REVIEW

Use of software in the ICU

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ABSTRACT

In the continuum of the complex therapy process of a critically ill patient, the intensive care unit (ICU) period must be followed very meticulously because of the extremely data-intensive circumstances. Intensive care medicine is a lot more reliant on "numbers" than most of the other medical disciplines, and minor errors in the records may lead to wrong decisions, which may cause major harm to the patient. Manual records are prone to errors, inaccuracies and are time-consuming for both nurses maintaining them and physicians trying to interpret them, especially in patients with complex pathologies and long-term stays. Since the introduction of the first general-purpose computer, ENIAC (Electronic Numerical Integrator and Computer) in 1946, there have been attempts to integrate computers into medicine and in the last decades, we are witnessing the emergence of intensive care information systems (ICIS). ICIS has the potential to increase the quality and accuracy of the medical records, while also decreasing the incidence of medical errors. They present electronic decision support and tools for quality control and performance evaluation. More importantly, they allow a medium where the physician can easily assess the current condition of the patient from different perspectives. So far, the usage of ICIS has been limited due to high costs and some other factors. Although we are in a technologically advanced position today, it is still a challenge to implement an ICIS successfully. If not planned properly, it is a process prone to significant delays in time, additional costs, poor acceptance by the staff and even total failure. In this study, we are going to evaluate the past, present and future of intensive care information systems and share our experiences in implementing them.

Keywords: Data management; ICU; information systems; quality management; software.

Critically ill patients may have many typical characteristics in their complex treatment needs, often with multiple organs affected and they are a heterogeneous group, including patients with traumatic injuries (e.g. to the skeletal system, brain, thorax, or abdomen) or burns, systemic infections, surgical complications (e.g. major blood loss or respiratory deficiencies) and multiple organ failure. However, a common feature of different critical illness pathologies is that they all give rise to severe metabolic stress often, develop systemic inflammation and multiple organ dysfunctions.

In the continuum of this complex therapy process of a critically ill patient, the intensive care unit (ICU) period must be followed very meticulously because of the extremely data-intensive circumstances. The quality of the care administered during this phase is difficult to evaluate and quantify since there are many factors affecting the process. ICU beds are used for those patients who have the chance to survive with specific therapeutic and supportive approaches depending on an accurate collection of the real-time data measurements gathered from many different devices that are in function. Thus, the collection of the laboratory and radiological findings are also of great importance.

A majority of the ICU's are still using traditional paper worksheets maintained in folders. The nursing care also has its special records system based on manual records and maintains them in different sections of the folder. Meantime, the inadequacies of the paper record are observed frequently. During long term stays, the relationship and pathological influence between the organ dysfunctions require some needs for a reevaluation of the patient; it becomes very difficult to

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source back the whole course through the voluminous collection of papers.

The easiest way to solve this heavy, uncomfortable and time-consuming problem in the ICU's is to implement Intensive Care Information System (ICIS). Between 1985–1990, some hospitals' administration departments have started to use computers for the billing and other office purposes for the first time. Within time, the development in modern information technology influenced the daily practice in the hospitals and especially in the ICU considerably. The main reason for the ICIS implementation delay in some ICUs in the past was the high cost, and unfortunately, this problem is still remaining. Another important point is that not enough funding can be provided to have technical staff for the maintenance of these clinically integrated complex computer systems.

History

The first forms of medical records dating back to ancient Egyptian papyri from 1600–3000 BC. However, until 1900–1920, medical records were not used in a steady and organized manner.

Silent period: Since the introduction (1946) of the first general-purpose computer, ENIAC (Electronic Numerical Integrator and Computer) weighing over thirty tons, there have been attempts to integrate computers into medicine. Even in the 1950s, the National Institutes of Health started research for problems that would be suitable for computers to solve. During that period, large hospitals began using computers for archival purposes, as well. The first mainstream experiences with information technology in healthcare started in the 1960s and were based on administrative and billing purposes. First reports of ICIS usage in the ICU were from the 1970s and demonstrated a decrease in ICU length of stay.[1,2]

Active period: Only a few early Electronic Health Records (EHRs) allowed for physician order entry and data entry through keyboard-only interfaces, and were focused mostly on laboratory results and medication review. While the computers were mostly used by scientists and engineers in the past, advances in technology allowed for smaller, more powerful and more affordable devices and after the invention of mouse, operating systems with graphic user interfaces introduced in the 1990s certainly made the computers and therefore EHRs more mainstream and open to average consumer usage. As the shortcomings of manual records were becoming more apparent in the 1990s, the Institute of Medicine suggested a transition from manual records to electronic health records. However, the widespread usage of EHRs delayed due to high costs, data entry errors and poor initial acceptance by staff. The goal of a complete transition to paperless records was not deemed financially feasible at that time, and the authors suggested that only key data should be computerised, so EHRs would complement but not replace manual records.[2]

The 1990s saw the networks of personal computers that were used to prescribe inpatient orders linked to EHRs. While this significantly lowered charges, it was more time-consuming than the manual charts. After the development of patient data management systems, the EHRs were able to connect to bedside monitors so that the clinical data could be recorded and interpreted. The early forms of EHRs were developed with hierarchical or relational databases around or added to hospital scheduling and billing systems, while others, such as TMR, HELP, COSTAR, and PROMIS, were developed as clinical systems to help the physician with their patient data management systems. The EHRs were able to connect to bedside monitors, so clinical data could be recorded and interpreted. Since the laws still held physicians accountable for the accuracy and completeness of the medical orders, all the collected data had to be re-evaluated and approved by the physician. Soon, there was a significant amount of data ready for research and epidemiologic studies, but these efforts showed that the "quality" of the data should always be double-checked to prevent misinformation and patient harm.[2]

Computers in the ICU

The first publications about the computer usage in the ICU date back to 1965 by Stacy et al., 1966 by Shubin et al, and to 1968 by Osborn et al., but they were used mainly to assist in calculations. After these first attempts, the first generation of commercial systems emerged between 1972–1988, enabling to connect to patient monitors and collect clinical data. The second generation of these systems between 1988 and 1994 was able to present data graphically and were easier to use with their graphical user interface after the emergence of personal computers. Since the last decade, the third generation of systems made significant progress in data collection from all the devices connected to each patient with improvements in networking technologies and the ability to deploy a personal computer for each patient.[2]

Since the 1990s, computers have become an integral part of the daily routine of healthcare professionals; especially the intensivists put their challenge in the field as they worked within a digital concept in their daily life using all the modern devices. Whether we work in a paperless ICU or a completely conventional manual ICU, today, almost every clinical task is somehow dependent on computers since most of the devices we use have built-in hardware processors. Any modern device, whether they are patient monitors, ventilators, infusion pumps, pulse-wave analysis devices, blood-gas analysis, or almost all of the lab devices, hemodiafiltration machines, or ECMO devices are working with the same concept. Their main disadvantage as of today is that most of them have the ability to store the data they produced only within limited periods of time, and more importantly, they are incapable of putting them in a meaningful context.

The problem is that this data contributes to a flood of information, overloading the physicians with over 1000 pieces of data to analyse from each of their patients.[1] It must be considered that computers have the possibility to do the synthesis of knowledge much more intelligently than professional individuals. And furthermore, more than 236 different variable categories have been reported in an ICU record and considering that humans are capable of properly analyzing only five to nine parameters at a time, this exceeds human intellectual capability by far.[3] Considering the leaps in technology happening each day, this overload only seems to grow day by day with each new ICU equipment.

The Yearbook of Medical Informatics published in 1999 gave rise to some questions as "the renewed promised of medical informatics", which were discussed by JH van Bemmel and AT McCray in 2016. This paper demonstrates the areas with the early promises, and the authors grouped them into four main categories as follows: electronic patient records, clinical support systems, decision support systems, ethical and philosophical aspects, the evolution of the computer and model for computer applications in health care. They summarize, giving the details within a concept comparing to a building with six floors. The bottom first three levels are the most difficult levels to perform and are directly related to the implementation of an ICIS in an ICU. The other top 4th, 5th, 6th levels must be governed by professional individuals because of their dependency.[4]

Traditional Paper-based Unit (Paperwork) and Errors

Medical errors are common among patients requiring intensive care. As mentioned above, intensive care medicine is a lot more reliant on "numbers" than most of the other medical disciplines and little errors in charting may lead to wrong decisions, which may cause serious harm to the patient. The ICU staff works hard to record each event, but the limits of manual records with their preset time intervals may give rise to the physician to miss the details "in-between." Not everyone's handwriting is perfect, so the readability is another disadvantage in manual records when reading charts and may bring about major problems in data interpretation. Although clinical observations are still very important, numerical values, such as laboratory results, fluid balance and monitor data, may influence our choice in treatment much more frequently than we imagine in intensive care medicine. Any error in transcribing these values may cause serious harm to the patient.[1]

Considering the rapid advances in science nowadays, the amount of information regarding new drugs, dosing, treatment protocols and adverse effects makes the memory of a physician not a reliable tool. Manual prescription is a major source of errors, both in the choice of drugs and the appropriate dose and also in the execution of drug administration by the nurses. Long working hours and sleep deprivation are unfortunate facts in the clinician's life and render them susceptible to fatigue-induced medical errors, as well.[3] Many studies have shown that the nurses' paperwork is very loaded, which results in a long time spent in the ICU and comparatively less patient care. In a complex patient who needs more care, the reverse happens, and sometimes, the charting quality decreases considerably.

Manpower and Costs

Although the idea of a paperless ICU sounds inviting, the installation, setting up and maintenance requires a considerable amount of manpower and money. The acquisition of software by itself is not the only financial burden; the regular maintenance of the software, and the payrolls of the IT staff should not be overlooked as well. There are also reports of physicians and other healthcare staff's complaints regarding increased workload and inflexibility of EHRs and Computerized Physician Order Entry (CPOE). These complaints resulted in the use of medical scribes specialized in charting medical data and navigating the EHRs. Despite these complaints, to our knowledge, there have been no studies comparing the ICIS and manual records regarding the utilization of ICU physician's time.[2,3]

When robots entered the factories, they helped companies to decrease the size of their worker force. The ICIS may not decrease the nursing work, therefore it has no potential of reducing the nursing staff as of today, but it does improve the quality, accuracy, timely capture and recall of important clinical data, while also reducing nursing clerical work.[1]

ICIS from vendors are mostly expensive, but there are reports of successful usage of open source systems in poor countries. Although these have limited capabilities, they often offer a better option than manual records, and their functionalities are getting improved each day.[2]

Intensive care medicine is an extremely expensive specialty and consumes a significant amount of available healthcare resources. In the USA alone, the ICU medicine is estimated to consume 1% of the gross domestic product. The ICIS could help in the optimization of resources on the management level and lead to significant amounts of financial benefits.[3]

There have been reports of fully integrated CIS to be cost-saving, while also reducing hospital length of stay, morbidity and mortality. Although they may sound like an expensive investment, the improvements in quality and efficiency of care administered and the reduction in medical errors result in significant direct and indirect financial gains as well as nonfinancial gains that are impossible to measure in any currency.[1]

Unfortunately, the implementation of the information technology, especially in the ICU, is not the way to decrease the workload of the medical staff. The need for the use of many devices generates more data. Thus, the amount of information will increase; and the interpretation will be facilitated, but it will consume more time. This situation may sometimes disturb medical staff, but the pool obtained from accurate and healthy data should be taken into consideration as main preference.

The database of an ICIS is an important tool for comparing ICU performance and costs Many commercially designed ICU software with their ability to integrate to billing software used in healthcare institutions help immensely with providing these statistical values within minutes, no matter which analysis method is used. The elimination of human error and timeframe constraints in manual data collection facilitates a much more precise way for statistical evaluation of ICU performance. Quoting Paul Batalden, "Every system is perfectly designed to achieve the results it achieves," and considering the customization possibilities of ICU software, they may serve as an invaluable tool in the quality management of an ICU, as well.[3]

Physician Order Entry Systems

Computerized Physician Order Entry (CPOE) systems are the electronic prescription of medical orders. One of the main advantages of CPOE systems is to reduce errors that arise from handwritten readings, another advantage is its ability to help the clinician by recognizing the drug allergies and drug interactions, by showing relevant laboratory results, recommending the correct dose or dose adjustments in case of hepatic or renal failure and showing guidelines.[3]

The optimal way of prescription should allow the physician to interact with three databases: (1) Patient's drug history and current medications (2) Scientific drug information reference and guideline database (3) Patient-specific information, such as age, weight, allergies, diagnosis and laboratory results.

While the built-in computerized physician order entry (CPOE) systems in the ICIS may sound like an optimal solution and have the potential to eliminate this problem, the results of the studies conducted to evaluate its efficacy are too varied. On the one hand, there have been reports of the complete elimination of drug prescription errors and a significant reduction in adverse drug events (ADE) after the implementation of CPOEs. Bates reported a 55% decrease in non-intercepted serious medical errors after the introduction of CPOE. However, on the other hand, there are reports of consistently high rates of ADEs after the implementation of a CPOE and even higher mortality after CPOE implementation than before as well.[1]

Successful implementation of CPOE with a sophisticated computerized decision support system for prescribing antibiotics was shown to significantly reduce the cost of drugs, total costs and the hospital length of stay. The effects of CPOEs in the ICU on medical errors were evaluated in a pediatric ICU, and a significant decrease in medication errors and a substantial decrease in adverse drug events was shown. Another study showed a remarkable decrease of 26.5% vs 3.6% in medication errors after the implementation of an ICIS, and a dosing error in patients with renal failure was significantly reduced, as well.[3]

Performance Evaluation

The collection of accurately measured data is highly important and gives rise to evaluate the performance of an ICU. For many years, several scoring studies have been realized to collect scientific evidence. The ultimate aim was to develop effective and efficient treatments to reduce mortality and morbidity ratios in the ICU.

In 1974, Cullen et al. created the first version of Traumatic Injury Scoring System (TISS), but in the 1980s, it was realized that the scores were decreasing each day even in non-survivors and the predicted mortality rates at their day of death was approximately 12%. Therefore, after APACHE score was introduced in 1981 by Knaus et al. and it was the first scoring system for evaluating the severity of illness applicable to most critically ill patients. Then, in 1986, Knaus et al. went on to propose the standardised mortality ratio (SMR) which is the ratio between the observed and predicted mortality. This was an important step towards the evalution of the performance of an ICU. The APACHE Score underwent two revisions, namely APACHE II (1985 Knaus) and APACHE III (1991 Knaus). Le Gall presented the Simplified Acute Physiology Score (SAPS) in 1983 which was revised by the same author in 1993 as SAPS II. In 1985, the first version of Mortality Probability Model (MPM) was introduced by Lemeshow et al. and saw an update in 1993.

The Sequential (or Sepsis-related) organ failure assessment (SOFA) scoring system was created in a consensus meeting of the European Society of Intensive Care Medicine in 1994, and further revised in 1996.[5] SOFA is a widely used scoring system based on the number of organ failures present at the time of evaluation.

All of these scoring systems are still relevant and may be used in conjunction with SMR as a tool to evaluate how well an ICU performs based on the outcome. However, the consensus conference of European Society of Intensive Care Medicine in 1994 stated that although these systems are highly specific and may predict survival in 90% of the cases, their sensitivity is lower and may predict death in only 50–70% of the patients and therefore should not be used to predict the prognosis in individual patients.

One striking aspect is that the predicted mortality rates (PMR) in these scoring systems rise approximately 15–20% when data collection is carried out via intensive care information systems. Bosman wrote in 1998 that this might be related to the continuity of data collection with the electronic systems, whereas manual charts do the data collection within set time frames, mostly hourly and may miss abnormal physiological values, which leads to the underestimation of predicted mortality rates.[6]

Risk-Adjusted Hospital Mortality Rate (RAHMR) is still an important outcome for institutions and the Joint Commission on Accreditation of Healthcare Organisations (JCAHO) since 2007 uses it to evaluate ICU performance.

In our unit, we use APACHE II, SOFA Scores to predict mortality rates (and also NUTRIC score to assess the nutritional status of the patients), and we compare these results with the realized mortality rates each month to evaluate our performance regarding mortality (Fig. 1). The introduction of the ICIS in our unit greatly improved the accuracy of the scores as well as the statistics. ICIS also facilitated a significant reduction in time spent in calculating both the scores and in the creation of the statistics.

However, since the ICU is a complex network with multiple factors affecting its quality, Elwood et al. (1988) proposed "outcome management" in 1988 with some additional endpoints. Another important aspect of the performance evaluation of an ICU is the effective utilization of its resources. Although the ICUs in the UK receive 1–2% of the hospital budget compared to 20% in the US (Bion 1995), they perform equally well according to severity-adjusted outcomes. Economic restrictions may have a positive effect on streamlining healthcare processes and the elimination of unnecessary procedures without sacrificing the quality of care. The evaluation of cost-effectiveness is often carried out via the number of survivors, probability of survival, years of survival, or quality adjusted life years (QALYs) (Chalfin 1995). Smithies et al. in 1994 realized a cost-performance analysis based on APACHE II scores, TISS in relation to costs per survivor (CPS), costs per non-survivor (CPNS) and the effective cost per survivor (ECPS) in their ICU and while the CPS and CPNS remained in a narrow spectrum, ECPS showed an exponential rise as the predicted mortality ratios of the patients increased.[6]

Decision Support

Computer Decision Support in the ICU should cover the following four basic areas:[3]

- Interpretation of the collected data
- Alerts (such as drug interaction, abnormal results)
- Diagnoses (such as early detection of sepsis, renal failure)
- Treatment suggestions (such as the most appropriate antibiotic based on the culture results)

For most of the chronic diseases, such as hypertension, cancer, or chronic obstructive pulmonary disease, the treatment may take weeks, months, or even years. In a typical ICU scenario, this cycle is reduced to days, hours, sometimes minutes and even seconds. Therefore, the clinician is constantly facing a race against time to analyse and act quickly.[3] Built-in Electronic Decision Support (EDS) systems have the potential to help the clinician to analyse the data if the customisation is done correctly, but as of today, we still need more improvements in EDS technology to replace human judgement.[7]

Most of the EDS modules are focused on specific, clearly defined problems based mostly on one parameter and cannot be relied on in complex scenarios compared to a clinican's reasoning. For example when the heart rate of a patient rises above 100 beats/min the EDS still cannot do the differentiation between agitation, seizure, fever, sepsis, electrolyte abnormalities, e.g., because to do that, it needs much more than complex algorithms: Clinical observation, physical examination and experience are still important tools in the arsenal of an intensivist.

Even though we complain of data overload in the ICU, we should consider that the computers have the potential to do the synthesis of knowledge much more intelligently then professional individuals. The human brain's ability to connect all these dots is still far too superior to the ability of the computers. Therefore, in our unit, we do not rely on EDS modules on diagnosis and treatment, but we use some of them just as alarming tools for the staff, both nurses and physicians. The reason for the inadequacy of the EDS modules is not only the lack of technology but also the lack of universally accepted decision support models or rules for the ICU, as well. However, even if the EDS modules of an ICIS are not used, the ICIS itself can be identified as an EDS as well, because it helps the clinician to analyse the data faster, more accurately and in a much more organized manner than manual records and enriches the clinician's reasoning process with trends, graphs and images in little time. A good decision requires

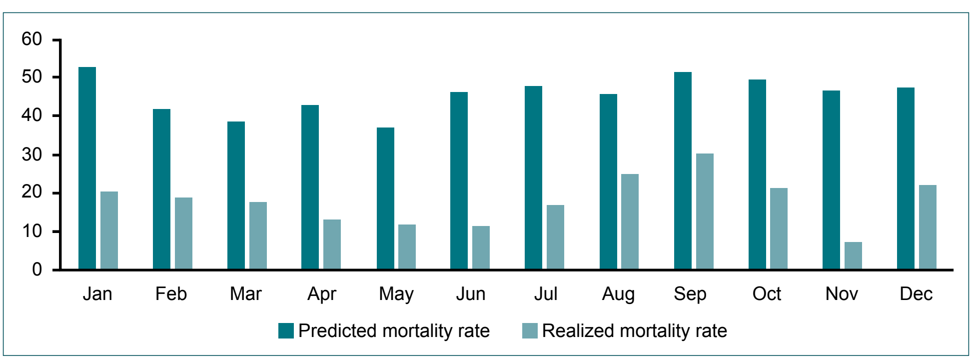

Figure 1. Graph showing the difference between the predicted and realized mortality rates (%) in 2017 (American Hospital ICU Istanbul).

good information and the ICIS, with its ability to integrate and organize the data coming from numerous devices in the ICU is a major help in this regard.

Quality Control

One major disadvantage of these systems is "the artefact problem". Measures must be in place to guarantee the accuracy of the retrieved data.[1] Otherwise, when the clinician is calculating APACHE II, a perfectly stable patient may have the minimum blood pressure showing up as 50/40 mmHg just because the nurse collects a blood sample from the arterial catheter. Considering the increase in the number of devices that are used in the ICU and the increase in the parameters they bring to the table, the possibility of more alarms increases as well. We are drowned in a flood of alarms each day and are at risk of overlooking important situations because of the "alarm fatigue", but so far the efforts to facilitate "intelligent alarming" suffered from the loss of alarm sensitivity and resulted in an increase in the risk of missing important events. When the alarm specificity is increased, then, it becomes easier to miss potentially hazardous events, too.[8] All these alarms get recorded in the ICIS as well, since the systems cannot differentiate the artefacts from the real events, yet. Therefore, it is important to weed out these artefacts by the human hand to keep the records accurate. Otherwise, they may lead to false calculations and decisions, especially when calculating various ICU scores (e.g., APACHE II, SOFA, SAPS II, NUTRIC). To be able to differentiate the good information from the bad ones is a key factor when using ICIS. In an editorial, Purves pointed out the clinical behaviour needs and stated that the tools of "knowledge management" are more than a technical approach; they are also about human behaviours and mind-set, and the language used is not just evidence-based: it is experience-based, too.[9]

The rapid technological advances in computer engineering and the research on artificial intelligence, as well as the steady increase in our knowledge in intensive care medicine, may allow significant improvements in the EDS systems in the near future.

Implementation of an ICIS

The data overload we face every day in the ICU are problems for the computers, as well. It has become extremely hard and time-consuming to develop an ICIS on-site with the entire complex networking needs and the abundance of parameters needed to be implemented.

When we decided to implement an ICIS in our unit, we visited various ICUs that were using an ICIS. We believed that the most appropriate way was to experience a few days inside their unit to have the chance to analyse the first-hand experiences, understand the problems they are facing and their approaches on how to solve them. Therefore. we decided to follow the first step, which was the most viable option, to buy a commercially available product that can be customised step-by-step until it suits the needs of our ICU. Finally, we understood that none of the products on the market is perfect and each has its own advantages as well as its disadvantages.

Although we are in a technologically advanced position today, it is still a challenge to implement an ICIS successfully. If not planned properly, it is a process prone to significant delays in time, additional costs, poor acceptance by the staff and even total failure.

Steps for a Successful Implementation of an ICIS (The Turkish Experience)

Step 1. Decision: Our experience was mainly in line with this general approach. Our director made frequent visits to ICUs, which were using ICIS before deciding on a system. The hospital management was enthusiastic about the idea and gave total support, both by presenting the financial resources we needed and by encouraging us.

Step 2. The Build-up of the ICU Infrastructure: Although the main attention before the implementation period is usually focused on the choice of software, we would like to emphasize the importance of the equipment and infrastructure of the ICU where the ICIS is going to be implemented in. There is no advantage of using an ICIS if the equipment is not able to communicate with the software. We decided to use an ICIS around the time of a complete renovation process, so before all the implementation period began, we made sure that the IT infrastructure of our ICU was able to handle all the data-traffic and chose only the equipment which was able to communicate with ICIS. We requested assurance from all the vendors of the devices that their devices are fully compatible with ICIS, and all the payments were made after their compatibilities with the ICIS were confirmed in real-time.

Step 3. Involvement of the Staff: Before the whole transition period began, three physicians and three nurses were designated to work cooperatively with the engineers of the software company to customise the software according to our specific needs. Physicians were mainly responsible for the translation and verification of data signals coming from the medical devices into the software, transcription of examination charts, enhancement of the drug database, and verification of the accuracy of the scoring system modules. Nurses transcribed their charts about various topics, including admission, routine care, quality management, safety protocols. Meanwhile, two engineers from the hospital's IT department were trained about the network needs of the software.

Step 4. Connection of the Monitor's Data: The first step in connecting the devices with the ICIS was to make sure that the system was collecting all the relevant data from the patient monitors. We collected the data by hand and by ICIS and checked the data on multiple occasions minute-to-minute to ensure their accuracy. We created an interface window in the ICIS, identical to our main written ICU worksheet.

Step 5. Connection to the Hospital Central Laboratory Department: A direct connection to the laboratory server was created, which enabled us to see the results as soon as they were confirmed by the responsible physician in the laboratory. We ensured that each day that the routine test results were collected at 07:00 AM by the ICIS, just before the patient rounds began. The laboratory window in the ICIS was customised to group the results from the laboratory by each organ system.

Just like most of the ICUs, our ICU has its own blood gas analysis device, and we were able to connect this device to the ICIS, and all the results showed up on the blood gas screen as soon as they were compiled by the device.

Step 6. Connection to the Hospital Pharmacy Department: One of the most difficult aspects of the implementation was the CPOE system's connection to the pharmacy. Since all the other departments of the hospital used another CPOE system, it was a difficult task to create a coherence. However, after many days, maybe weeks of brainstorming and negotiations, we were able to create a pharmacy interface in the ICIS in accordance with the Joint Commission International (JCI) standards and installed a mirror in the pharmacy department for their use. Unfortunately, despite all the hard work, we were unable to connect the medication dispenser system (PYXIS MedStationTM, BD International) to our ICIS.

Step 7. Preparation of the Nurse's Worksheets: The creation of the forms which were related to nursing was one of the hardest and most time-consuming tasks. The transcription of every detail in their manual records to the electronic medium was carried out in accordance with the JCI standards.

Step 8. The Connection between ICIS and ICU Devices: Before all the ICU devices were properly introduced to the system, they required special network interface devices (terminal servers), which enabled them to send their signals to the ICIS via the network cables. The reimbursement of these network devices was a problematic process since neither the software company nor the device vendors wanted to take the responsibility at first, but it was decided that the software company should pay the additional costs. This was another setback in our endeavor, which caused a minor delay.

Step 9. Translation of the Language of the Devices: After the completion of the network, to create a common ground between the ICU devices and the ICIS, we had to translate all the signals from most of the devices, and the mechanical ventilators proved to be the most time-consuming of all since we used three different brands of ventilators for specific types of patients and each of them sends a different alphanumeric signal for each parameter. For example, we saw that "EG34H" was showing 20 in the ICIS, but we did not know what "EG34H" was. We had to find out that the "EG34H" was the good old "peak inspiratory pressure" by ourselves. Translating countless parameters coming from three different ventilators was a process that took us days.

The infusion pumps were pre-loaded with presets for many standard medications, but we had to add many more to its registry to show every drug infusion properly labeled in the ICIS. Again, this required many negotiations with the vendor company and many visits from their tech-team.

Step 10. Training of the Staff: After all the preparations finished, we started with the training of the staff in the basics of the software. Only two beds were used for testing purposes during the training period, while maintaining both manual and electronic records and continuously monitoring both for errors. Once the staff got acquainted with the software, we slowly connected the remaining beds to the ICIS one by one. This period helped us to define occasional technical problems and solve them slowly and helped us to have good understanding of the technicalities of the software. When all beds were connected to the ICIS, the staff had already reached an acceptable experience level with the software.

Step 11. Before the Final Implementation: When the ICIS went live, one key difference in our implementation plan was using both the ICIS and manual records during the first six months to ensure the accuracy of the records. This of course caused an increase in the workload and was extremely time-consuming. Nevertheless, this approach caused complaints and a minor (albeit not outspoken) resistance among the staff. Providing extra staff during this period alleviated this problem to some extent.

Our aim with this approach was to double-check the records for accuracy during the patient rounds, and while we were expecting errors mostly in software data, to our surprise, most of the errors were present on the manual records, especially regarding the fluid balance. The time we spent on the infusion pumps during the preparation phase was certainly not in vain.

The patient rounds were taking double the amount of time because of the extra effort to compare both records per patient, but it had an immensely positive effect on the implementation period. It was a time for feedback, and everyone among the team contributed to some extent, giving input on how to make the software better. This way, in addition to making substantial improvements in the ICIS step-by-step each day, we created a gradual increase in the sense of ownership among the staff, as well.

Step 12. Start to Paperless ICU-Final Implementation: At the end of the sixth month, once we were absolutely sure that everything was working properly, paper and pen became obsolete. From then onwards, the process basically involved the correction of minor errors and further customisation. An interesting obstacle was the definition of the daily cycle for the software. Normally, calculations in our ICU start the day at 07:00 AM, but it took some time until we figured out that we should define the timeframe to start at 07:00 and end it at 06:59 at the following day to obtain accurate results for all of our calculations, such as fluid balance, caloric need and protein need.

Step 13. The Cooperation between the IT Engineers and the Medical Team: The presence of the software company during the implementation period and beyond was of immense importance in fixing the errors within minutes and tailoring the software to our needs. We also built a local team among physicians, IT department and senior nurses who know the ins and outs of the software to make non-critical changes to the software on the fly to decrease the dependence on the company for basic actions.

Step 14. Tailoring of the ICIS: As stated earlier, one of the main advantages of an ICIS is to put all the collected data in context. After months of tweaking, we created many frames within the ICIS to assess the condition of the patient from different perspectives. Some examples for the most frequently used windows are as follows:

- The main window is almost identical to the conventional manual charts.
- The trends window shows all the vital signs and important parameters in the last 24 hours as graphs.
- The respiration window is basically divided in three parts, where the first part shows the set parameters in the ventilator. The second part shows the measured parameters, and the third part shows the blood gas results concerning all these parameters.
- There is also a separate blood gas window for a more detailed analysis.
- The fluid balance window shows the input and output balance in detail. It has separate subsections showing the infusion.
- The infusions window shows all the continuous infusions being administered in real-time with labels, concentrations and infusion rates.
- The laboratory window groups all the test results by the organ systems they are related.
- The nutrition window is a section we have spent such a long time for and we decided to give it a separate name: Intensive Care Nutrition Software ICNUS.[10]

After getting the daily caloric requirement in Kcal directly from the metabolic monitor, the ICIS automatically calculates calorie and protein needs of patients and clearly demonstrates the daily nutritional aims. Since each product on the market for enteral and parenteral nutrition is in the database of ICNUS with their calorie and protein concentrations, it is also able to calculate the amount of the calories and protein given that day automatically. This way, we can assess whether we reached our nutritional aims or not. Specific nutritional calculators for calorie and protein intake were added, so we can assess whether we will reach the calculated aims with the given nutritional therapy. We can follow the body weight changes in patients and analyse its correlation to fluid balance on this screen, as well. All of these parameters can be evaluated as graphs within seconds.

Step 15. Secure Access via Internet Connection: Another major advantage of the ICIS is the ability to create remote connections. Our director has direct access to the system without any restrictions from his home or anywhere in the world, granted there is an internet connection. Multiple security measures were created for this process by the IT team to prevent breaches from potential outside threats.

Current Situation

ICIS's importance is much more pronounced as a tool for scientific research. Our experience with research was limited, but we decided to evaluate the effects of nutritional therapy on mortality, and all the data from more than 800 patients, organised and grouped specifically to our design, were ready for statistical analysis within minutes. Given that more and more ICUs are adopting this technology each day, this will contribute to a significant volume of data for important multi-center studies with a high impact in the future. The only problem is ensuring the accuracy of data and facilitating the interconnectivity between these databases.

The data overload we face every day in the ICU is a problem for the computers, as well. It has become extremely hard and time-consuming to develop an ICIS on-site with all the complex networking needs and the abundance of parameters needed to be implemented. The most viable option is the successful way we follow in our unit. To buy a commercially available product and then customise it step-by-step until it suits the needs of the ICU, it is implemented. As of today, all of the software products share two main functions:

- Collection and storage of clinical data from various devices (e.g. monitors, ventilators, pumps)
- A Computerized Physician Order Entry (CPOE) system to replace manual prescription

In our opinion and experience, the implementation of an ideal ICIS should cover these basic areas:

- Accurate collection and storage of data from medical devices in the ICU.
- The ability to communicate with various systems used in the hospital (such as HIS, PACS, Pharmacy, Drug Informa-

tion Database, Clinical Guidelines Database).

- A simple but effective CPOE system (better combined with basic Computer Decision Support Systems)
- Ability to sort clinical data in various ways (such as Graphs, Tables, Charts) to help in the analysis
- Computer Decision Support leading to a diagnosis and optimal treatment, but today's technology does not offer a replacement for human judgement yet.
- Quality management tools.

Given that we are still far away from these goals, especially regarding computer decision support, it must be emphasized that no ICIS is perfect as of today.

Although we are in a technologically advanced position today, it is still a challenge to implement an ICIS successfully. If not planned properly, it is a process prone to significant delays in time, additional costs, poor acceptance by the staff and even total failure (Fig. 2).

Future Trends and Conclusion

The computers have been a part of our professional lives for more than three decades in the ICUs, and now, we have software to connect all the devices we use and record their data in a digital medium, having the ability to replace the conventional manual records and resulting in a paperless ICU with many benefits. However, the adoption rate of this technology is still too low (probably less than 5%), due to the high implementation costs, the complexity of the hardware and software, problems with interconnectivity between other departments of the hospital, concerns about security and the lack of significant, proven benefits.[3]

As of now, we are using the third generation of ICIS, which still requires a significant amount of insight on computers. As with every technology, early products of a newborn field are complicated to use, but as the technology rapidly advances and matures, the usability of these products becomes significantly easier for the end-user. The ICIS will not be an exception and the fourth generation of ICIS will see significant improvements in usability and connectivity. With the aid of the new generation of ICIS, the ICU physicians will hopefully be allowed to concentrate on their main mission without feeling the need for IT expertise: Caring for the critically ill!

The ICIS is only a vehicle for the intensivist to reach their destinations, so not everything should be expected from it. There "will" be problems in data collection, no matter how well the system works and this is a completely expected side-effect. The staff should be prepared to face them since these problems start to surface as soon as the system goes live. We experienced a lot of them, and a solution for a problem sometimes caused another completely different problem. This is a process that requires a lot of patience and determination. On the other hand, you may just settle with the barebones version of the software without customising it and therefore missing its full potential. As intensivists, we are already working under hard conditions, and the implementation period of an ICIS will certainly multiply the amount of workload at first. Our biggest asset in this period was the determination, dedication and experience level of the whole staff. The accuracy of computer documentation is superior to manual records, and ICIS can be beneficial only if the staff has a significant experience deriving from good intensive care medicine training based on physiology.

The meaning of "good" in medicine is certainly not only equal to "modern". It must not be forgotten that everything once modern is getting old. In our age, the amount of time to become obsolete is getting shorter every day. We still do emphasize the importance of human factors. And what matters is not only the quality of the physicians but of the whole staff.

Conflict of interest: None declared.

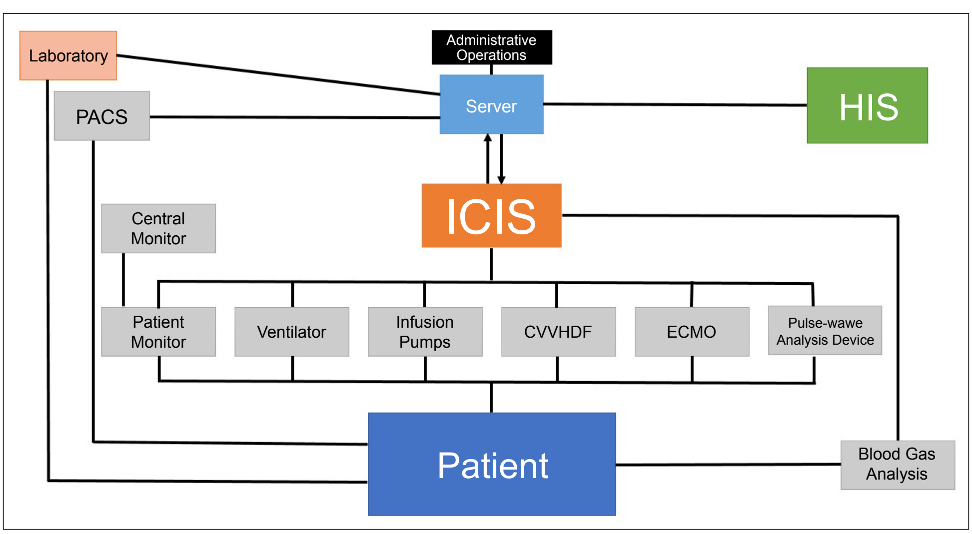

Figure 2. ICIS working schematics in our ICU.

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DERLEME - *ÖZET*

Yoğun bakımda yazılım kullanımı

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Yoğun bakımdaki hastanın kompleks tedavi süreci, ciddi oranda verilere bağımlı durumlar nedeniyle dikkatle izlenmelidir. Yoğun bakım hekimliği, diğer branşlara oranla sayılarla çok daha fazla iç içe olmayı gerektirdiğinden, bu verilerdeki ufak hatalar dahi hastalar üzerinde ciddi hasarlar bırakabilecek önemli hatalara sebep olabilmektedir. Tıbbi kayıtların elle tutulması hataya eğilimi arttırdığı gibi hem bu kayıtları tutan hemşireler hem de verileri analiz eden hekimler için anlamlı ölçüde zaman alan bir durumdur. Bu durum hastalık sürecinin karmaşıklaşması ve yatış süresinin uzadığı durumlarda çok daha belirgin hale gelmektedir. ENIAC (Electronic Numerical Integrator and Computer) isimli ilk bilgisayarın 1946'da ortaya çıkmasının ardından bilgisayarları tıp pratiğine entegre etmeye yönelik birçok girişim olmuştur ve son yıllarda da yoğun bakım yazılımlarının ortaya çıkışına şahit olmaktayız. Bu yazılımlar tıbbi kayıtların doğruluğunu ve kalitesini arttırma ve medikal hataların görülme sıklığını azaltma potansiyeline sahip oldukları gibi elektronik karar desteği sunmakta; kalite kontrol ve performans değerlendirmesi gibi alanlar için de araçlar içermektedirler. Daha da önemlisi, bu sistemler hastanın anlık durumunu değerlendirme gayretindeki hekimlere farklı bakış açılarıyla yaklaşabilmesi yönünde bir ortam sunabilirler. Günümüze kadar yoğun bakım yazılımlarının kullanımı, yüksek finansal maliyetler ve diğer bir takım faktörler nedeniyle kısıtlı kalmıştır. Günümüzde her ne kadar teknolojik yönden ileri bir konumda olsak dahi bir yoğun bakım yazılımının etkin bir şekilde kullanıma sunulması zorlu ve düzgün planlanmadığı takdirde anlamlı gecikmelere, ek finansal maliyetlere, ekip içerisinde kabullenişe yönelik zorluklara ve hatta tamamen başarısızlığa mahkum bir süreçtir. Bu yazıda, yoğun bakım yazılımlarının geçmişini, günümüzdeki halini ve geleceğini değerlendirdiğimiz gibi bu yazılımlara geçiş sürecinde kendi yaşadığımız deneyimleri de paylaşacağız.

Anahtar sözcükler: Bilgi-işlem sistemleri; data yönetimi; kalite kontrol; yoğun bakım; yazılım.

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