Planning, implementation, and evaluation of multicomponent, case-based learning for first-year Indian medical undergraduates

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INTRODUCTION

There is a general perception among the medical fraternity throughout the world that lecture-based teaching alone is insufficient to address all learners’ needs and is not suitable for teaching higher order skills, such as synthesis, analysis, and application, which are critical for medical practitioners (15, 38). There is a constant search by the medical educators for supplementary methods to traditional lectures for self-directed learning (6, 27, 29, 39). Realizing the need of the hour, curricular reforms are being recommended by the statutory bodies controlling medical education standards in many nations, including India, to ensure that students play an active role in the learning process and are prepared for life-long, self-directed learning (12, 16, 24, 30). Case-based learning (CBL) is one of the supplementary methods to traditional lecture-based curriculum, and it appears to be appropriate for medical undergraduates (12, 22).

CBL typically focuses on the discussion of patient case, and the fundamental concepts required for understanding the patient case are presented via lectures or readings before conducting case discussion in a CBL session (12, 19, 26). It is a small-group method in which learning objectives are predefined, and preparatory readings are assigned, while discussion among students and guided inquiry around case-related problems are still encouraged (31). Studies have reported that students generally enjoy the use of CBL sessions and appreciate the similarity of clinical cases to real-life scenarios (9, 21). The CBL method contributes to student learning by enhancing relevance, understanding of concepts, and problem-solving skills (35). Importantly, according to students’ self-evaluation, the CBL method helps them to make better connections between knowledge and clinical practice (14). Instructors also believe that case-based teaching motivates students and engages them actively in the learning process (5, 35).

While there are many studies that have demonstrated the application of case-based methods for subjects, such as pathology, medicine, and surgery (3, 13, 20, 23, 25, 33, 34, 37), only a few reports have used case-based teaching for basic science courses, such as physiology (4, 5, 8, 21). Nevertheless, CBL has been proposed to increase student understanding of physiological concepts and also of the clinical relevance of the concepts (5). Previously reported studies on conducting CBL activity were primarily based on clinical cases (3–5, 8, 20, 21, 25). We have planned and designed the proposed CBL activity using multiple components, with case discussion as the first component, followed by two components that were application exercises linked with the clinical case. Multicomponent CBL (MC-CBL) activity was implemented as an active learning session integrated with the ongoing lecture series on gastrointestinal physiology. In this paper, we share our experience of preparation, implementation, and evaluation of the MC-CBL.
method for teaching physiology to first-year medical undergraduates.

METHODS

Background

A total of 107 students enroll in the Bachelor of Medicine, Bachelor of Surgery (MBBS) course each year at All India Institute of Medical Sciences, New Delhi, India. These students attend preclinical courses, such as anatomy, physiology, and biochemistry, in the first year. The physiology course is organized into two semesters, with four major systems being taught in both first (cellular, neuromuscular, cardiovascular, and respiratory physiology) and second (neuro-, gastrointestinal, renal, and endocrine physiology) semesters. After approval from the Institutional Review Board, 3 h on February 1, 2019 were allotted for CBL, as a part of the gastrointestinal physiology teaching program for first-year MBBS, second semester, January to June 2019. The CBL session was preceded by traditional lectures to address the fundamental physiological concepts necessary for understanding the clinical case of peptic ulcer disease (PUD).

Pre-CBL Preparation

Three faculty members and nine instructors were involved in the process of preparation, implementation, and evaluation of MC-CBL method (Fig. 1). Four meetings were organized in the span of 1 mo, starting from December 29, 2018, for conducting the ultimate event, i.e., MC-CBL on February 1, 2019. Instructors were divided into small teams for preparing learning objectives and CBL components, as described below.

- First, six learning objectives for MC-CBL were framed (APPENDIX A).
- Three components, i.e., clinical case discussion, concept map, and critical thinking exercise, each for 1 h, were planned to address the learning objectives.
- For conducting clinical case discussion, a simulated case scenario of PUD that included a patient-doctor conversation closely mimicking a real-life scenario, with the history and clinical signs highlighting the physiological concepts covered during the lectures on gastrointestinal system, was developed by a team of instructors (APPENDIX B). A video of the clinical scenario visualizing the patient-doctor conversation (enacted by two instructors) was also

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**Fig. 1.** Sequence of events involved in the process of preparation, implementation, and evaluation of multi-component case-based learning (MC-CBL) method used in this study. MC-CBL was conducted using a simulated case scenario of peptic ulcer disease as a supplementary active learning session integrated with the lecture series on gastrointestinal physiology.
For conducting a concept map, a team of instructors developed a concept map for PUD (Fig. 2). Information necessary for successful completion of the concept map was provided in the lectures on the gastrointestinal system. The concept map was designed to focus on key physiological concepts, including the possible mechanisms that disrupt normal physiology in PUD and how certain treatments can help restore it.

For conducting critical thinking exercise, eight reason- and assertion-type multiple-choice questions were framed by a team of instructors to stimulate logical reasoning and problem-solving skills. Each question had a stem describing the background in brief, followed by reason and assertion statements (APPENDIX C). The concept map and multiple-choice questions developed by the instructors were verified independently for content validity by three faculty members before they were used in the finally accepted form.

**Participants**

According to the teaching program approved by Institutional Review Board, 66 first-year MBBS students participated in the MC-CBL activity on February 1, 2019. As per the teaching schedule, we had 3 h (9–10 AM, 2–4 PM) for the MC-CBL activity. Students were divided into nine groups, with each group comprising seven to eight students allotted to each instructor. Grouping was done, taking into consideration the academic performance of students, as denoted by first-semester scores in physiology, to ensure similar distribution of different grades of performers in all groups.

**MC-CBL Activity**

On the day of MC-CBL, 66 first-year MBBS students assembled in the demonstration room of the department at 9 AM. Instructors moved their respective group of students to the assigned venues for their groups within the department premises. Venues remained the same for all 3 h of MC-CBL. The learning objectives were presented at the very beginning of MC-CBL.

Clinical case discussion was conducted between 9 and 10 AM on February 1, 2019. The clinical case of PUD was projected as a video, and the printed version of the same was also supplied to the students. Students were allowed to work on the case presented to them as a group and could refer to their textbooks, lecture notes, journal articles, and soft tools, as well as take guidance from the instructor. Instructors raised questions with specific answers and guided the students to apply the physiological concepts taught to them in the lecture classes for solving the clinical case. The notion behind this directed case discussion was to guide the students to apply the knowledge and prevent frustration due to their limited experience in applying knowledge to clinical-based scenarios. At the end of the case discussion, students were informed by the instructors that the group and venue would remain the same for MC-CBL between 2 and 4 PM.

Concept map and critical thinking exercise were conducted in sequence between 2 and 4 PM on the same day. First, for the concept map, students in each group were instructed to work in two small teams. Students were allowed to consult resources of their choice to solve the concept map. Following team-based discussion, each group presented the completed concept map with explanations to their instructor. On an average, each group took ~30 min to complete the concept map. At the end of the concept map, the instructor discussed the correct answers with the students.

Critical thinking exercise was conducted after the concept map. Instructors supplied a printed copy of eight reason and assertion multiple-choice questions to each student in their respective groups. Students were allowed to refer to lecture notes, textbooks, soft tools, or any other resources to solve the questions. First, students were asked to solve the questions individually, and their responses were collected. Later, the students were instructed to discuss questions in the group and agree on the single, best answer for each of the questions. At the end of the critical thinking exercise, the instructor discussed the correct answers with the students.

The learning objectives were projected again at the end of the MC-CBL to receive confirmation from the students if those objectives were achieved, and the response was unanimously positive. Student feedback on MC-CBL was collected in a structured feedback form.

**Data Collection and Analysis**

The student feedback survey contained a series of four questions designed to evaluate the effectiveness of the MC-CBL method quantitatively, followed by a series of three open-ended questions designed to gather additional qualitative feedback from the students.

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![Fig. 2. The concept map, having two components, namely the concept map with blank boxes (A) and the list of propositions (B) to be used to appropriately fill up the blank boxes in A, was used during the case-based learning on peptic ulcer disease (PUD). The students were provided the list of propositions to complete the concept map. The instructions given to the students for concept map are as follows. 1) The control of gastric acid secretion involves the activity of a large number of physiological components. These components can be displayed as a concept map in which each node (shaded box) represents a component, and pairs of components are linked by a proposition (a word or phrase) that describes how the two components are related functionally. 2) You have been provided a concept map that displays gastric acid secretion. The propositions linking these concepts have been removed from the map and placed in the list. Your task is to enter each proposition in the list in the correct location. 3) The propositions can be used as many times as have been provided in the list.](link-to-image)
to receive suggestions from students on improving the MC-CBL method. Feedback inputs from instructors were collected for each of three CBL components on their experience of interactions with the students under the following topics: observations, challenges, and other special remarks. Instructors’ self-evaluations were also collected on their participation in the preparation for MC-CBL under the following topics: task involved, learning, challenges, and suggestions. Descriptive statistics on the quantitative data were carried out using SPSS version 20.0.

RESULTS

Student Feedback

The results of the student survey revealed that the majority of students agreed or strongly agreed that the MC-CBL method improved learning efficiency (64 of 65 students, 98.46%), promoted self-learning (65 of 66 students, 98.48%), helped to apply knowledge better than lecture (61 of 66 students, 92.42%), and helped in integrating basic and clinical science (64 of 65 students, 98.46%), (Fig. 3). Overall, the quantitative data of the students’ feedback survey revealed the positive effect of the MC-CBL method for teaching first-year medical undergraduates (Table 1). In support of this quantitative result, several comments for the open-ended questions on MC-CBL method are included below:

“Case discussion made the learning process more efficient.”
“CBL improves the way we apply our previous knowledge and better for memory.”
“I don’t feel sleepy. CBL method provides better interaction with teacher.”
“CBL generates interest. Makes us know our targets.”
“Clinical discussion helps in better retention of concepts.”
“CBL provides logical algorithm of thinking or tracking disease.”
“CBL promoted ingenuity of thought and better and long-lasting learning through interactive sessions.”

Instructor Feedback

Regarding the instructors’ experience of interaction with the students during each of the three CBL components, they found all three components to be effective in engaging students for active learning. Seven out of nine instructors, however, mentioned that the concept map promoted better group interactions and team building among students. Several comments from the instructors regarding their interactions with the students while conducting the three components of CBL were notable, as indicted below.

Comments on clinical case discussion.
“Students were engrossed in watching the video, the dialogues additionally helped in deciphering the symptoms and probable underlying causes of the condition.”
“Students could understand the importance of history taking and the process of forming the differential diagnoses.”
“Students discussed the case in terms of each symptom presented by the patient and looked up each sentence and correlated themselves with the physiology involved.”

Comments on concept map.
“Students formed groups and deliberated over the concept map with much interest. The discussions brought the stu-

CBL promotes curiosity. People are made to listen unlike lectures.”
“Time spent well. All topics should be taught using CBL method. Lectures are really boring!”

Five of sixty-six students (7.58%) responded neutral to the third question in the questionnaire (question 3: “CBL helped me to apply previous knowledge better than lecture”). The other three questions in the questionnaire received a neutral response by one student for each question (Fig. 3). No student graded the MC-CBL activity negatively (disagreed or strongly disagreed to any question in the questionnaire) (Fig. 3).

Table 1. Quantitative data of the students’ feedback survey

| Question No. | Question | Mean  | SD   | 95% CI for Mean | n  | %Agree |
|--------------|----------|-------|------|----------------|----|--------|
| 1            | Case-based learning improved my learning efficiency. | 4.71  | 0.49 | 4.59–4.83       | 65 | 98.46  |
| 2            | Case-based learning was helpful in promoting self-learning. | 4.70  | 0.50 | 4.58–4.82       | 66 | 98.48  |
| 3            | Case-based learning helped me apply previous knowledge better than lecture. | 4.65  | 0.62 | 4.50–4.80       | 66 | 92.42  |
| 4            | Case-based learning helped integrate basic science and clinical science. | 4.75  | 0.47 | 4.64–4.87       | 65 | 98.46  |

n, No. of students. CI, confidence interval.
Students having varying degrees of knowledge on the subject to more or less the same page.”

“Concept map was a good team building exercise. They debated, taught each other and came to final solution.”

“Students were divided in two small teams. They were provided concept map and directed to fill it after discussing within their teams. Students were most actively participating in this task.”

Comments on critical thinking exercise.

“The students were using logic and actively trying to solve the questions. Some students showed less interest in this task as compared to the other two components.”

“Provided a chance of self-evaluation for students. Discussion was interactive.”

“More of an individual than a group activity. Some of the answers were controversial, but they provoked interest.”

Instructors’ Self-Evaluation

Regarding the instructors’ experience of participation in the preparation for MC-CBL, they found it unanimously challenging, which many of them believed to be due to lack of previous exposure to various tasks, such as framing learning objectives, framing a case scenario, creating a concept map, framing reason- and assertion-type questions, and so on. Besides the difficulty involved in the preparation for MC-CBL, all of them appreciated it as a worthy learning experience.

DISCUSSION

Students’ response to the questionnaire survey revealed that MC-CBL provoked interest in them, as it allowed the application of the knowledge learned in lectures in a more appropriate context (92.42% positive response). Students felt that the addition of clinical relevance enhanced their learning efficiency (98.46% positive response). This is in agreement with Knowles’ (18) learning theory, which proposes that learning is more effective when learners are engaged in a relevant and realistic context. Students expressed positive views on their interaction within the group and with the teachers who promoted their active participation in the learning process (98.48% positive response). Many students mentioned that they were not sleepy during the MC-CBL session, as it was more interesting and engaging than lectures. Students believed that MC-CBL significantly contributed in integrating physiological concepts with clinical science, which could help in better retention of concepts (98.46% positive response). In line with the present study results, previous reports also found that the CBL method facilitated student learning by enhancing context relevance and improving integration of concepts (35). It is noteworthy that 5 of 66 students did not find MC-CBL to be helpful in applying previous knowledge better than lecture (7.58% neutral response). Why a few students were indeed similarly comfortable with both didactic lectures and CBL was, however, not investigated in the present study. It may, however, be concluded, based on the observed responses from students, that combining or supplementing didactic lectures with CBL would address students’ learning preferences better than any one of these methods alone (1, 5, 21).

In line with students’ feedback, instructors found all three CBL components to be effective in engaging students’ attention on learning. Previous studies have also reported similar observations from instructors on the students’ motivation and engagement during CBL (5, 35). Unlike previous reports on CBL, which have used case discussion as the solitary component (3–5, 8, 20, 21, 25), the MC-CBL method was used in the present study. Out of the three components implemented in MC-CBL, instructors appreciated the active participation of students more in the concept map. During the concept map, a group of seven to eight students with an instructor was further divided into two small teams of three to four students. Instructors believed that the small team size and the opportunity for discussions between two teams in a group were responsible for more active learning during the concept map. This is in agreement with the previous study, which found small discussion groups to be more effective than individual activity in a CBL environment (10).

The instructors had their first experience of conducting a CBL and found it challenging in terms of time, space, and efforts that were required for planning and implementing it. Faculties took effort to prime the instructors by actively involving them in the creation of resources for conducting the MC-CBL activity. Four meetings, for a total duration of 6 h, were organized by the faculties to ensure appropriate training of instructors to maintain uniformity in conducting MC-CBL. Instructors were also guided by the faculties through electronic group messages. Instructors felt rewarded after conducting MC-CBL, as it promoted self-learning among students, and they are now more interested in conducting MC-CBL projects for other systems in physiology. Nevertheless, it needs to be acknowledged that MC-CBL is more resource intensive compared with lectures, which is apparent from the present study, as it involved three faculty members, nine instructors, several hours of time for brainstorming and content development, and the infrastructure conducive for independent, small-group discussions. This is one of the downsides to MC-CBL, a reason for which it may not be feasible for some institutions.

The Medical Council of India (MCI), the regulatory body for medical education in India, has recommended curricular reforms in its Vision 2015 document for the undergraduates (23a). MCI recommends early clinical exposure of the students by starting the clinical training from their first-year course to orient them to national health scenarios, basic clinical skills, communication, and professionalism, and emphasizes the introduction of case scenarios for classroom discussion/CBL. Although CBL has been introduced in some medical colleges in India (2, 12), only one study has demonstrated it for teaching first-year MBBS students (12). Nevertheless, the results of these Indian studies are encouraging and in agreement with the present study.

The present study used a simulated case scenario. A previous study has involved a real patient in the design and implementation of CBL during the gastrointestinal course for second-year medical undergraduates (7). Authors found that involvement of real patients in CBL helped students in understanding the disease process, enhancing awareness of the complexity of patient care, providing an authentic learning experience, and eliciting a feeling of empathy. However, there are reports suggesting a few drawbacks of real-patient-based CBL that included patients’ concerns over recalling negative experiences, being judged, and feeling “used” or viewed as a representation of their disease rather than a person (17, 28, 32,
Thus using a simulated patient could avoid these potential issues in involving a real patient for CBL.

Limitations of the Study

We are not the first to use CBL for teaching physiology to first-year undergraduates (11, 12); however, we believe that this report on MC-CBL activity could be beneficial for medical teachers, as we have adopted a novel design for CBL by incorporating various components, such as case discussion using video of a case scenario, concept map, and critical thinking exercise. We identify three categorical limitations in the present study.

First, as this study was designed to evaluate students’ and teachers’ feedback inputs on supplementing lecture-based teaching with MC-CBL, it did not involve comparison of MC-CBL with any other traditional and active learning methods. Also, there was no control group in the present study.

Second, in the present study, the anonymity of students on the feedback forms was preserved by not instructing the students to provide their identity in any form, based on the assumption that this process could potentially affect the authenticity of feedback, as it might impede their free and critical inputs regarding the learning activities that they experienced. As a result, we could not study any decipherable common characteristics among the students from their feedback inputs. This issue may be addressed while designing similar studies on CBL in the future.

Third, the present project involved three faculty members, nine instructors, several hours of time for brainstorming and content development, and the infrastructure conducive for independent small-group discussions, which is possible in premier medical institutions. We have, however, not investigated any operating system appropriate for institutional scenarios with limited resources and large teaching load. Nevertheless, we believe that the proposed MC-CBL design can be modified to adapt the given specific infrastructure, manpower, and teaching program of the institute implementing it.

Conclusion

As physiology is considered to be the mother subject for all branches of medicine, its understanding is fundamental toward studying and practicing medicine. By integrating the knowledge from medical education literature and our own experience, we designed a MC-CBL activity comprising case discussion, concept map, and critical thinking exercise that provided an engaging learning experience for studying physiology to our students. Our study results indicated that the MC-CBL motivated students to develop self-directed learning, analytic, and problem-solving skills, which are considered critical for medical practice. Even though didactic lectures still serve as an effective method to educate a large number of students in a short span of time, the passive nature of lecture-based learning can benefit from the supplementation of CBL. Moreover, use of variety in the teaching formats is more effective than just depending on a single teaching method. In summary, the present study indicates that proper planning of students and teachers’ time, space, and efforts would lead to the successful implementation of CBL that would prime the medical students for clinical practice.

APPENDIX A: SPECIFIC LEARNING OBJECTIVES

After engaging in the content and activities for the case-based learning (CBL) session, students should be able to:
1. List the composition of gastric juice and their functions.
2. Explain the mechanism of gastric acid secretion.
3. Explain the three phases of gastric secretion and their regulation by neural, hormonal, and paracrine mechanisms.
4. Define gastric mucosal barrier.
5. State various factors that can disrupt the gastric mucosal barrier. Explain the mechanisms by which each of the factors disrupts the mucosal barrier.
6. Define peptic ulcer disease (PUD). State the physiological basis of the treatment and management of PUD.

APPENDIX B: SIMULATED CASE SCENARIO OF PUD

Mr. Vishal: “Hello doctor, my stomach has been aching, and it just keeps getting worse. I couldn’t even go to work today. Please help me.”

Dr. A: “Don’t worry sir, we’re here to help. Can I have your name and age please?”

Mr. Vishal: “I’m Vishal. I’m 35.”

Dr. A: “Tell me more about your abdominal pain Mr. Vishal. When did it begin? Is it turning more severe?”

Mr. Vishal: “It started around 4 AM. That’s when I had some cold milk as that usually helps and went for breakfast as usual. But there was no relief; in fact, it’s gotten worse.”

Dr. A: “Can you point out where you feel the pain?”

Mr. Vishal: (Places his hand on upper abdomen, could not point out exactly.)

Dr. A: “Is it restricted to that area or is it spreading anywhere?”

Mr. Vishal: “No, it’s just here.”

Dr. A: “Can you describe the pain for me.”

Mr. Vishal: “It’s like something is burning in here (points to upper abdomen) and it feels so full.”

Dr. A: “Is it sharp/dull, coming in bouts/continuous?”

Mr. Vishal: “It’s very vague, discomforting, continuous, and growing worse. Please help me.”

Dr. A: “Have you had vomiting/loose stools/fever?”

Mr. Vishal: “Twice I felt like whatever I had eaten was coming out. . . . It had bitter taste in my mouth.”

Dr. A: “Ever have spotted blood in your stools or vomitus?”

Mr. Vishal: “No.”

Dr. A: “Have you had such complaints before?”

Mr. Vishal: “I have been having a similar problem from past 4-5 months, especially after I eat, but it was never this bad.”

Dr. A: “Did you take any medication for it?”

Mr. Vishal: “Two months ago, I had a similar episode; I had consulted a doctor then. He had asked me to take a tablet in the morning an hour before food; he gave me a syrup too. I took that for a week, but stopped after I started feeling better.”

Dr. A: “Do you smoke? Do you take alcohol?”

Mr. Vishal: “Yes, just to get over the work stress . . . about 4-5 cigarettes a day. I don’t drink too much, just some beer on and off.”

Dr. A: “All right Mr. Vishal, please let me examine you.”

Examination findings: epigastric tenderness plus no abdominal rigidity/mass, no rebound tenderness, normal bowel sounds. Vitals: normal.

APPENDIX C: REASON AND ASSERTION MULTIPLE-CHOICE QUESTIONS

The instructions for choosing an option are as follows:
A. Both assertion (A) and reason (R) are true, and R is the correct explanation of A.
B. Both A and R are true, but R is NOT the correct explanation of A.
C. A is true, but R is false.
D. A is false, but R is true.
E. Both A and R are false.

The questions are as follows:

1. Whenever the patient skips meal in the morning, he develops severe heartburn.
   A: Severe heartburn in the morning results from high acid secretion due to high vagal activity in the morning.
   R: Food neutralizes the gastric acid.

2. The patient feels fullness in his stomach after having a fatty meal.
   A: Fat increases gastric emptying time.
   R: Fats coalesce into large globules and adhere to solid food particles, which are emptied at a slow rate from the stomach.

3. Mr. Vishal, diagnosed to have PUD, gives a history of frequent intake of painkillers (NSAIDS) to relieve his body pain due to his work stress.
   A: NSAID intake is one of the risk factors for the development of PUD.
   R: NSAIDs increase prostaglandin synthesis, which impairs gastroduodenal mucosal integrity and repair.

4. Mr. Vishal, suffering from PUD, gives a history of exacerbation of burning pain in his stomach when he skips his meals.
   A: Buring epigastric pain is exacerbated by fasting in PUD.
   R: Fasting enhances duodenal sensitivity to acids and pepsin.

5. Mr. Vishal, a PUD patient, smokes 4–5 cigarettes a day.
   A: Cigarette smoking has been associated with the development of PUD.
   R: Smoking decreases proximal duodenal bicarbonate production due to increased generation of noxious mucosal free radicals.

6. Chronic infection with the bacterium H. pylori accounts for the majority of PUD.
   A: H. pylori reduces the efficacy of the mucosal defense.
   R: H. pylori produces proteases and phospholipases that break down the glycoprotein lipid complex of the mucous gel.

7. Antihistaminic drugs can be used for the treatment of PUD.
   A: H2 histamine antagonist drugs inhibit gastric acid secretion.
   R: Inhibition of the receptor-mediated action of histamine directly suppresses proton pump of the gastric parietal cells.

8. Gastric pH lower than 3.0 reduces gastric acid secretion.
   A: Low gastric pH increases somatostatin release from gastric G cells.
   R: Somatostatin inhibits gastrin secretion from neighboring G cells.

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DISCLOSURES

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

AUTHOR CONTRIBUTIONS

S.P.M., D.S.C., D.G., and K.K.D. conceived and designed research; S.P.M., D.S.C., and D.G. analyzed data; S.P.M., D.S.C., D.G., and K.K.D. interpreted results of experiments; S.P.M. prepared figures; S.P.M. drafted manuscript; D.S.C., D.G., and K.K.D. edited and revised manuscript; N.A., M.B., S.G.D., S.P.M. prepared figures; S.P.M. drafted manuscript; N.A., M.B., S.G.D., D.S.C., D.G., and K.K.D. approved final version of manuscript.

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