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Potential of use of modern information technology solutions in the work of hospital infection control team, including antibiotic therapy optimisation, reduction of alert pathogen infections and vaccination popularisation

ROBERT SUSŁO[1, A, B, D–F], MATEUSZ PAPLICKI[2, B, D–F], JAROSŁAW DROBNIK[3, B, D],
ORCID ID: 0000-0002-2680-7617 ORCID ID: 0000-0002-4169-9298 ORCID ID: 0000-0001-5472-1485
JACEK KLAKOČAR[4, B, D], JAN GODZIŃSKI[2, A, D, G]
ORCID ID: 0000-0003-3906-459X ORCID ID: 0000-0001-9687-7146

[1] Epidemiology and Medical Education Unit, Population Health Department, Health Sciences Faculty, Wroclaw Medical University, Wroclaw, Poland
[2] Developmental Age Traumatology and Emergency Medicine Unit, General Medicine Faculty, Wroclaw Medical University, Wroclaw, Poland
[3] Family Medicine Unit, Family Medicine Department, General Medicine Faculty, Wroclaw Medical University, Wroclaw, Poland
[4] Lower Silesian Voivodship Sanitary and Epidemiological Station, Wroclaw, Poland

A – Study Design, **B** – Data Collection, **C** – Statistical Analysis, **D** – Data Interpretation, **E** – Manuscript Preparation, **F** – Literature Search, **G** – Funds Collection

Summary **Background.** Classic hospital information technology (IT) systems are being upgraded to new functional levels due to the rapid evolution and introduction into everyday operation emerging solutions based on machine learning (ML), artificial intelligence (AI), augmented reality (AR) and large language models (LLM), including the famous ChatGPT.
Objectives. The objective of the study was identification of potential practical applications of emerging IT solutions to various aspects of identified routine activities of ICTs, including hospital hygiene improvement, antibiotic stewardship adherence and vaccination enforcement and popularisation.
Material and methods. Related merit and legally defined duties of infection control teams (ICTs) at Polish hospitals were examined and compared against the capabilities of emerging IT solutions.
Results. It presents as inevitable that personal universal AI-based virtual assistant of medical staff, melting together modern broadband wireless connection to expanding IT infrastructure and its new emerging solutions, including ML, LLM and already relatively inexpensive AR tools, will revolutionise the everyday practice of hospital epidemiology.
Conclusions. It is foreseeable that in the near future, all hospital IT tools will present a single coherent solution oriented on the common goal of achieving maximal patient health and staff safety, providing holistic, individualised, continuous and omnipresent support to Hospital Infection Control Teams, every other member of the hospital staff, all hospitalised patients, as well as their accompanying persons.
Key words: medical informatics, artificial intelligence, machine learning, augmented reality, infection control, medical law.

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Background

Traditional information storing and processing relies on input and interpretation performed manually by trained medical staff, which is time-consuming, often rich in mechanical errors and can, to a significant degree, be subjective [1]. In contrast to that, information technology (IT) promises development of automated data input and tracing [2] along with more reliable and predictable processing tools [1], making it possible for medical professionals to make decisions [3]. Modern medicine relies not only on proper implementation of the already available knowledge and established best standards but also on the everlasting demand for innovation required for their advancement, aiming at improvement of the patients' quality of life and their medical safety [4]. The personalised care model expected by patients nowadays is possible to introduce into medical practice only based on implementation of wide IT solutions, allowing the medical staff to keep up with the fast-paced flow of information and innovation [5].

Medical informatics can serve the improvement of information management, facilitation of communication and deployment of new solutions in both clinical practice and research activities [6]. Managing information systems in medical settings needs to encompass recording, storing, altering, utilising, securing and making available [7] information resulting both directly from working with the patient, in case of clinical information

systems (CIS), and from routine running of a medical facility, in case of resources allocation, technical maintenance and financial systems [8]. Conventional medical expert systems are computer algorithms operating on the basis of rigid sets of rules derived from existing, already well-established, general medical knowledge on the topic in question that are then utilised to suggest conclusions based on data input on a given concrete clinical case [9]. There are growing tendencies to use information technology-based networked solutions for remote keeping of medical records [10], diagnostics, monitoring and facilitation of communication [11], but their introduction is slowed because of low levels of digital literacy, especially in older age groups, not only in the case of patients but also medical staff [12]. Nevertheless, the spreading use of electronic health records (EHR) facilitates data processing algorithm applications as a source of a large quantity of high quality medical content that presents as highly valuable big data set for machine learning [13]. Due to novel algorithms and their innovative applications, growing storage capacity and low cost rising available computational power, machine learning identifies new rules that predict highly reliable outcomes based on analysis of millions of complex, not uniform, unstructured – or "raw" – and seemingly not causally connected observation data, which in medicine translates into improved monitoring, prognostic and diagnostic accuracy [9]. Artificial neural networks (ANN) [14] are built so that the algorithms sifting through large training datasets are first able to recognise patterns and correlations then correct them, and next build upon the output of the first successful round next layer of identified patterns and correlations, producing, in the end, a self-evolving multi-layered model [9] that provides highly accurate predictions for concrete clinical case problems of high complexity [15].

Machine learning (ML) has already proven its usefulness in medicine, mainly in medical image-based diagnostics, including radiology imaging, like X-ray [13] or computed tomography (CT) [1], magnetic resonance imaging (MRI) [16] and interpretation of visual images of skin pathologies [17]. New fields of medical applications of these technologies are invented, from expedited and deepened education of medical staff [5], automated pooling data from multiple scientific studies for elevated-level analyses [18], optimisation of drugs and medical equipment supply chain and logistics [19], designing and coordinating take-back programmes for unused medications [20] to making drug supply chains counterfeit-proof [21]. By lowering the threshold of entry cost into research, that now can utilise the already existing large datasets for analyses by multiple research projects, machine learning also provides new hopes to people suffering from numerous diseases that, even if put together, affect a small part of the general population (ailments affecting 1 per 2,000 people constitute rare diseases according to the definition adopted by the European Union) [22] or diseases affecting mainly the populations of poor countries, which have been thus far orphaned by the mainstream of the medical scientific community and industry as economically unattractive [23]. For over a decade now, artificial neural networks are being prepared to replace [24], or at least support, medical staff in the clinical diagnostic process [25], in fields ranging from microscopic cytology [26] and intestinal capsule image analysis [27] to coronary heart disease [28]. Infectious diseases and epidemiology applications include tuberculosis diagnosis [29] and prompt recognition of infections in closely monitored patients [30].

Artificial Intelligence (AI) technologies, defined as a "branch of computer science that simulates intelligent behaviour in computers" [31] present the biggest innovation of the 21st century, and as such, they challenge the established standards, verified solutions and well-known societal patterns, which in the field of modern medicine, translates into making many of the existing approaches and technologies obsolete and forces medical staff to adapt new habits and unlearn old ones, as well as demands from managerial staff to allocate substantial expenses on new hardware, software and staff training [4]. The rapid development of AI is enabled thanks to transfer learning, which is a machine learning technique that allows one to build upon the basis of an already existing pre-trained model that has already learned basic aim-relevant features from a large dataset different from the target dataset it was planned to actually operate on and which can then be fine-tuned on a much smaller specialised dataset for a chosen specific task [13]. At the current stage of AI application development, human supervision is still needed, but the door for their use has already been opened; thus, it is crucial to foresee the real benefits of this emerging technology in health activities. However, the major obstacle is medical professionals' scepticism or lack of knowledge and readiness to adopt the use of AI-based technologies in their practice [32].

The AI-based solutions often adapt the shape of agent-based systems (ABS) designed to interact with users and autonomously solve well-defined problems of different levels of complexity, which can be linked to communicate and cooperate in the form of multi-agent systems (MAS) in order to be able to address more diverse challenges [33]. Dynamically developing conversational large language models (LLM), similar to the well-known ChatGPT, bring the potential benefits to everyday health promotion, medical education, research and practice, including: faster scientific and science popularising writing that can be individually addressing at a time people belonging to wider and more varied audiences; individual and problem-oriented approach to medicine learning; improvements in healthcare research with rapid theoretical and experimental data collection, aggregation, analysis and presentation, leaving scientific staff more time for creative activities; better organised, less bureaucratic and cheaper in operation patient-oriented health care demanding a low entry-level of health literacy and computer literacy and, at the same time, promoting their elevation in ways easily adapted by patients and medical staff [34]. AI-based solutions optimise capturing data on health and disease states, enhance the flow and analysis of clinical information and open the opportunity for the introduction of a personalised approach to patients in medicine at a low cost and despite increasing year to year medical staff shortages [35].

Augmented Reality (AR) is defined as "physical reality in which participants also see virtual elements (...) allowing for the creation of links, direct or triggered by user interaction with the device, between the real world and the information generated by a device or electronic information" and can be working independently (using own positioning data for orientation and anchoring in space) or in connection with markers (using beacons or bar codes), projections (using light beam-based interactions) or overlaps (replacing chosen real-world objects) [36]. Commercially available AR equipment, based on head-mounted displays like Google Glass and Microsoft HoloLens, was first introduced in industry but also in medical imaging and the branches of medicine intertwined and overlapping with it, including interventional radiology [37]. Although the comparably high cost and early advancement stage of technology development, resulting in short battery life, limited storage capacity and fast visual strain in operators, prevented the wide popularisation of AR in medicine thus far, it has already revealed considerable potential, especially in surgical specialties, motor function rehabilitation, telemedicine and skill training of medical staff [38].

Hospital infection control faces new challenges that place considerable strain on the provision of already scarce health services, including rapid migrant influxes resulting from a wide variety of recently emerging crises that demand relevant, proportionate and targeted actions and thus novel preparedness approaches for prevention and management of possible massive communicable disease outbreaks, precipitated by pathogens both well-known and untypical for a given location [39].

The computerisation of various areas of hospital operation has progressed at various paces over the last few decades, and it is currently gaining additional momentum due to the ap-

proaching, though postponed in Poland several times in the past, statutory deadline for introducing the obligation to keep all medical records solely in electronic form [40]. The forced migration of medical document circulation to an exclusively digital form gives Polish hospitals an unprecedented opportunity to introduce advanced IT solutions that can be used not only to conduct and control ongoing diagnostics and therapy of individual patients, as well as a basis for settlements with payers of medical services, but also for the broadly understood needs of epidemiological supervision [41].

There are numerous challenges any modern hospital currently needs to meet in terms of epidemiology. One of the biggest is limiting the number of hospital infections, especially those caused by antibiotic-resistant microorganisms. The tasks of an epidemiology specialist working in an inpatient healthcare facility and an epidemiological nurse in Poland are mainly related to the issues of nosocomial infections, occurrence of alert pathogens and participation in the processes of optimising the way health services are provided, with particular emphasis on the rationalisation of antibiotic therapy. This is due to a number of applicable legal regulations [41].

Material and methods

In order to evaluate the potential impact of emerging Information Technologies (IT), including machine learning (ML), artificial intelligence (AI) and augmented reality-based (AR) solutions, on the work of infection control teams, including antibiotic therapy optimisation, reduction of alert pathogen infections and vaccination popularisation, the legal regulations currently in force in Poland were analysed to identify the scope of the tasks of the Hospital Infection Control Team and then compared against the literature review-founded concepts of known and predicted medical implementations of emerging IT tools.

The study received a positive opinion from the Wrocław Medical University Ethics Committee (KB-525/2022).

Results

Infection control teams (ICT) are created to support and monitor the implementation of infection control guidelines in healthcare facilities [42]. In Poland, their work and cooperation with other entities is regulated not only by professional standards but also by numerous intertwined and often amended or replaced legal regulations, which include in particular: the Act on preventing and combating infections and infectious diseases in humans [43], the Regulation of the Minister of Health on the qualifications of members of the hospital infection control team [44], the Regulation of the Minister of Health on the scope, method and frequency of internal control in the area of implementation of activities preventing the spread of infections and infectious diseases [45], the Regulation of the Minister of Health on the method of documenting the implementation of activities preventing the spread of infections and infectious diseases and the conditions and period of storage of this documentation [46], the Regulation of the Minister of Health on the list of alarm factors, registers of nosocomial infections and alarm factors, as well as reports on the current epidemiological situation of a hospital [47], the Regulation of the Minister of Health on the method of keeping the register of infectious diseases and the period of storage of data contained in this register [48], the Regulation of the Minister of Health on infectious diseases resulting in the obligation of hospitalisation, isolation at home, quarantine or epidemiological supervision [49], the Regulation of the Minister of Health on reporting suspected and diagnosed infections, infectious diseases and deaths due to them [50], the Regulation of the Minister of Health on reporting the results of tests for biological pathogens in humans [51].

According to Polish law, a special place is reserved in the structure of the hospital for the Hospital Infection Control Team operating under the supervision of a specialist in the field of epidemiology [44]. Its tasks include: consulting cases of people suspected of infection or infectious disease and those diagnosed with infection or infectious disease, as well as documenting the actions taken; staff training in hospital infection control; developing and updating a system for preventing and combating nosocomial infections; conducting internal control of actions taken to prevent the spread of infections and infectious diseases; periodically presenting the results and conclusions of this internal audit to the head of the hospital and the Committee of Nosocomial Infections Control. The Committee evaluates the internal control results presented by the Hospital Infection Control Team and is responsible for: developing plans and directions for the system of preventing and combating nosocomial infections and developing and updating standards for pharmacoprophylaxis and pharmacotherapy of infections and infectious diseases in the hospital [43].

The hospital IT system should support the effective performance of tasks by the Hospital Infection Control Team and ensure safety of resulting documentation [46]. In particular, development and updating of the system for preventing and combating nosocomial infections requires the hospital IT system to ensure effective communication between various units within the hospital and, in particular, prompt delivery of updated relevant algorithms and procedures to all employees included in them [41].

Internal control of activities undertaken in the hospital to prevent the spread of infections and infectious diseases includes: assessing the risk of infection related to the provision of health services; monitoring alert pathogens and infections related to the provision of health services in the scope of services provided; developing, implementing and supervising procedures to prevent infections and infectious diseases related to the provision of health services; the use of individual and collective protection measures to prevent the transmission of biological pathogens to others; performing laboratory tests and analyses of the local epidemiological situation in order to optimise perioperative antibiotic prophylaxis (PAP) and antibiotic therapy [45].

The hospital IT system should facilitate the routine assessment of the risk of infection associated with the provision of health services. Conducting an ongoing assessment of the risk of infection when patients are admitted to the hospital may be facilitated by collecting and pre-documenting the epidemiological interview in the form of electronic questionnaires to be completed by patients on their own, supplemented by sets of templates and checklists available for medical staff, taking into account key issues. The hospital IT system can – by generating current and periodic summaries – facilitate the assessment of the adequacy of ordering screening tests in risk groups, monitoring the use of invasive procedures and the use of antibiotics in hospital units. Support of the IT system is also necessary for planning and verification of performance and evaluation of the results of periodic assessments of cleanliness of rooms, equipment and touchable surfaces [41].

Monitoring of alert pathogens and infections related to the provision of health services in the scope of services provided [47] should be supported by a hospital IT system – facilitating the processes of registration of nosocomial infections by physicians managing patients and registration of alert pathogens based on the results of microbiological tests enriched with an in-depth interview from the patient [48]. The data obtained by the personnel should, to a large extent, be entered in a structured form, enabling computer processing of the collected data in order to automatically generate basic reports presenting the current epidemiological situation. Ongoing analysis of the results of microbiological tests for the presence of alert pathogens in the materials collected for these tests, both in patients with nosocomial

infections and carriers, should also take into account the use of the hospital IT system for quick transmission of test results. Complex activities enabling the preparation of microbiological maps of hospital units can be planned, coordinated and analysed in practice only by means of an IT system [41].

Reporting is one of the basic and routine duties of a physician specialist in the field of epidemiology – these include periodic reports on the occurrence of nosocomial infections and alert pathogens in the hospital, as well as reports applicable in the event of a suspected or occurrence of an epidemic outbreak, as well as on preventing a possible outbreak [47]. Physicians are obliged to report infectious diseases demanding hospitalisation, isolation, quarantine or epidemiologic supervision [49], as well as certain cases of suspected and diagnosed infections, infectious diseases and deaths due to them [50], and laboratories have a similar obligation regarding the results of tests for biological pathogens in humans [51], of which the infection control team is informed. The hospital IT system should support the efficient collection and aggregation of data necessary to prepare these reports, because, in their case, there are time frames, especially narrow for the initial report on the suspicion or occurrence of an epidemic outbreak, for which there is only 1 day left to prepare [41].

Developing, implementing and supervising procedures to prevent infections and infectious diseases related to the provision of health services requires coordination of activities between various units within the hospital involved in tasks in the field of skin and mucous membranes or other tissue decontamination, medical devices and their equipment, as well as area of rooms and devices. This requires the development, implementation, monitoring of compliance in practice and periodic updating of numerous infection reduction procedures and training of hospital staff. The hospital IT system should enable the staff involved in the update process to have free access to sources of legal information and repositories of scientific publications and national and international guidelines, as well as internal reports on the epidemiological situation of the hospital, and should then work together on shared documents [41].

Procedures for washing and disinfecting hands and the use of personal and collective protective equipment to prevent the transmission of biological pathogens to other people should be promoted, among others by means of initial training and periodic refresher training using e-learning, and in practice monitored both directly and by means of indirect indicators [52] that can be provided by the hospital IT system, such as the amount of cleaning and disinfecting agents and personal and collective protection equipment used by a given hospital unit with regard to the number of staff, patients and activities carried out requiring the use of hand hygiene and personal protective equipment [41]. In a similar way, the hospital IT system can support the functioning of procedures relating to the decontamination [53] of hospital rooms and utility equipment, as well as the handling of hospital linen and waste [54], in accordance with current legal regulations [55]. Education of hospital staff on the principles of prevention and conduct in the event of occupational exposure to blood or other potentially infectious materials that may transmit infection with blood-borne viruses [56], as well as ongoing monitoring of the occurrence of these phenomena, should be supported by the hospital IT system – respectively in the form of cyclical training using e-learning and a system aggregating data on possible cases. Computer records of information on vaccinations of hospital staff should enable automatic generation of messages in the absence of vaccinations required or recommended at a given workplace [57]. The principles of isolation of patients who have been diagnosed with an infection, as well as those at an increased risk of infection, should use data already entered into the hospital IT system. This system should also support the process of identifying and suppressing epidemic outbreaks, including ongoing analysis of available medical data and automatically generating messages in the event of circumstances that may indicate the occurrence of such an outbreak, including the parallel occurrence of the same set of symptoms or obtaining an identical result of a microbiological test in a predetermined number of different patients within the hospital, or possibly an increase in the demand for certain groups of drugs, in particular antibiotics. The hospital IT system should provide the medical staff with the current criteria for the diagnosis of nosocomial infections, including the definition of their clinical forms, as well as data on how to deal with infections with multidrug-resistant strains of microorganisms. The hospital information system can also support the management of a patient's death due to an infectious disease by suggesting the appropriate course of action to the hospital staff, including restrictions on post-mortem examination or release of the body to the family for burial. The principles of proper conduct in the case of procedures with a high risk of hospital infection, such as inserting and maintaining catheters of blood vessels or urinary tracts, should be popularised in the form of e-learning training available as part of the hospital IT system, and the possible occurrence of complications of the implemented procedure should be recorded by this system and included in the form of automatically generated current and periodic reports. The hospital IT system also has an important role to play in preventing the growth of drug resistance of microorganisms by applying the principles of rational antibiotic therapy, e.g. enabling the aggregation of data on the diagnoses established by doctors, the fact of implementing antibiotic treatment, taking into account its type and intensity in individual patients and its consistency within groups of patients with the same diagnosis, as well as the performance or non-performance of microbiological tests and their possible results – and finally, a comparison of all listed circumstances with the relevant hospital guidelines [41].

Polish legal regulations recognise among the biggest public health threats [58] the emergence of antibiotic resistance in microorganisms and the urgent need to prevent this [59]. As part of preventing the growth of drug resistance of microorganisms in the hospital, it is important to optimise the principles of perioperative antibiotic prophylaxis (PAP) and the typically used antibiotic treatment [59]. This is achieved by analysing epidemiological data, with particular emphasis on the results of microbiological tests of materials collected from patients of various hospital units and sometimes also materials collected from the hospital environment or from hospital staff. The hospital IT system can significantly support the planning and coordination of the above activities, as well as the aggregation of the obtained data, their analysis and subsequent presentation in categories typically used in epidemiology: people, places and time. As part of this system, information should be provided to medical staff on the availability of antibiotics in accordance with the formulary, restrictions on the use of selected antibiotics and guidelines for antibiotic therapy in typical situations – as well as the possibility for staff to submit comments on an ongoing basis, which facilitates periodic updating of the hospital formulary and therapeutic guidelines [41].

Periodic presentation by the Hospital Infections Control Team of the results and conclusions from the internal control of measures taken to prevent the spread of infections and infectious diseases to the hospital manager and the Hospital Infections Committee [43] requires support from the hospital IT system, providing tools for obtaining the necessary data from the relevant employees in the least possible cumbersome way, taking into account the import of data previously entered into the system, tools for efficient aggregation of reported data, in particular those compiled routinely, as well as facilitating the export of data in a form that allows for their presentation [41].

In a modern hospital, staff training in the field of nosocomial infection control requires basing it to a large extent on the hospital IT system [60] – each member of the hospital staff should have continuous, unlimited and easy access to the current computer knowledge base on how to prevent nosocomial

infections, taking into account the hospital's current in the field of algorithms and procedures, as well as participate in a continuing education programme based on e-learning technology, ensuring participation in cyclical training courses providing up-to-date knowledge in this area [41].

Consultation of persons suspected of infection or infectious disease or those diagnosed with infection or infectious disease may be based on the results of tests available remotely [11] and can take place, particularly in large hospitals with a dispersed structure or between branches [61], especially in the initial phase, with the use of teleconferences or teleconsultations, supported by the hospital IT system, securely transmitted between medical data units, as it is already practiced by multiple medical specialties [62–64] – which is conducive to the speed of response to the occurring circumstances and changes in the epidemiological situation [41].

Effective documentation of the activities of the members of the Hospital Infection Control Team should be supported by a hospital IT system that meets the requirements necessary to keep medical records only in electronic form and support for the digitisation of incoming documents in a non-digital form, eliminating the need to work with paper documents [65]. The reliability of the data stored in the hospital IT system must meet the requirements relevant to the evidence material that can be used in the event of any court proceedings [66].

Infectious disease epidemics that not only spread among patients but also involve hospital personnel, as it was demonstrated during the COVID-19 pandemic as well as numerous flu seasons, pose a significant threat to the continuity of provision of health services due to medical staff shortages and present as a big challenge to the Hospital Infection Control Team struggling to limit them [67]. This results in the crucial need for efficient strategic partnership between the Hospital Infection Control Team and various other units at the hospital that undertake joint actions aimed at enforcing mandatory vaccinations [68] using legal regulations for the benefit of the community health, as well as promoting the recommended elective vaccinations, especially flu vaccinations, among the hospital staff [69]. The intertwined ubiquitous IT systems of the hospital [70] can become a powerful platform for communication of various intensity of persuasion, ranging from just providing objective information to pervasive pro-health and suggestive and emotion-oriented advertising [71].

Discussion

The computerisation of various areas of hospital operation has been progressing in almost all countries of the world [72] at a different pace over the last few decades [66], and in Poland, it is currently gaining additional momentum due to the approaching, postponed several times in the past, statutory deadline for introducing the obligation to keep medical records solely in electronic form. Many other countries are currently in a similar situation, but some are more advanced and already guarantee citizens not only fully computerised storing and processing of their medical data [73] but also full and timely access to all of it [74]. Unfortunately, improving hospital performance with information technologies is not an easy task [75], and simply providing medical professionals with access to a patient's full history does not automatically translate into savings of time and money in the healthcare system [76], especially concerning limiting the demand for new tests [77]. Successful implementation of a hospital information system demands from healthcare workers motivation, adding additional effort and flexibility [78]. As a rule, in Poland, medical records shall already be kept in electronic form and may be kept in paper form only if a specific provision of law so provides or organisational and technical conditions prevent keeping records in electronic form [79]. Healthcare information technologies need to be chosen wisely [80], as possibly dysfunctional solutions once introduced are difficult to be changed or replaced later [81]. Nevertheless, the forced migration of the circulation of medical documents to a digital form gives hospitals an unprecedented opportunity to introduce IT solutions that can be used not only to conduct and control current diagnostics and therapy of individual patients and as the basis for settlements with payers of medical services, thus improving quality and safety of medical services [82], but also for the broadly understood needs of the so-called digital epidemiology that utilises a wide spectrum of data generated primarily for purposes other than those of public health [83], including administrative health data [84] and syndromic tracking [85] and other more classic forms of epidemiological supervision, in particular detecting nosocomial infections, practical implementation of the principles of rational antibiotic therapy and ongoing analysis of treatment quality indicators and pharmacoeconomic parameters [41]. Moreover, modern tools of hospital epidemiology, like electronic hand hygiene monitoring, generate and accumulate large amounts of data [86]. Consequently, in addition to equipping the hospital IT system with appropriate tools for statistical analysis, generating reports, graphic representations and data export, along with training the epidemiologists in processing data [87], large scale data analyses [88] and interpretation of such studies [89], it is also necessary to care for the design of the system database in a way that allows for the collection of data in a form that permits their automatic processing to the greatest extent possible – in particular discrete values, codes and classifications, imported directly from their places of origin, which are currently more and more often automated systems producing and able to share digital data compared to the manual input of human operators [11]. Proper coding of medical data is crucial for its use in computer information systems [90]. However, in striving to minimise the share of continuous text in the collected data, as it is still of little use for automated analyses, moderation should be exercised, as routinely entering a significant part of data in numerical form or their codification is burdensome for medical personnel and may result in limiting the amount of important information entered into the hospital IT system in general, its inadequacy or repeated cliché inputs, which is undesirable due to the evidentiary role of medical records [7]. Working with the hospital IT system cannot require the epidemiologist to routinely use the support of IT specialists, but the IT systems need to be seamlessly incorporated into everyday working routines and able to independently facilitate them where possible [41].

Efficient computerisation is a complicated and highly demanding process – both when it concerns individual elements of the healthcare system and its large functional blocks, often with many drawbacks on the way [91]. If it is successful, it brings hope for a significant improvement of activities in multiple fields on many levels [68], including hospital epidemiology; however, this is significantly hindered by the conditions and limitations of information processing specific to medical facilities [65], which entails numerous risks that have been recognised and fought against successively for many years now [92]. Data acquisition for hospital epidemiology and infection control purposes, especially in the case of using Internet-of-Things (IoT) network-connected tools [93], behaviour monitoring systems [94], real-time locating systems for contact tracing [95] or even seemingly simple electronic hand hygiene monitoring, may lead to numerous problems, including generating additional costs that need to be reallocated from elsewhere or autonomy, privacy and confidentiality issues [96, 97].

Despite limited resources, especially staff shortages, the role of healthcare epidemiology and hospital infection control is expanding [98], as are the respective standards and demands imposed by the rising number and size of Polish legal regulations [43–51, 55, 58, 59, 79]. Analysis of the emerging capabilities of new information technology (IT) solutions in comparison to current IT applications and the demands of hospital epide-

miology leads to the conclusion that AI-based solutions – using machine learning (ML)-based technologies that are capable of detecting patterns based on large amounts of data without being pre-programmed to do so [83] in order to be capable of linking, in a way available only for Artificial Neural Networks (ANN), a very wide variety of often incomplete input data to singular, concrete and practically applicable outputs, like diagnoses [99] – can be a valuable asset in supporting and monitoring the infection control guidelines implementation in healthcare facilities by the infection control teams (ICT). Medical expert systems and AI-based solutions can, as it has already been demonstrated in different medical disciplines [26–28], significantly improve and speed up consulting cases of people suspected of infection or infectious disease and those diagnosed with an infection or infectious disease [29, 30]. Agent-based systems (ABS) and multi-agent systems (MAS) [33] can be of help in collecting the required large amounts of data and documenting the actions taken by the epidemiologists. Large language models (LLMs), similar to ChatGPT [34], especially if merged with augmented reality (AR) solutions [36], can be utilised in the process of staff training in hospital infection control [38]. Developing and updating a system for preventing and combating nosocomial infections requires both deep and wide analyses of problems and finding unobvious solutions for them, which can be facilitated both by the machine learning (ML) [83], defined as the set of computation tools and methods for searching patterns in datasets to create models [100], and large language models (LLMs) [34]. Conducting internal control of actions aiming to prevent the spread of infections and infectious diseases can be efficiently supported at various stages: the collection of data can be facilitated by agent-based systems (ABS) [33] and augmented reality (AR) solutions [38], data analyses can benefit from machine learning (ML) solutions [83], while the consolidation stage of the process can be optimised by artificial intelligence (AI) systems [35]. Periodical presentations of the results and conclusions of internal audits to the heads of the hospital and the Committee of Nosocomial Infections Control especially leave space for ChatGPT-like solutions [34].

Digitally-mediated communication increases its impact on human interactions in the healthcare settings with the rise in computer power and accumulation of data, as well as ubiquitous telecommunication networks and mobile technologies [101]. The multitude of emerging IT technologies, if used in combination, or better merged into a single universal solution of high flexibility and problem-adaptation potential, like a virtual medical assistant service or automated preventive medicine manager [102], may prove highly valuable in providing suggestive, individualised and pervasive tools of professional diligence fostering health promotion, highly efficient in the fields of hospital hygiene improvement, antibiotic stewardship adherence and vaccination enforcement and popularisation.

Conclusions

The information technology (IT) system of the hospital is a valuable tool supporting, and sometimes even enabling, the epidemiology specialist and the epidemiological nurse to perform their tasks within a modern hospital. In addition to equipping this system with appropriate tools for statistical analysis, generating reports, graphic representations and data export, it is also necessary to care about designing the system database in a way that allows for the collection of data in a form that permits their automatic processing to the greatest extent possible – in particular when using discrete codes and classifications. In striving to minimise the share of continuous text in the collected data, as it is of little use for automated analyses, moderation should be exercised, as routinely entering a significant part of data in numerical form or its codification is burdensome for medical personnel and may result in limiting the amount of important information entered into the information system of the hospital in general, their inadequacy or template character, which is undesirable due to the evidentiary role of medical records. Working with the hospital IT system may not require members of the Hospital Infection Control Team to routinely rely on IT support. A personal universal artificial intelligence (AI)-based virtual assistant of medical staff, utilising access to the medical databases, modern broadband wireless connection to the conventional information technology (IT) infrastructure and the currently relatively inexpensive Augmented Reality (AR) tools, could revolutionise the key elements of hospital epidemiology. It is foreseeable that in the near future, all these, both classic and emerging, hospital IT tools will be merged into a single coherent solution oriented on a common goal of achieving maximal patient health and staff safety, providing holistic, individualised, continuous and omnipresent support to Hospital Infection Control Teams, all other members of the hospital staff, all hospitalised patients, as well as their accompanying persons.

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Address for correspondence:
Robert Susło, MD, PhD
Zakład Epidemiologii i Edukacji Zdrowotnej
Katedra Zdrowia Populacyjnego
Wydział Nauk o Zdrowiu
Uniwersytet Medyczny we Wrocławiu
ul. Bujwida 44
50-345 Wrocław
Poland
Tel.: +48 713282145
E-mail: robert.suslo@umw.edu.pl