be medical institution management staff members as well as patients themselves.

One of the examples of common benefits for both sides, both medical professionals and patients, in the Health Care Center Niš is using reports showing scheduling of appointments of selected doctor from the system Medis.NET. Reports on scheduled appointments by department, doctor and patient are used by medical nurses in order to prepare patients charts for the appointments they have for that day, i.e. in order for patients to have insight of their own appointments. These reports could be used for education of medical staff in healthcare institutions in the country, in order to improve work efficiency for some departments and staff employed in these departments. In order to use these reports, it is not necessary for users to be additionally educated for informatics, but only to pass the training for work with MIS. Therefore, this fact makes this kind of report useful in wider healthcare circles.

Table 1. Abstract from the Table 19.7. Department of General Practice - the City of Niš Statistical Yearbook for 2007

Year	Visits to doctors' office		Total visits	No. of visits by one doctor per year	Home visits
	First visit	Another visit			
1998	220 551	385 475	606 026	7 390	17 715
1999	214 549	392 159	606 708	7 399	17 987
2000	261 378	465 199	726 577	8 146	18 429
2001	278 694	507 511	786 205	8 276	19 613
2002	288 092	454 697	742 789	7 902	19 811
2003	262 603	513 943	776 546	8 261	20 268
2004	287 352	486 403	773 755	7 661	12 138
2005	275 923	532 314	808 237	8 164	5 069
2006	268 735	536 795	805 530	7 897	7 662
2007	227 938	515 049	742 987	6 694	17 915

Figure 1. Statistical report from Medis.NET MIS which presents provided healthcare services by departments and service provider

Other type of reports which could be extracted from the huge amount of data can be defined as generic reports. These reports are acquired by software tools which are designed in such way that users have the possibility of interactive query over data, and where parameters and the report overview are not predefined, or just partially predefined. These reports could have special application in scientific research.

These reports could be of great value for doctors when they want to follow the status of patient or group of patients in certain period of time, or when they want to detect the links between the patients' conditions and some figuring parameters related to the patient and treatment. Generic reports could be used for education of medical staff for the same reasons as statistical ones. For the purposes of science research they could be used in order to prove or disprove established hypothesis. Using the example of the module designed within the Laboratory for Medical Informatics at the Faculty of Electronic Engineering in Niš, we will show how this type of report can be of great use in medicine (6).

Module for automatic report generating (Report Generator or REPORTER) MIS Medis. NET offers possibility for doctors to define themselves what type of data they want to see in the report. Figure 2 shows one profile of this module named "Cardiology anamnesis". Items within the named profile are organized in several levels, and as seen in figure on the left side (titles on Serbian) - present groups of first level. Their sub-nodes present groups which directly depend on them.

When user chooses one node on the left side, the list of accessory items is shown in the sub window on the right side. On the right side at the bottom of the profile there is a component for posting dynamic queries, which present the basis for this type of reports. Figure 3 presents one query generated by the doctor. User, by choosing above mentioned items, with previous basic knowledge of logical operations (AND, OR, NOT) and few necessary mathematical functions, could define query for report which results could be enclosed as statistical calculations, and for the purpose of proving or disproving various hypothesis in medicine.

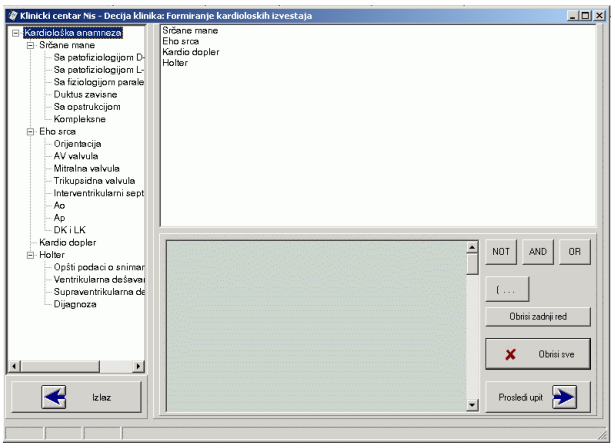

Figure 1. Software application for generating specialized reports

Figure 2. Generic query for reports from medical data for the purpose of research

Business Intelligence (worldwide accepted abbreviation is BI) is more and more used in developed countries in all fields of businesses, as well as in science. Among other things, this term comprehends the use of OLAP (Online Analytical Processing) analytics over data. When there is a huge amount of data, like for example in state healthcare system, no other way of reporting and analytics over data is more efficient as OLAP. OLAP implies the integration of huge amount of data that could derive from few information systems, e.g. from primary and secondary healthcare system at the same time, then their refinement and generating of schemes that are practical for quick and exact analytics.

If we want for example to observe the frequency of various diagnoses in relation with few parameters at the same time (e.g. patients' gender, origin, age, marital status, various risk factors such as smoking, alcohol, hypertension, etc.) classic way of generating these reports would take minutes, even hours for one MIS, and therefore for its users.

OLAP systems enable easy and quick moving through this kind of analytics, and report generating last 1000 or few dozen thousand times faster that statistical reports, as already proofed by our research over concrete medical data collected at the Clinic for Neurology of the Clinical Center in Niš in time period from 1997 to 2008 (7).

Special conveniences in design and development of these systems are offered by software tools which are more and more developing at the market, and are used for integration and transformation of data acquired from heterogeneous sources (for example from primary healthcare and department for statistical data processing at the same time) and for design and implementation of so called cubes (multi-dimensional data sources) (SQL Server Business Intelligence Development Studio, Fast Cubes, Pentaho BI, etc.). Beside tools for OLAP system design, there are many available tools for analytics of these systems. Some of these tools are very well known for wider circle of users in medicine, such as MS Office Excel, but unfortunately small number of users are familiar with the fact that MS Office Excel (through so called pivot tables) could be used for very fast analytics over cubes with possibility of automatic generating of various graphs (Figure. 5).

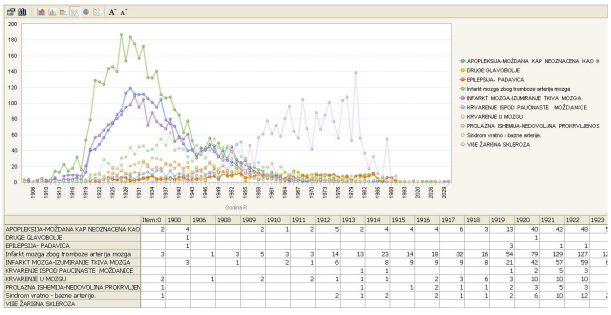

Figure 3. Example of generated report

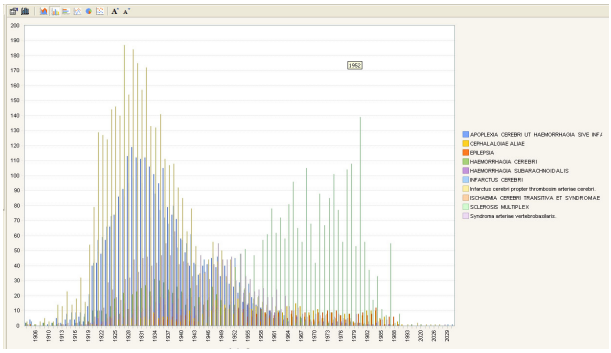

Figure 5. Chart shown in Figure 4

If we cross huge amount of data e.g. from the Department for statistic data processing (for example number of inhabitants on the territory of Southern Serbia, their gender and age) with huge amount of data deriving from electronic patient records, we could get very important medical reports, which implies the existence of certain cause of illness or similar. Such an example is presented in Figure 4, where graph acquired by OLAP analytics shows the number of admissions for hospital treatment during the time period from 1997 to 2008 for the Clinic of Neurology of the Clinical Center in Niš, and in relation with the year of patients' birth, and only for "frequent diagnoses". Here the frequent diagnoses are the ones which occur on every 400 or more admissions for the above mentioned period of time. Graph shows some expected results, for example, the number of elderly patients is the highest related to other patients, but also some unexpected results - e.g. considering patients suffering from multiple sclerosis, the number of patients born in 1981 is much higher than the number of patients of similar age. This kind of analytics presents an excellent basis for medical research and quick postulating of hypothesis in science.

MIS and education

Medical information systems could also play a significant role in education of students at all level of studies, from bachelor, through master and specialized and sub specialized to PhD studies. What is the origin of such claim?

If we observe the traditional way of education in medicine, it was performed on the basis of printed materials and exercises with patients in predetermined time. Very often in practice, students do not see most of the diagnoses, pathologies and medical conditions they have studied, due to the fact that some of them are rare or just were not present in the hospital at the time of practice. How in this case could MIS improve education?

Gathering of all types of data (numerical, textual, graphic, audio, and video) about patients with rare or very rare diseases can be done every time the hospital admits such patient. Gathered heterogeneous data could be placed in specialized repositories or even in classic MIS from which they

could be extracted by different criteria and examined during education.

In such way we come to the term "virtual patients' room" or term "virtual patient" (15). The only thing that distinguishes "virtual" from real patient is the fact that student cannot apply diagnostic methods where it is necessary to physically touch patient, but could see all other aspects of treatment. Also, on the basis of change in clinical feature it is possible to realize the efficiency of certain treatment methods in relevant circumstances. Additional advantage offered by the concept of virtual patient is the possibility to compare different variations, i.e. appearances of the same illness in the moment and to have overview of all virtual patients that exist in database, which is impossible with real patients. In reality, we only have few active patients in rooms, but virtual ones we have as much as we need. Average hospital department in the Clinical Center in Niš have ten rooms with not more than 50 beds.

By creating the base of virtual patients with their histories of diseases in digital form a good foundation is made for creation of specialized software for education, the so called "tutorial" system. This system, depending on the level of complexity and expert knowledge implemented, could offer various possibilities for students, even to the level of "virtual treatment" where student on the basis of knowledge and symptoms patient has (and created by software) would be able to give therapy and follow the patients' response to the therapy and in several iterations, i.e. treatment episodes.

If MIS has the possibility of telemedicine, i.e. teleconsultations, then the possibility for good quality education of students is not limited only per one clinic, but possibility to reach physically dislocated clinics. It is possible to have live broadcast of certain surgical intervention for several dislocated places at the same time.

Important form of the so-called education during work, i.e. passive education could be performed if MIS is realized in a way that user has the possibility to have overview of several different sources of knowledge. Such an example is various code books. For example MKB10 has adequate codes and names. If MIS provides selection of disease then during certain period person goes through passive learning. Figure 6 presents form within MEDIS.NET for selection of diagnosis. Similar situation is with selection of medicaments, forms, doses, etc. Figure 7 presents form within MEDIS.NET where medicaments are enlisted.

Particular segment of functionalities are the so-called alarms; for example - warning on possible negative interactions between medicaments. This possibility has effect not only for learning process, but also for neutralizing the possible mistakes. Generally speaking, it is possible to realize certain segments of MIS in a way that they "lead" doctor during the examination of patient offering examinations that should be done, meaning parameters which should be examined or fields that should be filled out.

In such way, the doctor is "led", meaning standard processes and procedures are prepared in advance, which at last has significant effect on the learning process. MIS only should avoid "suggestions" except in specialized modules appointed for that purpose, i.e. in decision support systems. These systems are realized for many diseases and have excellent results (11, 12). Besides decision support, i.e. defining a diagnosis, these systems have indirect effect on learning process of doctors during everyday practice. Systems which present basis of "good practice" are well known worldwide and they are very useful not only for treatment but also for education of doctors.

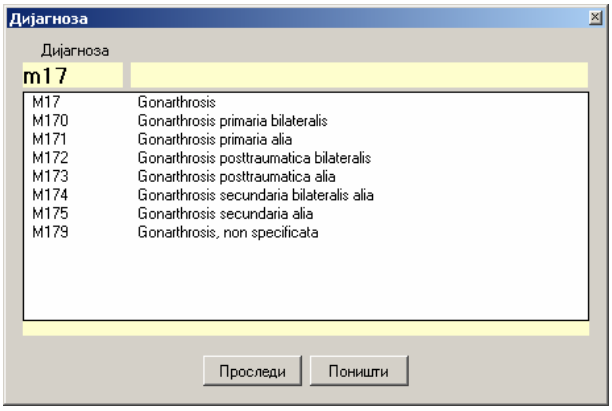

Figure 6. Example of control for selection by code and name - selection of diagnosis

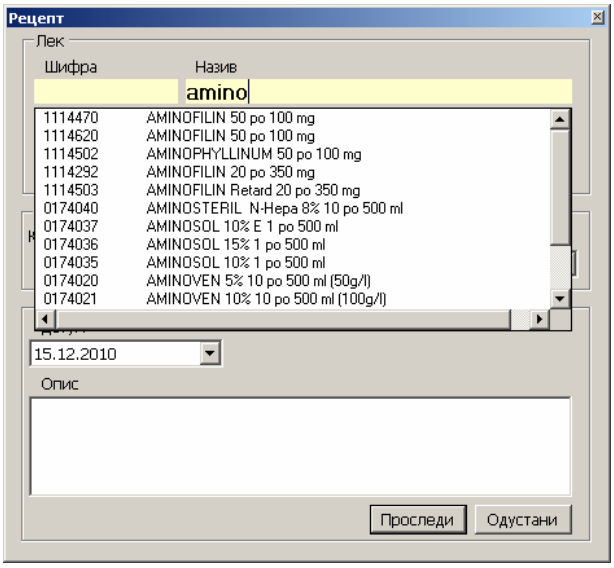

Figure 7. - Example of form with control for selection of medicament - form for receipt creation

MIS and research

Significant number of medical research is leaning on processing and analysis of huge amount of medical data gathered during provision of medical services for patients, meaning during

treatment process. If MIS are implemented within healthcare institutions, then data collection, selection and extracting is much more efficient compared to classic way of data collection from paper-based version of history of diseases.

On the other hand, automatized way of data collection significantly improves their accuracy, since the process of selection and access to data is performed in enormously short period of time, and does not require from researcher hours and hours of work in some disease history card archive with possibility of wrong interpretation of data due to tiredness or unreadable handwriting.

In order to have MIS that could be used by researches, beside standard and configurable reports MIS should also provide simple data search by all fields with different criteria according to the needs of researcher. MEDIS.NET offers possibility of information selection based on criteria that could be presented by the exponent gained by the combination of operators NOT, AND and OR and brackets as well as adequate values of considered fields (Figure 3). For example - extraction of all patients older than 40 years who are male and married, with blood pressure over 160. MEDIS.NET has implemented tool for this purposes called REPORTER (6) mentioned in the chapter 3 of this paper.

MIS has very important possibility and that is simultaneous work of several researchers with the same data, which is completely impossible for working with papers since only one disease history could be physically in hands of one researcher.

Important fact is that researchers are not limited to work only within healthcare institutions, they also have remote approach to data (e.g. from home) if MIS is realized in such a way that enables data exchange with other similar system (8).

In order to have efficient and quality data analysis, their comparison and quick posting of hypothesis, it is necessary to have several tools existing as part of MIS or as independent tools that will use data located in the base of MIS and which will allow efficient work with data. These possibilities are offered by BI (Business Intelligence) tools as well as various tools of artificial intelligence (different types of classificatory, predictors, etc.) and where many different methods are used (statistical methods, decision trees, SVM (support vector machine), HMM (hidden Markov model), neural networks, etc.) (13,14). During the researches which comprehend data analysis from various fields of medicine there is a need for data from few different healthcare institutions. With adequate realization and system users with different privileges, MIS could offer to researcher an efficient approach and data analysis from MIS within different healthcare institutions (e.g. clinics within one Clinical Center).

In order to conduct complex research and discuss all relevant data it is necessary to provide common databases which will not be limited only on data collected from one healthcare institution. These bases present repositories which in some cases could be of great value such as central repository for rare diseases (10).

If all the abovementioned things are provided, one logical consequence would be a higher productivity of researchers measured by the fact how quick they come to the scientific results as well as the creation and publishing of scientific and expert papers.

Conclusion

Beside everyday use in healthcare service provision, MIS have significant use in the process of education for students, medical staff and patients as well as for the purposes of research work. In order for MIS to fulfill all these functions it is important to be designed and realized in a special way with set of functionalities which enable that. This paper discusses some of the aspects of MIS application for the purposes of education of medical students at all levels as well as an application of MIS in scientific and research work. Therefore, this paper should help MIS designers to have more comprehensive approach during designing and implementation of MIS, meaning to address medical staff and students to some possibilities and potentials which bring along well designed, realized and used MIS.

This paper describes all necessary requests through functionalities implemented within MIS, which is developed in the Laboratory for Medical Informatics at the Faculty of Electronic Engineering in Niš, named MEDIS. NET.

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PRIMENA MEDICINSKIH INFORMACIONIH SISTEMA U EDUKACIJI I ISTRAŽIVANJIMA U MEDICINI

Dragan Janković, Petar Rajković, Tatjana Stanković, Aleksandar Milenković i Ivana Kocić

Ovaj rad razmatra medicinske informacione sisteme sa aspekta njihove primenljivosti u edukaciji i istraživanjima u medicini. Razmatrani su mogući slučajevi upotrebe i potencijal medicinskih informacionih sistema u kontekstu edukacije medicinskog osoblja. Rad takođe donosi i osvrt na mnoge značajne prednosti koje medicinski informacioni sistemi mogu doneti naučno-istraživačkom radu. Dat je pregled najvažnijih funkcionalnosti koje su bitne za edukaciju i istraživanja. Diskutovane su funkcionalnosti koje bi trebalo da budu realizovane u jednom savremenom medicinskom informacionom sistemu kako bi on mogao da se efikasno primenjuje u edukaciji i istraživanjima. Pojedine razmatrane funkcionalnosti ilustrovane su na primeru medicinskog informacionog sistema MEDIS.NET, razvijenog u Laboratoriji za medicinsku informatiku Elektronskog fakulteta u Nišu. *Acta Medica Medianae 2012; 51(1):73-80.*

***Ključne reči**: medicinski informacioni sistemi, istraživanje, edukacija*