LINKING CARDIOVASCULAR THEORY TO PRACTICE IN AN UNDERGRADUATE MEDICAL CURRICULUM

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Case-based teaching (CBT) tutorials were introduced by the Physiology Department at Adelaide University to bridge the gap between theory and practice in the early years of undergraduate medical education. With the use of a clinical case-based environment, CBT aimed to achieve integration of structure-function relationships and an increase in students' capacity to apply a physiological understanding to clinical observations/symptoms and data. With peer-peer interactions in small groups, students could trial history taking and examination skills, interpret common investigations, and relate their findings to an understanding of structure and function. Here, the cardiovascular tutorials highlight the centrality of an understanding of structure and function in the evaluation of a case of syncope. An independent evaluation of the students' learning experience demonstrated that CBT tutorials were successful in their aims. The "hands-on" experience was highly rated, with students reporting that the CBT approach gave relevance to structure and function. Whatever the curriculum learning style, underpinning practice with an understanding of theory remains a desirable feature of medical education.

Key words: cardiovascular physiology; medical education; case-based teaching; theory-practice gap

In most centers of medical education, the field of study of physiology continues to play a central role in the curriculum, regardless of the learning styles adopted. In clinical practice, an understanding of human function is an integral part of the evaluation of a clinical case. The symptoms, signs, and investigation findings reveal how normal physical or psychological function is disturbed. However, evaluation of a clinical case also requires an ability to integrate this understanding of function, be it normal or abnormal, with other medical sciences.

In her discussion paper on the future of teaching physiology, Sefton (14) illustrates, with the aid of a diagram (Fig. 1), the relationship between physiology and other medical sciences. Physiology lies at its center, sharing boundaries with multiple medical sciences. Sefton raises some of the problems that may arise in designing appropriate courses since the shared boundaries are often ill defined. However, blurred and dynamic borders with other disciplines offer exciting opportunities for physiology to play an integrative role in bringing together learning in these related medical disciplines.

“Case-based teaching” (CBT) tutorials were developed by the Department of Physiology at Adelaide Univer-
modell (10) reminds us that the call to embrace an active learning environment in science (17) and medical education (1) is not new. he defines an active learning environment as “...one in which students engage in the process of building and testing their own mental models from information that they are acquiring.” glaser (7) reports that teaching to develop this type of cognitive activity, rather than teaching to deliver knowledge, fosters competence. in the CBT setting, we wished to provide a learner-centered active environment as an alternative to the predominant passive-learning environment of the teacher-centered lecture. by giving students the opportunity to assume some responsibility for their learning, we aimed to develop independent, lifelong learning skills for use when they moved beyond the guidance of their teachers into professional practice.

Glaser (7), Brown et al. (3), and Perkins and Salomon (11), in their articles on learning, cognition, and educational practice, inform us of the social and situational context of learning. They discuss research that describes how students adopt forms of thinking they witness in others and the way in which the various social and physical features of the environment can support learning. Learning in small groups, such as in CBT, has added cognitive benefits due to collaborative effort. Contributions in a group amplify the available knowledge, presenting alternative problem solving and reasoning approaches. Self-regulatory activity is also increased as each student receives feedback from peers. Peers support and monitor individuals’ thinking, opinions, and beliefs. They can help clarify difficult points or offer alternative points of view to challenge a learner’s initial understanding. Complex tasks, such as problem solving or learning new psychomotor skills, can be made more manageable by sharing it among learners in a group.

Brown et al. (3) describe the positive cognitive accomplishments of learners who engage in tasks and problem-solving activities that have meaningful outcomes for them. in our initiative, a case-based learning environment was chosen because it represented an authentic domain of work for medical students. in the sessions, tutors encouraged students to understand the problems and challenges that competent medical practitioners encounter. While cases were chosen to facilitate learning in human structure and function, shared boundaries with related medical sciences were embraced as another opportunity to assist students to integrate rather than compartmentalize their knowledge. the initiative had the following objectives:

• to extend students’ understanding of physiology and anatomy through the use of clinical case material and data derived from common clinical investigations

• to encourage students to make the links between human structure and function and clinical medicine, with a tutor as a facilitator of the learning process

• to foster an understanding of the elements of history, physical examination, and investigation in a case-based learning environment
to provide an environment where students can learn how to elicit signs, symptoms, and investigation findings, dealing considerately with their colleagues as examples of “patients” with normal structure and function

to explain the mechanisms of various symptoms, signs, and investigation findings in terms of disturbance of normal structure and function

to strengthen problem solving and problem-based learning skills

to develop student communication and teamwork skills in small group sessions

The tutorials were first offered as part of the human structure and function course for second-year medical students. As the human structure and function course was organized within the framework of traditional body systems, CBT tutorials were grouped to support student learning in the major systems. Each student had 12 2-h tutorial sessions during the second year, with three sessions being devoted to each of the cardiovascular, respiratory, gastrointestinal, and urinary systems. Third-year CBT tutorials gave students a basic science/clinical integration experience in the nervous system.

The small group CBT learning environment and the perceived advantages of students learning with their peers as patients has previously been described in a short report. Chang and Power (4) reported student comfort in practicing peer physical examinations (PPEs) on fellow classmates at the University of Minnesota Medical School, and we also found that students were willing to participate in PPEs. Like these authors, we also felt that peer-peer interactions were valuable for introductory physical examination skills because students have time to practice and gain feedback from their colleagues on their techniques. Chang and Power (4) suggest that PPEs may also help develop camaraderie among students. At Adelaide University, CBT tutors reported a similar benefit from the history-taking role-play. This represented an extra bonus from the peer-instruction learning environment, since medical student feedback from 10 North American medical schools identified student camaraderie as an important element of medical school learning (12).

EDUCATIONAL INTERVENTION

CBT tutorial groups consisted of eight to nine students with a medically qualified tutor facilitator, some of whom also had teaching experience in anatomy and/or physiology. All tutors had attended training workshops in problem-based learning and/or small group teaching and were enthusiastic about these learning environments. The cardiovascular sessions are described below to illustrate how clinical skills were introduced in the context of the case history, physical examination, and investigation findings, and how these findings are used to reveal the underlying structure and function. The three sessions are centered around a case of syncope, demonstrating how an understanding of the structure and function of the heart and its vasculature forms the basis of an ability to evaluate a cardiovascular problem. Failure of the “pump” or its dynamic “vessels” to maintain cerebral perfusion is the essence of this case. It also illustrates the focal role of physiology in integrating learning of the medical sciences. The sessions are summarized here:

**Session 1: taking a cardiovascular history.** The objective of this session was to reveal how normal blood pressure control is one of the determinants of an upright posture and how presenting symptoms form an understanding of structure and function. Students brainstormed possible hypotheses to explain the presentation of an elderly woman who collapsed in a supermarket on a warm afternoon. This led to a variety of diagnoses ranging from a vasovagal attack, through possible cardiovascular causes, to neurological dysfunction, with students being prompted to explain the mechanism of their hypotheses. Students were able to draw on their previous learning experiences to develop a rich discussion.

After this, the tutor role-played the patient, and a student role-played the doctor to obtain a history of the presenting complaint. The cardiovascular system review questions formed a critical part of the questioning, with students being prompted to consider how each symptom formed an understanding of underlying structure and function. Other group mem-
bers shared the role of the doctor to determine the social, family, past, medication, and allergy history from the patient. The role-playing involved all students and added to the “icebreaker” activities of the first session. Finally, the history was summarized, leading to an important discussion of what features of the history were salient to determine whether normal structure and function were perturbed in this case. The presence of hyperlipidemia, hypertension, a family history of ischemic heart disease, possible reflux disease, a recent emotional stress, and the use of an “anginine” tablet while standing expanded the differential diagnosis and discussion.

Session 2: examination of the precordium and interpretation of the electrocardiograph. This session’s aim was to relate the mechanical, electrical, and valvular events of the cardiac cycle to examination of the precordium. In this session and using their peers as patients, students obtained hands-on experience with a tutor facilitating their efforts. Tutors ensured that students were comfortable examining and being examined by their colleagues, and students enjoyed working with self-selected peers. Screened examination bays were provided for student pairs who preferred this more private location.

An understanding of the surface anatomy of the precordium underpinned the examination of the precordium and the subsequent placement of the electrocardiograph (ECG) leads on the chest. For these medical students who were recent high school graduates, it provided their first opportunity to auscultate normal heart sounds and see how an ECG tracing was obtained.

Because arrhythmia had been tendered as a possible hypothesis to explain the syncopal episode, an ECG was suggested as a way of testing this hypothesis. To understand how a 12-lead ECG is obtained, students recorded tracings from volunteers in their group. Placement of the chest leads prompted a discussion of the surface anatomy of the thorax as well as possible technical difficulties. This activity also reinforced a basic understanding of what the ECG illustrates about the structure and function of the heart, how to calculate the heart rate (HR) from the ECG, and why sinus arrhythmia may be seen with inspiration and expiration. The HR response to a Valsalva maneuver was also recorded and discussed. Students were able to compare the ECG tracings of their “normal” peers with the normal ECG of the elderly woman from the syncope case. This led to an appreciation of the wide variation of normals, and the discussion of differences fostered a greater understanding of the ECG.

Session 3: evaluation of the peripheral pulses and arterial blood pressure. In this session, we aimed to show how the peripheral vasculature and arterial blood pressure are examined to assess their state. Students used their anatomical knowledge to determine the optimal sites for palpation of the peripheral pulses and were challenged to consider the basis of auscultation of the systolic and diastolic blood pressures.

With an understanding of how the signs are obtained, the students were then able to integrate the physical examination and investigation findings with the previously obtained symptoms to test their hypotheses for the case. It highlighted the common problem of hypotension in the elderly and factors that may precipitate it. The final case discussion summarized how events such as rapid postural change, nitrate-induced venous pooling, diuretic-induced reduction in circulating blood volume, or baroreflex dysfunction due to age may contribute to low cerebral perfusion and syncope.

In the fourth session, before the respiratory system CBT sessions commenced, there was a brief cardiovascular review to consolidate learning from the previous sessions. Students had the opportunity to perform a complete cardiovascular examination to integrate the individual components they had tried in the previous three sessions. Again the emphasis was on basic skills rather than a sophisticated physical examination of the cardiovascular system.

EVIDENCE FOR EFFECTIVENESS OF INTERVENTION

In an independent evaluation conducted by the Advisory Centre for University Education at Adelaide University, students made a value judgment of several statements in relation to the aims and objectives of the second-year CBT tutorials (Likert scale responses: 7 = strongly agree, 6 = agree, 5 = slightly agree, 4 =
uncertain, 3 = slightly disagree, 2 = disagree, 1 = strongly disagree), illustrated in Fig. 2.

More than 90% of students believed that the tutorials had been a valuable learning experience, which was relevant to the stated aims, and that the tutorials had made them aware of how and why clinicians interview and examine patients. The majority of students believed that the tutorials stimulated their interest in, and furthered their understanding of, normal body structure and function. Students rated highly the small group style of teaching, agreeing that the initiative had been well organized and relevant to their professional training. Fifty percent of this student cohort reported that the tutorials did improve their self-confidence.

Two open-ended questions in relation to CBT sought more qualitative data from the same cohort of students, and their responses are summarized in Table 1. Eighty percent of students highlighted the hands-on experience as the best feature of the tutorials. Many enjoyed the opportunity to use “the medical equipment” in a relaxed environment with a small group of their peers. It was their first introduction to history taking and clinical examination, and 21% of students felt that the tutorials provided them with a learning environment in which they could integrate these introductory clinical skills with their developing theoretical knowledge. Many unsolicited comments expressed how CBT was a learning format that stimulated their interest in structure and function, where they could apply learning from other settings in a clinical context. A selection of responses to the question “What aspects of the tutorials did you like best?” supports these conclusions.

- “Gave relevance to structure and function, through the clinical approach”
- “The idea is very good—it shows us the clinical aspects of the subject and made it interesting”
- “Gave relevancy to clinical medical/lecture material and it was interesting and fun”
- “Practical application of theory”

### Table 1: Student responses to two open ended questions regarding the CBT tutorials

<table>
<thead>
<tr>
<th>No. Students, n</th>
<th>% of Class</th>
<th>Nature of Comments</th>
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<tbody>
<tr>
<td>Question 1: What aspect of the tutorials did you like best?</td>
<td></td>
<td></td>
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<tr>
<td>70 80%</td>
<td>Positive comments about the practical nature of the sessions or “hands-on” experience</td>
<td></td>
</tr>
<tr>
<td>18 21%</td>
<td>Positive comments about the integration of the clinical skills with its underlying theoretical knowledge</td>
<td></td>
</tr>
<tr>
<td>7 7%</td>
<td>Positive comments about the tutors</td>
<td></td>
</tr>
<tr>
<td>5 6%</td>
<td>Positive comments about the benefits of case-based learning</td>
<td></td>
</tr>
<tr>
<td>5 6%</td>
<td>Positive comments about the small group format</td>
<td></td>
</tr>
<tr>
<td>Question 2: How may the sessions be improved?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 10%</td>
<td>Comments suggesting that tutors had a “clinical background”</td>
<td></td>
</tr>
<tr>
<td>7 7%</td>
<td>Request to concentrate more on physical examination procedures rather than communication skills or “paper cases”</td>
<td></td>
</tr>
<tr>
<td>5 6%</td>
<td>Requests for smaller numbers of students in the group</td>
<td></td>
</tr>
<tr>
<td>3 3%</td>
<td>Requests for “expert tutors”</td>
<td></td>
</tr>
<tr>
<td>1 1%</td>
<td>Request for his/her tutor to do less didactic teaching</td>
<td></td>
</tr>
</tbody>
</table>

n = 88. CBT, case-based teaching.

- “Thought that they were interesting and gave a practical aspect to the course material”
- “They complemented the lectures. Learned things that were not taught in the lectures but very relevant to the profession”
- “It was good to have a practical session in which we could actually use some of the theory that was taught to us in the lectures”
- “So that you apply what you have learned in the lecture in a practical”
- “The practical helps put other aspects of our learning in place”
- “Gave us a chance to try out physical examination and understand why each was done”
1. The CBT tutorials were relevant to the aims of the subject

2. The CBT tutorials were well organized

3. The CBT tutorials stimulated my interest in the subject

4. The CBT tutorials furthered my understanding of normal structure and function

5. The CBT tutorials made me aware of how and why clinicians interview patients

6. The CBT tutorials made me aware of how and why clinicians examine patients

7. I benefited more from this style of teaching than if it were a lecture-based approach

8. The CBT tutorials provided me with a valuable learning experience

9. I have developed more confidence in myself

FIG. 2.

For each question, the mean response value is shown (●). The standard deviation is shown by the bar extending from the mean value. CBT, case-based teaching.
“The practical aspect was very interesting and made what we were doing in the lectures seem more applicable to the requirements of my profession.”

“The practical aspects of human structure and function topics were covered, which increased our understanding and recall of the theory.”

“The hands-on work showed the principles and theory behind it.”

“Hands-on practical work was very helpful for understanding structure and function and will be essential future skills.”

A few students commented that the choice of cases stimulated interest and helped them develop problem-solving skills, whereas others preferred that more tutorial time be allowed for physical examination skill development rather than for discussion of “paper cases.” However, to achieve the CBT objectives, a balance of activities had been planned, and in this evaluation a majority of students expressed satisfaction with the tutorial design.

**DISCUSSION**

This report describes how cardiovascular clinical skills and the basic sciences underlying them are integrated in a case-based setting for second-year medical undergraduates, the majority of whom entered medical school straight from high school. A novel learning environment (CBT tutorials) was developed to strengthen the link between theory and practice by showing medical undergraduates how history questions, physical examination signs, and investigation findings are derived from an understanding of normal structure and function. Situating the learning in the context of a case motivated students to draw on their knowledge of structure-function relationships integrated with other clinical sciences, to understand the cause of a case presentation, such as syncope. Small group tutorials were chosen to develop students’ communication and cooperative learning skills, and students valued this as a teaching and learning setting. In this environment, tutors introduced students to clinical skills in a way that aimed to build confidence for their first “real” patient encounters. Because confidence development was an important aim of the tutorials and recognizing that development takes place gradually and at different rates for different individuals, further evaluation of this early intervention has been planned. Student cohorts, who are now progressing through clinical skill development in the later years of the course, are being asked to reflect on the impact of CBT in relation to this aim.

An understanding of human function underpins the practice of medicine, and in a medical curriculum, it is the framework on which to pin further medical
science knowledge and skills. Walton and Matthews (19) make the analogy of a medical curriculum being like a house. The bricks and mortar alone do not make the house. It needs a structure that bonds the building blocks together. Figure 1 has previously illustrated physiology’s structural role in bonding together related medical sciences in a medical curriculum. This diagram has been expanded in Fig. 3 to illustrate how, in the CBT initiative, physiology played an integrative role in the learning derived from the evaluation of a case of syncope. To capture the full educational opportunity from these interactions for the vocational training of medical students, understanding of function must be linked to practice.

Other institutions have reported successful initiatives demonstrating to preclinical students how mastery of the basic sciences fosters an understanding of the mechanisms and treatment of disease. Shanies (15), a practicing cardiologist, designed a course to demonstrate the connections between cardiovascular science and medicine. Because the students were biology majors and premeds, he was limited in the “real medicine” that could be taught. Walters (18) incorporated case-stimulated learning sessions into endocrine physiology lectures to provide a more active and interesting learning experience for first-year medical students. Ghosh and Dawka (6) described small group, problem-based learning tutorials supplementing physiology lectures to motivate students toward self-directed learning and assist them in applying pathophysiological principles to various clinical conditions. Most of these methods, like CBT tutorials, were offered in “hybrid” curricula to reveal the relevance of the basic medical sciences and to capture student interest. Unlike CBT tutorials, they do not take the next step in relating the theory to practice.

In the 1910s, as the style of medical training evolved from the earlier apprenticeship model to the “Flexner” (5) approach in which a grounding in basic sciences was stressed, clinical skills training began to be separated from the teaching of theory. In the next wave of medical curricular reform over the last three decades, attempts have been made to close the widened gap between theory and practice. In many institutions, however, clinical skill development, although occurring earlier in the medical course, has been placed in a “skills” curriculum stream, parallel to, but separate from, a “scientific basis of medicine” stream. Further efforts are required to ensure that basic sciences such as physiology are truly integrated with the development of clinical skills and practice.

The essence of medical practice is diagnosis and management. After history taking, physical examination, and investigations are concluded, the practitioner must reflect on the findings and why the client has presented at this time. This judgment requires more than a technical command of the knowledge base. Schon (13) warns university educators against fostering professional knowledge that fails to include practical competence and professional artistry. He believes that professional education has tended to concentrate on the acquisition of a knowledge base, assuming the practical know-how is automatically acquired by learners. In most professions, novices gradually develop into experts by acquiring skills as they gather experience, and in medicine, this traditionally occurred in an apprenticeship environment. Here, theory was not separated from practice. It does, however, have other problems. This teaching environment has been less available with a rise in student numbers paralleling a decline in hospital patient numbers (2), and it is now less valued due to the difficulties it poses in the reliable assessment of medical students (16).

The CBT initiative has aimed to address this theory-practice gap by linking a problem-based learning approach with the development of practical competence so that students have a usable knowledge of human structure and function. It aimed to develop both the art and science of medicine early in the training of young medical undergraduates in a learning environment that built confidence to undertake the journey through to competence. Margetson (9) sees learning to become a thoroughly competent practitioner as “…the development of an integrated, coherent ‘growing web’ of understanding, knowledge, and skill in practice.” By careful selection of problems that reflect the whole world of the professional practitioner, all the associated learning experiences can add to the “growing web”. In this way, exciting scientific advances at “the bench” can be transformed into usable knowledge “at the bedside.”
We thank the medical students who participated in this teaching innovation and the staff of the Physiology Learning and Teaching Centre for technical support. We are also grateful to Gerald Buttfield for assistance in creating the physical learning environment for case-based teaching tutorials.

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