Illuminations

A simple hand mnemonic for teaching the cardiac cycle

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Introduction

Knowledge of the cardiac cycle, an important topic in the physiology of the cardiovascular system, is required by all healthcare students (9). The cardiac cycle, that is, the cardiac events that occur from the beginning of one heartbeat to the beginning of the next (7), is commonly recognized as one of the most difficult concepts in physiology (12, 16). Traditionally, the cardiac cycle is taught to undergraduates as a series of didactic lectures, followed by assessment in the form of a written test. These didactic lectures usually use PowerPoint slides, with pictures and animations. For instance, the Wiggers diagram is often used to teach the concept of the cardiac cycle in a cardiovascular physiology class. Teaching the cardiac cycle to students can be challenging for many teachers. Consider the Wiggers diagram, for example. This figure shows the different events during the cardiac cycle for the left side of the heart. The top three curves show the pressure changes in the aorta, left ventricle, and left atrium, respectively. The fourth curve depicts the changes in left ventricular volume, the fifth curve is the electrocardiogram, and the sixth curve is the phonocardiogram. It is especially important that the students study in detail this figure and understand the causes of all of the events shown (7). But the didactic lectures commonly used to present complex topics often fail to engage students, and, as a result, many students feel overwhelmed with all of the details and names involved (4).

There are several kinds of auditory, visual, and kinesthetic mnemonics. One variety of visual mnemonics is hand mnemonics, a simple visualization that can provide better and more understandable learning (8). Because of the large amount of information involved in the study of the cardiac cycle, a mnemonic strategy can be very helpful. We felt that a simple cardiac cycle hand mnemonic would further assist students in understanding this concept, as hand mnemonic associates the main information with some other cues and, therefore, can help to improve the memorization of these details (5, 11).

Hand mnemonic strategy can be easily incorporated in the classroom environment, and traditional didactic teaching of the cardiac cycle may be made more effective with the help of a hand mnemonic. Thus we introduced a hand mnemonic of the cardiac cycle to help students gain a better understanding of how the pump action of the heart works. In addition, we intended to provide a method to make it easier to learn some abstract concepts. The purpose of this illumination was to describe the cardiac cycle hand mnemonic and to present the perceptions of students about its use in an undergraduate cardiovascular physiology class.

Materials and Methods

Study participants. This study was conducted with 193 students from two consecutive classes of second-year medical students at Kunming Medical University in the fall semester of the 2018–2019 school year. These two classes were from the School of Basic Medical Science at Kunming Medical University. Every student in these two classes was enrolled in a 5-yr undergraduate program majoring in Clinical Medicine, and they had the same teaching syllabus. The topic covered was the cardiac cycle, and it was taught in a 1-h lecture in the fifth week of the academic calendar.

All procedures in the study presented here were approved by the Institutional Review Board of Kunming Medical University, and informed consent was obtained from all of the students in classes 1 and 2.

Study design. Two weeks before the cardiac cycle lecture, the hand mnemonic strategy and its use were explained to all students in classes 1 and 2, and they were then invited to participate or not to participate in the mnemonic intervention. Based on the choice of the majority of the students in each class, class 1 chose to incorporate the cardiac cycle hand mnemonic into their regular study strategy (intervention group, n = 82), whereas class 2 continued the traditional learning method (control group, n = 111). To assess the comparability of students in the intervention and control group, their first-year academic performance scores on exams were compared.

One week before the cardiac cycle lecture, preclass reading is assigned. The students in both groups were directed to study the cardiac cycle using a variety of ways, including textbooks, library, and the internet.

Based on preparation before class, a pretest assessment exercise was administered on arrival in the class, along with self-reported confidence level in the topic. Following the quiz, a theoretical class teaching a detailed description of the cardiac cycle was given. After the didactic lecture had been completed, students in the intervention group were taught the cardiac cycle using a hand mnemonic, whereas the control group studied the same topic using a self-directed study without discussion, and this self-learning mainly relied on the textbooks and the internet. The two groups of students, therefore, studied the same topic from the same teaching syllabus, but in a different way.

In the remainder of the class time, all of the students responded to the posttest assessment exercise and also self-reported their confidence level in the subject. Then the participants from the intervention group were asked to answer an evaluation questionnaire about the hand mnemonic strategy used.

Finally, after the posttest assessment, the students in the control group were invited to learn the cardiac cycle hand mnemonic, with the
help of instructor, if they so wished. The learning processes of the intervention group and the control group are shown in Fig. 1.

**Description of the hand mnemonic.** When the heart beats at the normal rate of 75 beats/min, the duration of each cardiac cycle is ~0.8 s (Fig. 2). The total duration of the cardiac cycle includes systole and diastole. The atrium contracts ahead of ventricular contraction, and the duration of atrial systole is 0.1 s. Then the atrium begins to relax, and the duration of atrial diastole is 0.7 s. Simultaneously, ventricular contraction starts; ventricular systole lasts for 0.3 s. The period after the contraction of the ventricles is ventricular diastole, and the duration of ventricular diastole is 0.5 s. During the 0.5 s of the ventricular diastole, the first 0.4 s coincide with atrial diastole. Then atrial systole starts and lasts for 0.1 s, which is the component of the next cardiac cycle. So the heart relaxes as a whole for 0.4 s. These changes are repeated during each heartbeat in a cyclical manner (7, 14, 17). In our class, the duration of each cardiac cycle is simplified into the following three components: atrial systole (which lasts for 0.1 s), ventricular systole (which lasts for 0.3 s), and whole heart relaxation (which lasts for 0.4 s).

In this activity, I used a hand mnemonic representing the atrium and ventricle. The instructor or student opened and closed his/her hands to mimic relaxation and contraction. The left forearm was assumed to be a portion of the vein, and the right forearm was assumed to be a portion of the artery. The connection parts of the two hands represented the atrioventricular valves, and the connection parts between right hand and right forearm represented the semilunar valves. This cardiac cycle hand mnemonic included the following three steps (Fig. 3). First, the instructor put the closed left hand in the upper position to demonstrate atrial contraction and the opened right hand in the connected lower position to demonstrate ventricular relaxation. At the same time the instructor counted “1,” which represented the duration of 0.1 s. In this step, the mnemonic mimicked the state of the atrial systole. To show the second step, the instructor opened his upper left hand to mimic atrial relaxation and closed his lower connected right hand to mimic ventricular contraction. Meanwhile, the instructor counted, “1, 2, 3,” which represented the duration of ventricular systole, ~0.3 s. Finally, to show the period of whole heart relaxation, the instructor opened both of his hands to represent the relaxation of the atrium and ventricle. Simultaneously, the instructor counted, “1, 2, 3, 4,” which represented the duration of whole heart relaxation, ~0.4 s.

Taking the ventricular cardiac cycle as an example, the following parts showed the further application of the cardiac cycle hand mnemonic. In scenario 1, immediately after ventricular contraction begins, ventricular pressure rises, then the ventricular pressure pushes the semilunar valves open, and blood pours out of the ventricle (7). What happens in this period in the hand mnemonic? In the second step of the cardiac cycle hand mnemonic, when we closed the lower right hand (which represented ventricle contraction), ventricular pressure increased, then the semilunar valves opened (which is represented by the connection parts between right hand and right forearm), and blood flowed into the artery (which is represented by the right forearm). The period before the opening of the semilunar valves is called the isovolumic relaxation period and then the ejection period. In scenario 2, at the end of systole, ventricular relaxation begins suddenly, intraventricular pressure decreases rapidly, then the atroventricular valves open, and blood flows into the ventricle (7). In the third step of the cardiac cycle hand mnemonic, we showed the period of whole heart relaxation. When we opened the lower right hand (which represented ventricle relaxation), ventricular pressure fell, then the atrioventricular valves (which are represented by the connection parts between two hands) opened, and ~80% of the blood flowed into the ventricle (which is represented by the right hand). The period before the atrioventricular valves open is the isovolumic relaxation period and then the ventricular filling period. In scenario 3, atrial systole is considered as the last phase of ventricular diastole. During this period, the atrium contracts, then atrial pressure increases, atroventricular valves have been opened, and an additional 20% of blood flows into the ventricle (7, 14). In the first step of the cardiac cycle hand mnemonic, we showed the period of atrial systole. When we closed the upper left hand (which represented atrial contraction), atrial pressure increased, the atroventricular valves (which are represented by the connection parts between two hands) kept the state of open, and ~20% of the blood flowed into the ventricle (which is represented by the right hand).

**Assessment.** Student mastery of the concept of the cardiac cycle was examined using multiple-choice questions, and the scores in the pretest and posttest assessment exercise were compared between the intervention and control groups. The pretest assessment exercise consists of six multiple-choice questions on various aspects of the cardiac cycle. The same questions were again presented in a multiple-choice format as the posttest assessment. In these tests, students could get one point for each correctly answered question and zero for an incorrect answer. So the total score of both tests is six. The self-reported confidence levels on each question were also assessed. The confidence level was self-graded using a 4-point Likert scale: 1 = very unsure, 2 = fairly unsure, 3 = fairly sure, 4 = very sure. During the whole process in this study, neither the intervention group nor the control group of students knew their scores in the pretest and posttest assessment exercise.

A questionnaire was distributed to the participants in the intervention group to estimate the additional cardiac cycle hand mnemonic strategy. The items in this questionnaire were mainly based on previous studies in medical education (3, 6), and some modifications have been made based on this study. *Items 1, 2, 3, 4, and 5 used a 5-point Likert scale, which ranged from strongly disagree to strongly agree. For *item 6, students were permitted to choose more than one option, and the last *item 7 was an open-ended question.*
Data analysis. For the data analysis, statistical analyses were performed using SPSS 13.0 software. Quantitative data were presented as means (SD) or percentage. Student’s t test (2-tailed) on test score performance and confidence level were performed to determine whether the strategy was effective. \( P \leq 0.05 \) was considered to be significant.

RESULTS

The average exam scores among students during the first academic year were 391.01 (SD 25.32) in the intervention group, and 396.15 (SD 31.32) in the control group. Comparison of students’ performance in the first academic year showed that there were no significant differences in the academic performance \( (P > 0.05) \), and this result suggested that scores were comparable between the two classes. The academic performance was based on the professional basic science course in systematic anatomy, histology and embryology, biochemistry and molecular biology, cell biology, and medical genetics.

When the assessment exercise was compared between the mnemonic intervention group and the control group, students in the intervention group had a higher score on the posttest assessment exercise \( (P < 0.001) \), but not on the pretest assessment exercise. In fact, the scores from the pretest assessment exercise were higher in the control group than in the intervention group \( (P < 0.01) \). Interestingly, however, when the self-reported confidence level scores were compared between the two groups, the students’ mean score of their confidence level on both the pretest assessment exercise and posttest assessment exercise was significantly lower in the intervention class \( (P < 0.01 \text{ and } P < 0.001, \text{ respectively}) \) (Fig. 4).

Considering their views about the cardiac cycle mnemonic, 77 students in the intervention group completed the survey, which represented a 93.90% response rate. The results of the first five items in the questionnaire are summarized in Table 1. In response to the questions, “The cardiac cycle mnemonic helped me to better understand the topic” and “I would recommend this mnemonic for future classes,” all students ranked the activity at ≥3 or higher, with mean score of 4.64 (SD 0.51) and 4.61 (SD 0.54), respectively. Most of the students (92.21%; \( n = 71 \)) considered that the mnemonic was clear and easy to follow, and 87.01% \( (n = 67) \) affirmed that this mnemonic was interesting and enjoyable. Finally, 72.73% \( (n = 56) \) of the participants considered that this type of educational approach was a new learning method that they have not used before.

In response to question 6, “With regards to understanding the cardiac cycle, this mnemonic ...” all of the participants considered the mnemonic as useful (Fig. 5). The students reported that the mnemonic strategy enabled them to visualize the abstract concept of the cardiac cycle and then helped them to understand the topic. Most of the students pointed out that they like this active learning method and found it interesting. The last item 7, “Comments including suggestions to the cardiac cycle mnemonic class,” was in an open-ended format. Of note was the low response to this question, only 48 participants replied. Terms such as “innovative,” “interesting,” “impressive,” “no change,” “continue,” and “I like your method” were the majority of the comments given by the students.

![Fig. 3. Hand mnemonic to show the cardiac cycle.](image_url)

In Fig. 3, hand mnemonic to show the cardiac cycle. Opened and closed hands mimic relaxation and contraction of the heart, respectively. A: atrial systole. B: ventricular systole. C: whole heart relaxation.
The students in the context of particularly difficult course material (2, accurate and may be especially effective when given to stu-
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different phases of the cardiac cycle. Therefore, designing a
key points of events during each cardiac cycle include 1) pressure gradient in the aorta, ventricle, and atrium; 2) state of atrioventricular valves and semilunar valves; 3) direction of blood flow; and 4) volume change of the ventricle and atrium. The students should study in detail all of these four key points in different phases of the cardiac cycle. Therefore, designing a teaching strategy to facilitate the learning of the cardiac cycle is required. Mnemonics are often used in education at the initial stage of knowledge acquisition. They may act in this early stage as scaffolding for more permanent schematic knowledge that develops as education advances. Instructor-provided mnemonics have the advantage of being consistently accurate and may be especially effective when given to students in the context of particularly difficult course material (2, 11). In this article, the students in the intervention group were introduced to use the hand mnemonic as a convenient external representation to learn the cardiac cycle. With the help of the cardiac cycle hand mnemonic, the students improved their understanding of the phases of the cardiac cycle, atrial state, ventricular state, state of atrioventricular valves and semilunar valves, and state of blood flow in the cardiac cycle, respectively. The teacher observed that the concept of the cardiac cycle, which was not understood so easily by the students, seemed to become more understandable in the mnemonic class. In this way, it would not be surprising if the students in the intervention group performed significantly better on the posttest assessment exercise than students in the control group, although the students in both groups attended the same courses with the same syllabus and obtained comparable scores during their first academic year. These results reiterate similar findings obtained by a number of other studies that mnemonics help to improve student performance (13, 15).

In many teachers’ experience in practice, students usually study after the lecture, not before (1). In this study, although both groups were recommended to study the cardiac cycle before the lecture, the findings indicated that the students’ preparation of the topic was insufficient, in both the intervention group and the control group.

The surprising result in our work was that the self-reported confidence levels in the posttest were significantly higher in the control group. Some studies in medical research have equipped multiple-choice questions with a confidence level. This allows teachers to differentiate between students who are competent (i.e., correct answer paired with high confidence), who are guessing (i.e., correct answer paired with low confidence), who have a lack of knowledge (i.e., incorrect answer paired with low confidence), and who have a potential misconception (i.e., incorrect answer paired with high confidence) (16). In the intervention group, 10.29% of the answers in the posttest assessment exercise were incorrect but paired with high confidence (i.e., potential misconception). In contrast, the percentage increased to 21.81% in the control group. The higher self-reported confidence levels in the control group in the posttest assessment exercise may be partly explained by the high percentage of potential misconception. Clearly, more research is required to further investigate the relation between confidence level and performance.

The survey given to the students in the intervention group indicated that the response to the questionnaire was overwhelmingly favorable. The students regarded the mnemonic as an innovative and simple learning method and felt that it

### DISCUSSION

The results of this study suggested that the use of the cardiac cycle hand mnemonic improved students’ learning about the concept of the cardiac cycle. In addition, the students were satisfied with this hand mnemonic learning strategy.

There are many difficulties that the students may encounter in learning the concept of the cardiac cycle. For example, the key points of events during each cardiac cycle include 1) pressure gradient in the aorta, ventricle, and atrium; 2) state of atrioventricular valves and semilunar valves; 3) direction of blood flow; and 4) volume change of the ventricle and atrium. The students should study in detail all of these four key points in different phases of the cardiac cycle. Therefore, designing a teaching strategy to facilitate the learning of the cardiac cycle is required. Mnemonics are often used in education at the initial stage of knowledge acquisition. They may act in this early stage as scaffolding for more permanent schematic knowledge that develops as education advances. Instructor-provided mnemonics have the advantage of being consistently accurate and may be especially effective when given to students in the context of particularly difficult course material (2, 11). In this article, the students in the intervention group were introduced to use the hand mnemonic as a convenient external representation to learn the cardiac cycle. With the help of the cardiac cycle hand mnemonic, the students improved their understanding of the phases of the cardiac cycle, atrial state, ventricular state, state of atrioventricular valves and semilunar valves, and state of blood flow in the cardiac cycle, respectively. The teacher observed that the concept of the cardiac cycle, which was not understood so easily by the students, seemed to become more understandable in the mnemonic class. In this way, it would not be surprising if the students in the intervention group performed significantly better on the posttest assessment exercise than students in the control group, although the students in both groups attended the same courses with the same syllabus and obtained comparable scores during their first academic year. These results reiterate similar findings obtained by a number of other studies that mnemonics help to improve student performance (13, 15).

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### Table 1. Responses of the participants to the cardiac cycle mnemonic questionnaire

| Questionnaire Item                                                                 | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree | n (%) | n (%) | n (%) | n (%) | n (%) | Mean (SD) |
|-----------------------------------------------------------------------------------|----------------|-------|---------|----------|------------------|-------|-------|-------|-------|-------|-----------|
| The cardiac cycle mnemonic was clear and easy to follow.                          | 43             | 55.84 | 28      | 36.36    | 5                | 6.49  | 1     | 1.3   | 1     | 0     | 4.47 (0.68) |
| The cardiac cycle mnemonic was interesting and enjoyable.                         | 36             | 46.75 | 31      | 40.26    | 9                | 11.69 | 1     | 1.3   | 1     | 0     | 4.32 (0.73) |
| This was a new learning method which I have not used before.                       | 32             | 41.56 | 24      | 31.17    | 12               | 15.58 | 9     | 11.69 | 0     | 0     | 4.03 (1.03) |
| The cardiac cycle mnemonic helped me to better understand the topic.              | 50             | 64.94 | 26      | 33.77    | 1                | 1.3   | 0     | 0     | 0     | 0     | 4.64 (0.51) |
| I would recommend this mnemonic for future classes.                                | 49             | 63.64 | 26      | 33.77    | 2                | 2.6   | 0     | 0     | 0     | 0     | 4.61 (0.54) |

Values are n, no., and percentage of responses and mean (SD); n = 77 students who returned the completed questionnaire (93.90% response rate). Responses were scored using a 5-point Likert scale, where 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree.

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**Fig. 5.** Student response on the usefulness of the cardiac cycle mnemonic.
facilitated their learning of the concept of the cardiac cycle. Meanwhile, the students reported that they enjoyed this learning experience and would recommend this strategy for future classes. One explanation for the response from the participants is that, although a large number of animations dealing with cardiac cycle are available, the live hand mnemonics of the cardiac cycle provided an opportunity for the learning to be more interactive and fun. The participants enjoyed this intervention, because this intervention made the learning process both informative and enjoyable (10).

Our hand mnemonic strategy in teaching the cardiac cycle may require more substantiated evidence to validate its efficacy. There are limitations to our study. First, this research was conducted with two different consecutive classes in the cardiac cycle class in our school. Although students in both groups attended the same courses with the same syllabus during their first academic year, and they experienced the same academic examination and obtained comparable scores, it is difficult to control the variations between two classes. Second, we only evaluated the immediate effect of the cardiac cycle hand mnemonic on students’ assessment exercise score.

In conclusion, the cardiac cycle hand mnemonic could be used to teach the concept of the cardiac cycle, and the demonstration helped students to understand better this abstract concept. Moreover, this simple mnemonic could be easily incorporated into a theory lecture and make a didactic lecture more effective.

GRANTS

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DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the authors.

AUTHOR CONTRIBUTIONS

H.B. conceived and designed research; H.B. and Jun Li performed experiments; Y.B., Jun Li, S.X., Jiao Li, and B.J. analyzed data. H.B. interpreted results of experiments; H.B. and X.S. prepared figures; H.B. drafted manuscript; H.B. edited and revised manuscript; H.B. approved final version of manuscript.

REFERENCES

1. Albuquerque FDS, Assis TS, Oliveira Júnior FA, Freitas MR, Sá RCDSE, Martins VJB, Lins LSĐS, Araújo JS, Sousa NAE, Gouveia RLB. Effect of the use of a model with peer instruction for the teaching of membrane potential and action potential. \textit{Adv Physiol Educ} 42: 661–667, 2018. doi:10.1152/advan.00110.2018.
2. Bellezza FS. Mnemonic Methods to Enhance Storage and Retrieval. San Diego, CA: Academic, 1996.
3. Bhaskar A, Oommen V. A simple model for demonstrating the factors affecting glomerular filtration rate. \textit{Adv Physiol Educ} 42: 380–382, 2018. doi:10.1152/advan.00195.2017.
4. Carvalho H. A group dynamic activity for learning the cardiac cycle and action potential. \textit{Adv Physiol Educ} 35: 312–313, 2011. doi:10.1152/advan.00128.2010.
5. Cheng WC, Lin XZ, Chen CY. Using modern teaching strategies to teach upper abdominal sonography to medical students. \textit{J Chin Med Assoc} 76: 395–400, 2013. doi:10.1016/j.jcma.2013.03.011.
6. Giuliani MJ, Lujan HL, DiCarlo SE. Peer instruction enhanced student performance on qualitative problem-solving questions. \textit{Adv Physiol Educ} 30: 168–173, 2006. doi:10.1152/advan.00133.2006.
7. Hall JE. Textbook of Medical Physiology (12th ed.). Peking, China: Peking University Medical Press, 2012.
8. Hosseini SM. A useful hand mnemonic to demonstrate ion channel gating. \textit{Adv Physiol Educ} 42: 321–323, 2018. doi:10.1152/advan.00080.2017.
9. Marcondes FK, Moura MJ, Sanches A, Costa R, de Lima PO, Groppo FC, Amaral ME, Zeni P, Gavião KC, Montrezor LH. A puzzle used to teach the cardiac cycle. \textit{Adv Physiol Educ} 39: 27–31, 2015. doi:10.1152/advan.00116.2014.
10. Mathew AJ, Chandrasekaran N, Oommen V. All play and no work: skits and models in teaching skeletal muscle physiology. \textit{Adv Physiol Educ} 42: 242–246, 2018. doi:10.1152/advan.00163.2017.
11. McCabe JA, Osha KL, Roche JA, Susser JA. Psychology students’ knowledge and use of mnemonics. \textit{Teach Psychol} 40: 183–192, 2013. doi:10.1177/0098628313487460.
12. Modell HI. Helping students make sense of physiological mechanisms: the “view from the inside”. \textit{Adv Physiol Educ} 31: 186–192, 2007. doi:10.1152/advan.00079.2006.
13. Qureshi A, Rizvi F, Syed A, Shahid A, Manzoor H. The method of loci as a mnemonic device to facilitate learning in endocrinology leads to improvement in student performance as measured by assessments. \textit{Adv Physiol Educ} 38: 140–144, 2014. doi:10.1152/advan.00092.2013.
14. Sembulingam K, Sembulingam P. Essentials of Medical Physiology (3rd ed.). New Delhi: Jaypee Brothers Medical Publishers, 2004.
15. Thompson M, Johansen D, Stoner R, Jarstad A, Sorrells R, McCormick ML, Justice W. Comparative effectiveness of a mnemonic-use approach vs. self-study to interpret a lateral chest X-ray. \textit{Adv Physiol Educ} 41: 518–521, 2017. doi:10.1152/advan.00034.2017.
16. Versteeg M, Wijnen-Meijer M, Steenwind P. Informing the uninformed: a multitier approach to uncover students’ misconceptions on cardiovascular physiology. \textit{Adv Physiol Educ} 43: 7–14, 2019. doi:10.1152/advan.00130.2018.
17. Zhi DN, Wang TH. \textit{Physiology} (8th ed.). Peking, China: People’s Medical Publishing House, 2015.