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Mannequin-Based Simulators: New Opportunities in Training of Anesthesia Residents in Providing General Inhalation Anesthesia

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Abstract

Introduction: In this article we analyze the use of the METI (Medical Education Technology Inc.) Human Patient Simulator (HPS) for the training of first-year anesthesiology residents in providing general inhalation anesthesia. The aim of this study was to compare simulation-based training on the METI HPS with traditional clinical-based training.

Methods: In this research were included 28 first-year anesthesiology residents which were randomly assigned to either traditional clinical-based (group A) or simulation-based (group B) training. The study consisted of two stages: the training stage (1) and the evaluation stage (2). On the 1st stage residents from both groups were passing through clinical-based and simulation-plus-clinical-based courses, respectively. After a number of giving anesthesia the residents participated in, the competent mentors decided whether they were ready to step to the evaluation stage. On the 2nd stage each of the participants had to provide general anesthesia on his/her own on the METI HPS. During all parts all participants were supervised by highly-qualified specialist. The results of the study were statistically processed by using a two-sample Student t-test.

Results: We found a statistically significant difference in the duration of the training stage between the two groups of participants. Residents from clinical-based group (group A) took part in 15,08 ± 1,83 anesthesia before they were allowed to proceed to the evaluation stage of the study. Residents from simulation-based group (group B) required only 7,27 ± 1,19 anesthesia for the same purpose.

In the evaluation stage there was a difference in average rating between the two groups. Group A scored 40,08 ± 2,57 out of 100 points, whereas group B got 70,55 ± 7,1 points, which is also a significant difference in terms of statistics ($p<0,05$).

Conclusions: The obtained data allow considering simulation training of residents with combined methods of anesthesia at the METI HPS. more effective.

Keywords: Inhalation anesthesia; Mannequin-Based Simulators; Training residents

Introduction

The first year of anesthesia resident education consists of lectures and classroom activities (so-called preclinical stage) and training directly in surgical operations – clinical stage. The fact that anesthesiology is quite an invasive profession and requires proficiency in practical skills provides a number of difficulties in training residents [1-6]. It makes the transition from preclinical to clinical stage one of the most difficult and important periods of resident's education. In particular the process of learning how to provide general anesthesia by using inhaled anesthetics besides theoretical knowledge requires skills in airway management and ventilation, as well as complex skills in providing adequate anesthetic protection. Those complex skills include the ability to achieve a sufficient level of analgesia, sedation, adequate depth of anesthesia, monitoring and controlling the vital functions of the patient, the ability to provide emergency algorithms if needed and to ensure timely awakening and extubation. Training such skills as mask ventilation, laryngeal mask application, intubation, etc. nowadays can be successfully provided by using quite simple mannequins, - the effectiveness of this practice is proved by a number of studies and leaves no doubt. But complex skills in providing adequate general anesthesia can be obtained only in clinical practice by watching and taking part in anesthesia. Residents traditionally obtain such an experience in an operating theater under the guidance of certified anesthesiologists, dealing with actual patients.

Unfortunately this kind of training format, especially in the beginning, raises a number of difficulties and risks. First of all a high probability of making errors can result in complications in patient's condition. This also causes the lack of self-confidence and even fear of treating patients, which can slow down the training process. Secondly, there is no possibility to fully train emergency algorithms because in clinical setting we cannot "simulate" emergencies. And finally, the unwillingness of the patients to become an object of training can arise ethical issues. Thus, it takes a lot of time before a resident can obtain sufficient skills, experience and self-confidence for independent and qualified working with patients.

Until recently traditional clinical-based training had no alternatives. But the appearance of patient simulators with high level of realism allows expanding the capabilities of training complex skills in the preclinical stage of education.

In particular METI's Human Patient Simulator® nowadays is the only patient simulator with the ability to provide respiratory gas exchange, anesthesia delivery, and patient monitoring with real physiological clinical monitors. Training on such kind of patient simulator in providing general anesthesia using inhaled anesthetics seems to be promising. But the issue of effectiveness of this method and the feasibility of including it in preclinical anesthesia resident's education plan is still open and needs to be investigated. So, the aims of this study were:

- To explore the effectiveness of training on METI HPS versus traditional only-clinical-training in providing general anesthesia using inhaled anesthetics;
- To explore whether this training method can provide continuity in the transition from the simulation-based classroom to clinical care;
- To define the role and the place of simulation-based and clinical-based training at an early stage of anesthesia resident education.

Methods

The subject of study was the process of training general anesthesia with intravenous induction and using an inhaled anesthetic Desflurane for maintaining anesthesia on the patients undergoing routine abdominal surgery. We included 28 first-year residents in anesthesiology in this study. All of them attended the same theoretical course and successfully passed the incoming test control, proving sufficient knowledge in general anesthesia pathophysiology, pharmacology of the drugs, the construction and operation of anesthesia-respiratory equipment. All of the included residents have never taken part in providing general anesthesia before. According to these inclusion criteria we consider the initial level of the participants equal – they all knew the theory of providing narcosis but still have never practiced it.

Residents were randomly divided into two groups: traditional clinical-based group (group A) – 15 residents, and simulation-based group (group B) – 13 residents. The study consisted of two stages: the training stage (1) and the evaluation stage (2).

Both groups had to train the process of providing general anesthesia with intravenous induction (Fentanyl, Propofol, Esmeron) and using inhaled anesthetic Desflurane for maintaining anesthesia. The only difference was that group B residents received a short training course on the METI HPS before starting their clinical training in the hospital.

This course was held in our simulation center in a room, which accurately simulates real surgical operations. The simulator classroom is equipped with METI's Human Patient Simulator and modern quality anesthesia equipment. Two neighboring rooms are separated from the simulator classroom with one-way mirrors, so that observers can watch all the process of training without bothering this process. Group B residents divided into two small groups of 6 and 7 people received a one-day training course on METI HPS. During the course mentors introduced anesthesia equipment to the residents and showed one complete anesthesia on METI HPS with detailed step-by-step explanation. Then each resident had to provide anesthesia on his/her own and a short debriefing after each anesthesia was held. After he first circles of practicing and discussions everyone had a chance to train once again the whole algorithm of providing narcosis. At the end we interviewed residents to receive their opinion and feelings about the course.

After that clinical training for both group A and B residents started. During the training in hospitals we tried to minimize distinguishes between the conditions for all of the residents, so we made the environment maximally equal. During our study the residents took part only in providing general anesthesia for the patients, who were undergoing routine abdominal surgery and had the same perioperative risk (ASA I-II). The operation rooms were provided with an equal narcosis equipment (equal to the simulator classroom equipment also). Anesthesiologists used the same drugs for intravenous induction and maintaining anesthesia (Fentanyl, Propofol, Esmeron, Desflurane). None of the mentors knew that some of the residents previously received a simulation course. The training process for the residents consisted of introduction. How to give anesthesia and then watching and repeating the actions of an experienced certificated anesthesiologist under his/her supervision, which is a traditional way of training residents. But our goal was not only teaching, but also evaluation of the duration from the first narcosis a resident took part in till the time he/she can provide narcosis on his/her own. It was a difficult task for us, considering that the residents were trained by different anesthesiologists. So, we developed a unified plan for teaching and evaluating residents and held a preliminary briefing with all the anesthesiologists-instructors.

Thus, the criterion for exclusion from testing was the impossibility of independent, without the help of a professor, conducting anesthesia at the clinical-simulation stage of the study.

An evaluation of the success of anesthesia on a robotic simulation complex was assessed by five parameters that contributed an equal sum (20 points each) to a total score of 100 points.

- Hemodynamics during anesthesia.
- Achieving and maintaining the target level of the bispectral index.
- Maintaining a constant concentration of anesthetic in the expired respiratory mixture (assessed by the value of the minimum alveolar concentration (MAC)).
- Time to extubation after the end of the operation.
- Time to transfer the patient to the ward.

For 100% of the level of implementation of each parameter (20 points), averaged indicators of tests of certified specialists were taken.

The second - evaluation stage of our study was held in the simulation classroom on the METI HPS. The goal was to evaluate the ability of the residents to provide adequate and safe narcosis. We consider that using a realistic mannequin simulator for this purpose is more convenient, more objective and does not cause ethical questions, comparing with examination on the real patient. Each resident provided one complete anesthesia, and for the evaluation we used the same algorithm and criteria as anesthesiologists used during the clinical practice. The statistical processing was carried out using a two-sample Student t-test, taking into account that the aim of the study was to compare unbound populations on a quantitative measurement scale with a symmetric distribution of the trait. The statistical dimension adopted for this work was expressed in the formula $M \pm \sigma$, where M is the arithmetic mean and σ is the standard quadratic deviation. We compared the degrees of freedom of feature f (in our case $f=21$) and the calculated value of the t-test with a table of critical values of the t-test. If the calculated value was equal to or exceeded the table values, the differences were considered statistically significant ($p<0.05$). If necessary, the coefficient of variation of characteristic Cv was analyzed.

Results

The duration of the clinical training stage was significantly different between group A (clinical-based) and group B (simulation-based) residents. Residents from group A took part in 15,08 ± 1,83 anesthesia before they were allowed, according to the score giving by instructors, to proceed to the evaluation stage of the study. Group B residents required only 7,27 ± 1,19 anesthesia for the same purpose. An important factor in the educational process, according to our observations, is the possibility of predictability of learning. In the simulation clinic, anesthesia at the robotic simulation complexes was performed according to a pre-approved plan without long breaks between sessions. In operating the same training largely depended on the plan of operations, the severity of the patient's condition and the presence of patients with certain pathology (Figure 1).

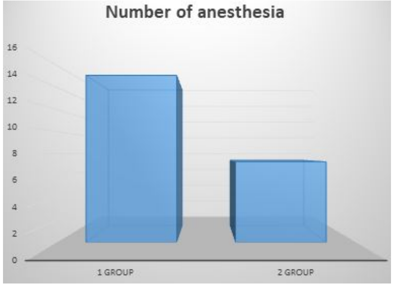

Figure 1: The number of anesthesia in which residents took part in the first stage of training.

We analyzed the intervals between sessions in two groups of observations (Figure 2). There were no statistically significant differences in this parameter. However, our attention was attracted by a wide spread in the first group: 2.83 ± 1.47 days with a high variation coefficient Cv=51.77%. Deviations of the average value, almost comparable with the average, indicated a significant spread in the schedule of educational anesthesia with the participation of the participants in a multi-profile hospital. Analysis of this parameter in the second group -1.91 ± 0.54 with a relatively low coefficient of variation of the sign Cv=28.25% indicates a greater predictability and accessibility of the simulated robotic anesthesia compared with educational anesthesia in clinical settings.

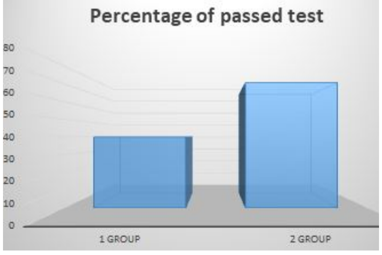

Figure 2: Intervals between training anesthesia, in both groups.

The theoretical component of the training programmers in both groups did not differ. At the first stage of the study, residents were admitted to a controlled learning participation in a real anesthesia (for the 1st group) or to robotic simulation anesthesia (for the 2nd group) after passing the standard theoretical cycle with the obligatory passing of the test according to the studied programme. In the course of the research, we analyzed the possibility of "transferring" the acquired knowledge and skills to clinical practice, using the 100-score test scale mentioned above for testing all residents at the second stage of training using a robotic simulation complex (Figure 3).

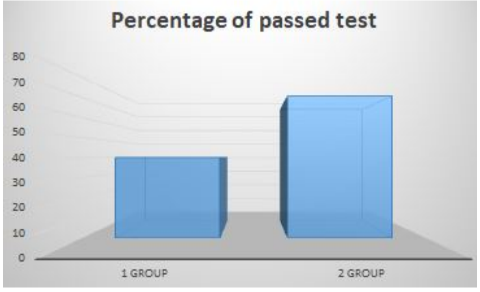

Figure 3: Results of the test at the 2nd stage of training.

The results of the evaluation stage showed a difference in the average rating between the two groups of participants. Thus, group A in average scored 40,08 ± 2,57 out of 100 points, whereas group B got 70,55 ± 7,1 points, which is also a significant difference in terms of statistics (p<0,05).

Discussion

Evidently, while planning and implementing the goals and objectives of this study, we tried to define the role and place of simulation training in the early stages of post-graduate training of specialist's anesthesiologists. The main interest for us was the level of continuity of the acquired skills in the transition from preclinical to clinical phase of their studying. During the analysis of the literature database, we met a variety of points of view on the effectiveness of a simulation study. Recently published studies show that training on the phantoms even of the elementary levels of realism, many manipulations such as: puncture and central venous catheterization, significantly improves the quality of the medical practice. It was also observed that testing this skill in the simulation center appears in decreasing in the number of the clinical difficulties, for instance pneumothorax [7].

Another research show that the use of simulators for training residents allowed them to significantly reduce the number of catheter-related infection of the circulatory system [2]. Exercising puncture and central venous catheterization allowed them to reduce the incidence of bloodstream infections by 10 times, which is comparable with the achievements of Florence Nightingale (1820-1910 years) in treating nosocomial infection during the Crimean War.

Imitation training has long been entered into the practice of not only anesthesiologists, but also doctors of other specialties, such as obstetricians, pediatricians, surgeons of various specialties [8-14]. This practice is used throughout the world.

The results of various studies are contradictory, but we think that simulation training is simply necessary, both at the stages of study and subsequently, in order to maintain the high qualification of specialist doctors. For example, a recent study has set a objectives to assess the relationship between quantitative and perceived cardiopulmonary

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resuscitation performance when healthcare providers have access to and familiarity with audiovisual feedback devices. Analyzing the results of this study, it was concluded that when conducting training on modeling a critical situation, the indicators of cardiopulmonary resuscitation did not meet the quality guidelines of the American Heart Association. Medical workers have a poor quality of medical care for cardiopulmonary resuscitation, despite the available and constant audio-visual information communication [9]. Some authors have separately investigated various simulation technologies, and methods for their manufacture, of a different nature and price category, to train important practical skills, for example, tracheostomy [11].

Other authors have separately studied not only modern simulation technologies represented by modern robots of varying degrees of realism, but the level of teachers and the teaching methods themselves, which is certainly very important in the formation of highly qualified medical personnel, both doctors and nurses [10]. In the resuscitation medicine we already generated enough experience in the simulation training that allows introducing this type of training in the educational process. For example, training in cardiopulmonary and cerebral resuscitation methods is traditionally carried out on mannequins, which has long become a classical principle of preclinical education and the basis for quality control of such training.

The theoretical part of the training programs in both groups did not differ. At the first stage of the study, residents were admitted to a controlled learning participation in a real anesthesia (for the 1st group) or to robotic simulation anesthesia (for the 2nd group) after passing the standard theoretical course with the obligatory passing of the exam according to the studied programme. During the study, we analyzed the possibility of "transferring" the acquired knowledge and skills to clinical practice, using the 100-score test scale mentioned above for testing all residents at the 2nd stage of training using a robotic simulation complex as criteria for assessing the level of training.

Our findings suggest that effective training on the simulators make residents safely conduct inhalation anesthesia on HIPS. The appearance of modern HIPS raised the efficiency of the learning process on a fundamentally different level. The acceleration of the educational process is important - it gives the opportunity for residents to quickly get basic skills for giving anesthesia, which further accelerate the mastery of the more complex skills and enable start independent work in the operating room earlier. Although we understand that the number of participated residents is not enough to get statistically reliable results, in our research we developed a universal algorithm for estimating the level of development for excellent anesthesia. The effectiveness of simulation technology is in accelerating, and most importantly in the quality of teaching basic skills in anesthesiology.

Moreover, the ability to analyze and change homeostatic constants in the simulator, for example, to influence the gas exchange processes, hemodynamics, rhythm disturbance, etc., allows us to give the features of a clinical training workshop. After that, residents become capable of providing the necessary manipulations in different clinical situations confidently. According to our observations, the study of the dynamics of physiological parameters and the impact on them, depending on the course of anesthesia on simulators creates optimal conditions for successful transition to clinical practice. For example, we conduct master classes for new anesthetic medicine and test the level of certified professionals. Additionally, using the simulator we can work through some "critical" scenario, for example a massive intraoperative bleeding, regurgitation and aspiration, the development of acute coronary syndrome, a power outage.

Our findings resonate with the published data [4,8]. The research of Hallikainen et al. shows that the use of simulation equipment for training medical students has a number of advantages over traditional methods of preparation. Students from "simulation" group showed better results with peripheral venous catheterization and intubation. Furthermore, during anesthesia they achieved clinically important exclusive results, such as the MAC, CO_2 exhalation, arterial oxygen saturation measured by pulse oximetry, the mean blood pressure. According to these indicators, the differences were significant and exceeded in the comparison group in a quarter [9]. In addition, the use of simulation systems for post-graduate trainings reduces the cost of care by decreasing the number of side effects difficulties [3,4].

During anesthesia, the resident focuses on the concentration of anesthetic on inhalation and exhalation. At the same time, the MAC value is displayed. Using different values of the flow, the learner can simulate a different rate of achievement of given concentrations of anesthetic. Also, depending on the flow, the cadet changes the desflurane consumption. In addition, the change in the concentration of anesthetic and, accordingly, the depth of anesthesia is accompanied by changes in the bispectral index and hemodynamic parameters, and the target values of these parameters can be designated arbitrarily or according to the scenario of the alleged "surgical intervention". After the supply of anesthetic is stopped and the MAC is reduced to a value of 0.3, the robot wakes up with a parallel increase in the values of the bispectral index. In addition, several "crisis" scenarios are being worked out in the simulation room: massive intraoperative bleeding, regurgitation and aspiration, development of acute coronary syndrome, and electricity shutdown.

Conclusion

Inclusion the simulation programme into the educational process of the residents has allowed us to make our own opinion about the effectiveness of the training of general anesthesia. We believe that the simulation technology for medical education is a link between the preclinical and clinical stages of training which do not have an alternative and provide good continuity while moving from one level to another. In addition, the simulation training for residents to use inhalation anesthesia using HIPS makes the educational programme more compact and predictable, unlike the traditional training. In addition, simulation training to use inhalation anesthesia more effectively prepares the student for clinical application skills than routine training.

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