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Comprehensive Cardiopulmonary Resuscitation Training for Foreign Medical Students

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Summary

The purpose of this study was to assess acquired knowledge and practical skills in foreign medical students (FMS) after theoretical and practical training in cardiopulmonary resuscitation.

Material and methods. We conducted a prospective randomized trial «Simulation-based CPR training among international medical students: perspectives for medical education» involving students undergoing training in the 31.05.01 specialty — General Medicine in English. Sealed envelope randomization was used to assign the participants (N=71) to 3 groups. European Resuscitation Council (ECR) educational Guidelines for Resuscitation was studied by students of all 3 groups. Group 1 (N=21) students did not receive additional training materials and practices. Group 2 (N=25) students were additionally provided a link to a video lesson on CPR on the ECR YouTube channel. Students from Group 3 (N=25) were additionally involved in developing 3 mind maps: on the anatomy and physiology of the heart and CPR algorithm. All participants underwent theoretical training at the 1st stage, and «Basic Cardiopulmonary Resuscitation and Automated External Defibrillation (AED)» simulation training at the second stage. At the end of the course, students' practical skills in performing continuous chest compressions were examined.

Results. Most examinees passed the ECR platform test on the first or second attempt. The participants of the simulation course demonstrated high learning efficiency: there were no statistically significant differences between the groups in the number and average frequency of compressions performed. Almost all participants correctly performed hand placement in the center of the chest for chest compression. Decompression phase efficiency reached 71–77% (P=0.811) in all groups. Most examinees performed chest compressions to the required depth and with the recommended frequency (P=0.62).

Conclusion. The educational project initiated by foreign students yielded positive results: acquired knowledge of CPR algorithm, gained essential techniques of performing chest compressions and giving rescue breaths, retained skills in using an automated external defibrillator, as well as teamwork skills.

Keywords: simulation training; cardiac arrest; training; chest compression; decompression; mind map.

Conflict of interest. The authors declare no conflict of interest.

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Introduction

Modern medical education is currently undergoing significant transformations aimed at improving the quality of students' education. The main objective of education is to train doctors who possess specific competencies and are capable and prepared for independent professional practice [1–4]. The rapidly evolving nature of the medical profession is driven by advancements in medical technologies, necessitating the re-engineering of the educational process [5–8], and the development and implementation of modern pedagogical technologies, including «hybrid» learning. The integration of educational engineering into pedagogical practice enables students to construct their individualized learning trajectory and utilize not only traditional teaching methods, but also electronic, simulation, and imitation training. Ultimately, this approach will contribute to the development of essential universal, general professional, and specialized competencies [1, 9, 10].

Currently, medical education is increasingly adopting a «hybrid» learning model that consists of four distinct components:

1. Theoretical component, which encompasses lectures (face-to-face or online), seminars, and practical sessions. Various technologies, such as mind maps, medical animations, and knowledge trees, are used to facilitate the acquisition of theoretical knowledge by the students.

2. Online learning, which involves the use of educational platforms that offer a wide range of learning resources and assessment tools. The main advantage of this approach is its flexibility, allowing

students to access information at any time and review materials repeatedly, as well as to have a level and final assessment. Additionally, students can independently tailor their learning trajectory on these platforms, which significantly enhances their motivation [11, 12]. An example of such a resource is the European Resuscitation Council (ERC) platform, specifically designed for teaching cardiopulmonary resuscitation (CPR).

3. Simulation training (ST), which is a rapidly evolving method of teaching practical clinical skills in simulated settings. Various clinical situations are modeled, providing an opportunity to systematically develop practical clinical skills without involving real patients [13, 14]. Various types of mannequins and simulators, from simple models to highly realistic computerized robots, are used for training. The advantage of this training is the ability to make mistakes without harming a real patient, to repeat the necessary algorithms based on clinical guidelines and standards of medical care, and to participate in the realization of sophisticated scenarios such as cardiac arrest or rare clinical cases, etc. Simulation training is integrated into the curriculum in a way that promotes the development of necessary practical skills and enables the successful application of acquired skills in clinical practice [1, 13, 14].

4. Clinical practical sessions, in which students apply the knowledge and experience gained in the previous stages.

Training students and physicians to perform effective cardiopulmonary resuscitation is a priority worldwide [14–17]. However, there are several issues that need to be addressed. These include fear of training, lack of dedicated teaching hours for CPR within the curriculum, large student groups that make it difficult to provide quality training during scheduled class time, missing pedagogical experience, and a lack of unified teaching doctrine for this subject. As a result, alternative learning opportunities arise, where students initiate their training on the topic of interest. The problem of cardiac mortality is a global issue, which is why international students studying in Russian medical universities seek high-quality education that includes both theoretical and practical training, including CPR training.

Publications focusing on the training of cardiopulmonary resuscitation (CPR) only reflect the results of simulation training and the evaluation of compression performance (depth, rate) and decompression quality. The theoretical preparation that precedes practical sessions is rarely discussed.

This study aims to examine the effectiveness of theoretical preparation and acquisition of practical skills during CPR training for international medical students.

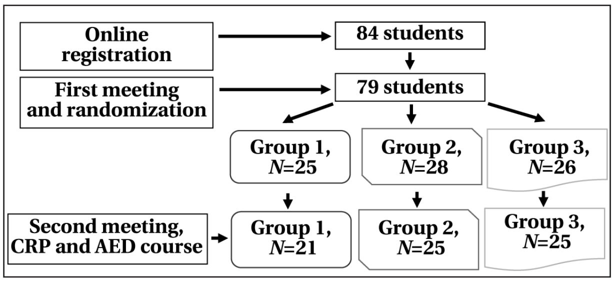

Fig. 1. The design of the prospective randomized trial.

Materials and Methods

We conducted a prospective randomized study on «Simulation-based CPR training among international medical students: perspectives for medical education.» The study included 71 international students learning general medicine (code within the Russian education system 31.05.01) in English. The participants were predominantly from India (68; 95.8%), with a smaller number from Brazil (2; 2.8%) and Ecuador (1; 1.4%). The study was approved by the Independent Ethics Committee of the Clinical Research Center of Immanuel Kant Baltic Federal University (Protocol of the IEC Meeting No. 39 dated April 26, 2023).

The prospective, randomized study design is shown in Figure 1. Participation was voluntary. Invitations and registration links to participate in the study were sent to all international students enrolled in years 2–5 of the specialty program. A total of 84 students registered and were invited to the first meeting. Of these, 79 students attended the meeting where the project was presented and all participants and organizers signed the informed consent form. The participants were then randomized into three groups using the envelope method.

Group 1 consisted of 25 students who studied the Instructor's Guide on the ERC platform.

Group 2 included 28 students who were provided with a link to a video lesson on CPR on the ERC YouTube channel in addition to the materials from the instructional manual on the ERC platform.

Group 3 comprised 26 students who studied the Instructor's Guide on the ERC platform and worked to create three mind maps on cardiac anatomy and physiology and the CPR algorithm.

The training was planned as part of the European Resuscitation Council (ERC) provider course, for which all participants were also registered on the platform.

The students in the study had no theoretical knowledge or practical skills in CPR. They were trained for the first time on this topic.

The activity was carried out in two phases: distance learning (theoretical training) and face-to-face training (simulation practice). The theoretical training differed between groups. Basic training for all groups included studying the European Resuscitation Council materials «Basic Life Support and Automatic External Defibrillation», an online testing on the ERC platform. The subsequent theoretical training depended on the group to which the participant was randomly assigned. Students were given 5 days to study all the material and complete the assignments.

The mandatory requirement for all participants was to pass the online test on the ERC platform. Everyone was required to complete the test one day prior to the start of the CPR provider course. Performance on the ERC platform was graded on a pass/fail basis with a passing score of ⩾80%. In the event of a failed attempt, participants were given the opportunity to retake the test up to 5 times until they achieved a passing score. The following indicators were used to evaluate test performance: number of attempts, maximum total score, and time taken to complete the test.

The second meeting of the project was a practical stage, which consisted of simulation training on «Basic life support and automated external defibrillation». This training was conducted at the Regional Resource Center for Simulation Education and Accreditation in Medicine, under the Department of surgical disciplines at the Institute of Medicine and Life Sciences of Immanuel Kant Baltic Federal University.

A total of 71 students participated in the practical session, divided into the following groups:

- Group 1: 21 students, including 11 males (52.4%) and 10 females (47.6%).
- Group 2: 25 students, including 8 males (32%) and 17 females (68%).
- Group 3: 25 students, including 10 males (40%) and 15 females (60%).

The Braydenpro manikin (Innosian Inc., Korea) was used for training. This manikin is designed to teach basic cardiopulmonary resuscitation and provides visual light control feedback on the effectiveness of chest compressions, as well as independent assessment of the quality of chest compressions, including correct hand placement, compression rate and depth, and decompression effectiveness. In addition, the AED Trainer XFT-120C+ (Shenzhen XFT Medical Limited, China) was used for defibrillation training.

At the end of the course, the practical skill of performing continuous chest compressions was evaluated. During the examination, male participants performed 120 continuous compressions, while female participants performed 90 compressions. Criteria for the effectiveness of CPR included proper hand placement in the middle of the chest, compression rate of 100–120 per minute, compression depth of 5–6 cm, and complete decompression.

After completing the training, an online survey was conducted to assess participant satisfaction. The students answered the following questions:

1. Was the theoretical preparation important for you?
2. Was the online course on the ERC platform helpful during the training process?
3. How was the overall atmosphere during the course?
4. Did you acquire the necessary theoretical knowledge that contributed to effective simulation training?
5. Did you acquire the necessary practical skills to conduct CPR and use AED?
6. Did you feel a constant connection with the course organizers and instructors?

All stages of the training were conducted in English.

Statistical analysis. Statistical analysis of the collected data was performed using Jamovi version 2.3.21 software package for Windows. The normality of the distribution of variables was assessed using the Kolmogorov–Smirnov test with Lilliefors correction. For data with a normal distribution, the mean *(M)* and standard deviation *(SD)* were calculated. For quantitative variables with non-normal distribution, the median *(Me)* and interquartile range *(Q1; Q3)* were determined. Qualitative variables were analyzed by calculating the percentage of each value. Categorical variables were compared using the Pearson chi-squared test, and an unpaired *t*-test was used to determine group differences in continuous variables. One-way analysis of variance (ANOVA) was used to compare groups. A two-tailed *P*-value was not used. Differences between groups were considered significant at $P<0.05$.

Results

All criteria for inclusion in the study were met by 71 international students, including 42 (59.2%) females and 29 (40.8%) males. Each group consisted of students studying in the 2nd to 5th year. The distribution of participants by year is shown in Fig. 2. In all groups, the maximum number of participants were studying in the 4th year, with the proportion of 5th year students being 2.3 times lower. Almost

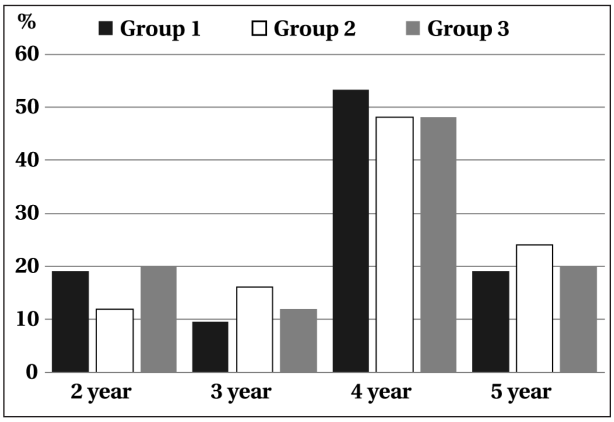

Fig. 2. Categorization of participants based on their academic year of study.

30% of participants were studying in the 2nd and 3rd years.

The level test on the ERC platform (Fig. 3) showed that the majority of students in all groups passed the test on their 1st or 2nd attempt. In the 3rd group, 4 students (16%) made 4 attempts, while in the 1st and 2nd groups, 5 students made more than 5 attempts.

The time taken to complete the test varied significantly among the groups. In the 1st group, the range was from 16 to 305 minutes, with a median time of 49.5 [30; 79] minutes. In the 2nd group, the time ranged from 10 to 161 minutes, with a median time of 49 [24; 87] minutes. In the 3rd group, students spent between 10 and 182 minutes on the test, with a median time of 61 [28; 83] minutes. No significant differences were found between the groups (P=0.996).

During the practical session on basic life support and automated external defibrillation, students learned the management algorithm for cardiac arrest and the rules of effective and safe use of AED. Attention was paid to the correct placement of hands, compression depth and rate, and complete decompression when performing chest compressions. The main results of the assessment of compression accuracy are presented in Fig. 4.

No significant differences were found between the groups in terms of the number of compressions performed and their average rate. The mean overall score was practically the same (P=0.673).

Central hand placement was performed by almost all students. The efficiency of decompressions in the groups was 71–77% (Fig. 5). There were no significant differences in these parameters between the groups (P=0.811).

Figure 5 shows the results of compression depth performance. In group 1, 13 (62%) students performed 90–100% of compressions to the depth of 5–6 cm, 5 (23.8%) students performed 70–89% of compressions to the required depth and 3 (14.3%) students performed less than 69% of quality compressions, the rest performed compressions to a depth of less than 5 cm. In group 2, 15 (60%) students performed 90–100% compressions to the required depth, 6 (24%) had effective 70–89% compressions and 4 (16%) students performed less than 69% quality compressions. In group 3, 13 (52%) students performed 90–100% compressions to the required depth, 8 (32%) had effective 70–89% compressions and 4 (16%) students performed less than 69% quality compressions (Fig. 6, *a*). No significant differences were found between the groups in terms of quality of compression depth (P=0.62).

Optimal blood circulation is achieved not only by the depth of compressions but also by their rate. Fig. 6, *b* illustrates the performance of chest compression rate in the groups.

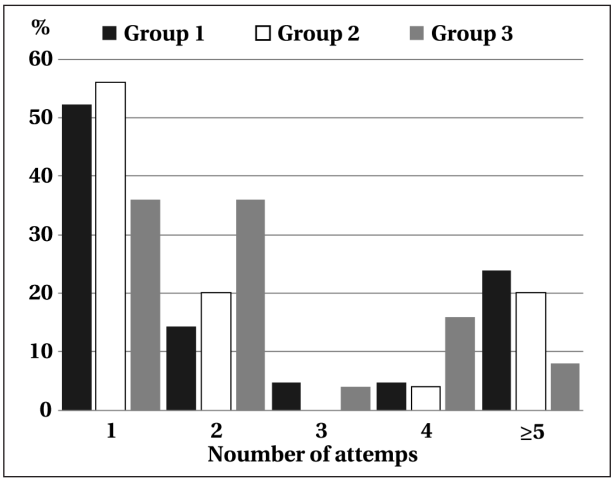

Fig. 3. Number of attempts at passing the test on the ERC platform.

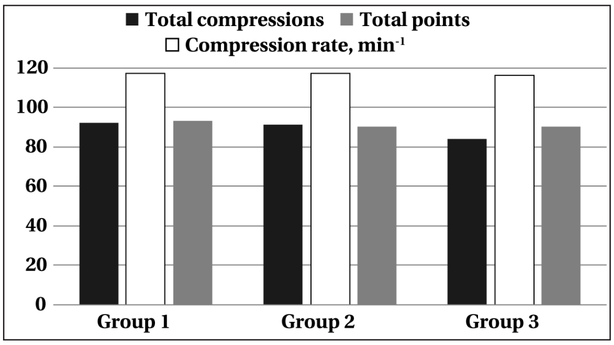

Fig. 4. Main training results.

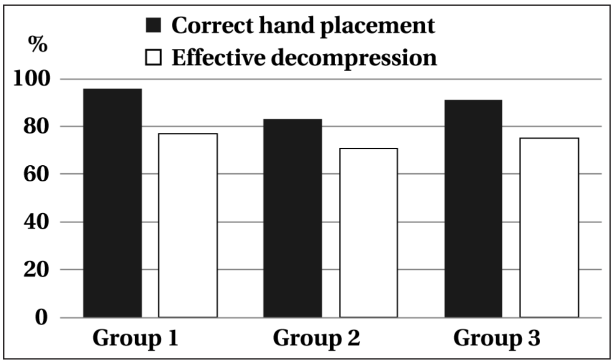

Fig. 5. Assessment of hand placement and decompression in the study groups.

In group 1, 13 (62%) students performed 70–100% of compressions with a rate of 100–120 min^{-1}, while 8 (38%) students performed 50% of compressions with a rate greater than 120 min^{-1}. In group 2, 11 (44%) students performed 70–100% of compressions at a rate of 100–120 min^{-1}, 11 (44%) students performed 50% of compressions at a rate greater than 120 min^{-1}, and 3 (12%) students performed 50% of compressions at a rate less than 100 min^{-1}. In group 3, 13 (52%) students performed 70–100% of compressions at a rate of 100–120 min^{-1}, 9 (36%) students performed 50% of compressions at a rate greater than 120 min^{-1}, and 3 (12%) students performed 50% of compressions at a rate less than 100 min^{-1}. There were no significant differences in the rate of compressions between the groups (*P*=0.652).

Students who performed CPR at a rate of more than 120 compressions per minute had lower compression depths and a lower percentage of complete decompressions. The survey revealed that theoretical preparation prior to the provider course was important for 20 (95.2%) students in the first group, 25 (100%) participants in the second group, and 23 (92%) in the third group. Participants in all groups noted that the theoretical course on the ERC platform was helpful during the learning process. Participants in all groups also reported that they acquired the necessary practical skills to perform CPR and use AEDs, and found the course convenient and conducive to material assimilation. 17 (80.9%) students in the first group, 20 (80%) in the second group, and 25 (100%) in the third group felt a strong connection to the instructor and course organizers. To better understand the role of alternative materials/methods in theoretical training, students in the second and third groups were asked additional questions. When asked, «Do you think the videos helped you learn and improved your knowledge?» 100% of the students in the second group answered «yes». When students in the third group were asked, «Do you believe that the mind maps facilitated your learning process?» 87.5% of the students answered «yes» and 12.5% answered «more yes than no». None of the students had difficulty creating mind maps on the topic being studied.

A sample mind map is shown in Fig. 7. The map systematizes and presents detailed information about cardiac physiology. It is notable for its in-depth exploration of the topic and emphasis on key points, such as the detailed structure of the heart, direction of blood flow, characteristics of systole, diastole, and others. The author of the mind map used his own images and notes.

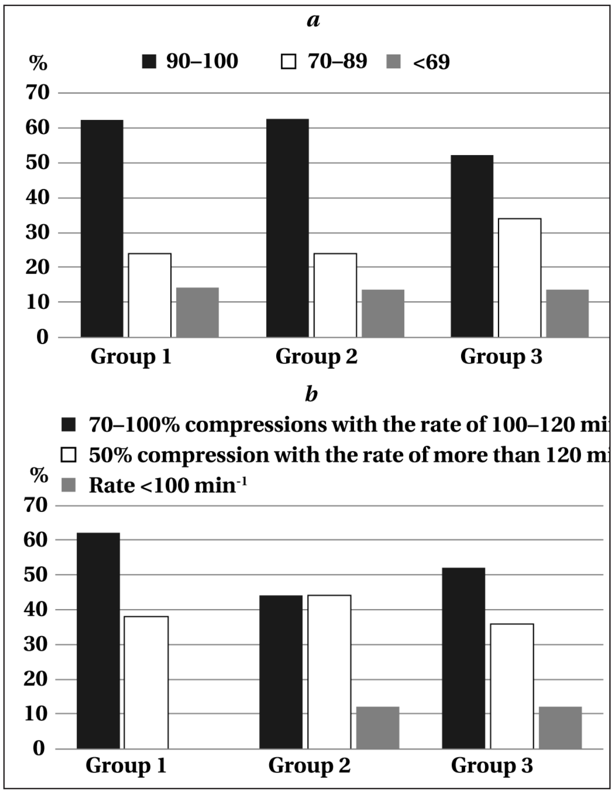

Fig. 6. Student performance in chest compression depth *(a)* and chest compression rate *(b)*.

Discussion

Training in cardiopulmonary resuscitation for sudden cardiac arrest is expanding beyond the «Anesthesiology, resuscitation and intensive care» subject, which is only taught in the 6th year of the internal medicine curriculum. This training is becoming increasingly important for international students in years 2–5, as the high mortality rate from cardiac causes is often due not only to high morbidity [18, 19], but also to reduced availability of quality medical care. Not all medical professionals know how to perform CPR when cardiac arrest occurs right in front of them, which increases the relevance of training medical professionals, including future physicians [11, 12, 20].

Training international students to perform high-quality CPR is a priority in higher medical education. Therefore, many authors emphasize the need for prospective research among students in higher medical institutions focusing on CPR skills training [20–22].

An integrated approach to CPR training should include two components, i.e., theoretical preparation and practical training in a simulation center. Theoretical preparation prior to hands-on training plays a critical role because it requires a thorough understanding of both the CPR algorithm and cardiovascular anatomy and physiology. This enables the physician performing CPR to gain a better understanding of the mechanisms of cardiac arrest, assess the effectiveness of resuscitation, and develop a treatment plan for the patient.

For theoretical preparation, educational materials, video resources, and concept maps can be used to enhance learning effectiveness [16, 17, 23–25].

The European Resuscitation Council (ERC) has developed and continuously updates guidelines for cardiopulmonary resuscitation (CPR) [23], which have been successfully integrated into the training process for specialists in many countries, including the Russian Federation. The ERC manual serves as the basis for learning the CPR algorithm and covers key principles such as the importance of proper hand placement, compression and decompression depth and rate. Prior to simulation training, theo-

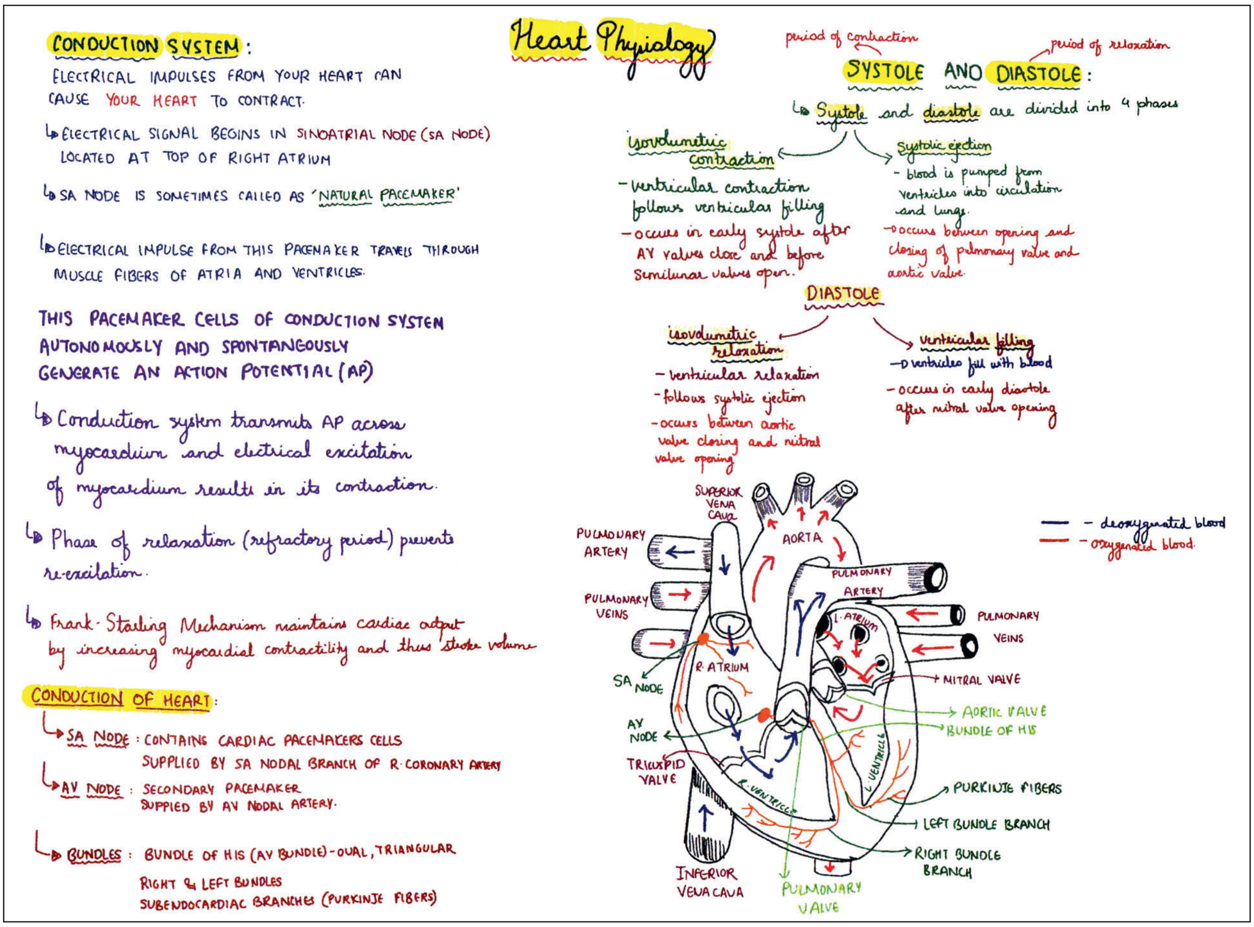

Fig. 7. Example of a mind map on cardiac physiology.

retical knowledge is assessed through an online platform. Tests conducted on the ERC platform showed that students who participated in the training had a good level of theoretical preparation, as the majority of participants passed the test on their first or second attempt. Although it was recommended not to take more than 5 attempts at the test, some students took the test repeatedly until they obtained a positive result, indicating their high motivation to learn. The time taken to complete the test varied widely, demonstrating the students' interest in this method of knowledge assessment.

The ERC manual served as the basic educational resource for all students. The video resources and mind maps provided a supplementary tool for two groups of participants, allowing for detailed and repeated viewing of all phases of resuscitation, key moments of performance, and technical accuracy. The use of mind maps helped students organize their knowledge of cardiovascular anatomy and physiology. The research results showed that theoretical preparation prior to practical sessions, regardless of its form, was effective. Students in all groups noted the usefulness of the theoretical course. Moreover, the students had a positive attitude toward watching the video and creating mind maps, despite the additional time required compared to the first group of students. All participants agreed that the training improved their knowledge and helped them master the CPR algorithm. The simulation training was the culmination of the training because it allowed for the development of technical skills necessary for practical medical activities [20–22]. During the simulation, participants learned to perform chest compressions at a specific depth and rate as well as to deliver decompressions. Some participants encountered a problem with a high compression rate, resulting in reduced depth. By analyzing their results, they understood that the quality of CPR decreases significantly in such cases. Collaboration between the instructor and students helped to improve the results. It is important to note that the training environment was friendly, and the organizers and instructors fostered a feeling of strong connection between students and teachers. The project participants rated all the proposed teaching methods positively.

The study limitation includes the lack of a priori sample calculation.

Conclusion

The educational project initiated by the international students has shown promising results, regardless of the theoretical background of the students. These results include the mastery of the cardiopulmonary resuscitation algorithm, the development of technical skills in chest compressions and ventilations, the competence in the use of an automated external defibrillator, and the promotion of teamwork skills. Several resources were used to prepare for the hands-on sessions, including a teaching manual, video resources, and mind maps.

The integrated approach to student education plays an important role in developing essential theoretical knowledge and practical skills.

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