

Original Publication

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Integrating Acid-Base and Metabolic Lab Panels Across Systems in an M1 Classroom Activity

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Citation: LeClair RJ, Binks AP. Integrating acid-base and metabolic lab panels across systems in an M1 classroom activity. *MedEdPORTAL*. 2019;15:10793. https://doi.org/10.15766/mep_2374-8265.10793

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Abstract

Introduction: It is important to deliver acid-base balance concepts in the context of multiple physiological systems and metabolic processes that influence acid-base homeostasis. This activity combines the interactions of the respiratory, gastrointestinal, and renal systems in conjunction with basic metabolism to generate an integrated activity for first-year medical students. **Methods:** We developed four concise case scenarios around various presentations of acid-base disturbance along with five sets of arterial blood gases (ABGs) and five different metabolic lab panels. M1 students were given class time to match the three different types of data in order to address how the underlying biochemistry and physiology of a scenario translated into ABG and metabolic laboratory values. **Results:** Although not statistically significant, the students' performance on acid-base questions was marginally higher than on standardized National Board of Medical Examiners questions on other topics covered in the same exam, and the improvement over national average scores on the same questions increased. Student evaluation of the activity was positive, with general appreciation of its application and integration of concepts. **Discussion:** The incorporation of this activity into the M1 year was positively received and enhanced integration of content related to acid-base balance. The activity is flexible and can be adapted to most any curricular structure, with the potential to include additional content depending on the level of the learner.

Keywords

Workshop, Metabolism, Acid, Base, Arteriole, Bicarbonate

Appendices

- A. Facilitator Guide.docx
- B. Acid-Base Case Notes.docx
- C. PowerPoint Presentation .pptx

All appendices are peer reviewed as integral parts of the Original Publication.

Educational Objectives

By the end of this session, learners will be able to:

1. Analyze brief clinical vignettes to determine possible sources of metabolic and acid-base dysregulation.
2. Analyze metabolic lab panels (blood glucose, blood urea nitrogen, albumin, and lactate) and arterial blood gases to determine the cause of dysregulation of metabolic and physiological pathways.
3. Align clinical scenarios with presentations of hypoglycemia, hyperglycemia, or metabolic/respiratory acidosis and metabolic/respiratory alkalosis.

Introduction

Acid-base balance is a difficult concept in preclerkship education and one that requires a strong understanding of the contributions of several biochemical pathways and physiological systems (i.e., renal, gastrointestinal, and respiratory). The concepts of acid-base balance are often delivered in an isolated session associated with a single physiological system and separate from metabolic considerations or clinical sequelae. Despite this, the expectation is that in the clinical years, learners will provide effective patient care that requires the integration of laboratory results, aspects of the clinical presentation, and incorporation of multisystem responses to evaluate and treat acid-base disorders. Without an intermediate step to develop a broader, integrated understanding, this progression can be a challenge for the novice learner. Our resource begins to address this challenge by providing an activity in which M1 learners evaluate systems-based disturbances and associated biochemical changes that contribute to acid-base disorders in a realistic clinical setting.

Given the diverse clinical scenarios in which acid-base disorders can occur, we generated the activity to span a breadth of clinical presentations that would be approachable from an M1 perspective. We generated four unique scenarios providing a significant clinical hook with distinct presentations. We then implemented the five S's of modified team-based learning to construct the activity.¹ Each scenario provided a significant clinical problem for groups to address. The groups worked on the same information within four different patient scenarios, five different sets of arterial blood gases (ABGs), and five different sets of abbreviated metabolic lab panels (blood glucose, blood urea nitrogen [BUN], albumin, and lactate) and were tasked to match each patient scenario with the most appropriate ABG and metabolic lab panel. Specific pairing of these defined data sets confined groups to relevant discussion and allowed them to simultaneously report answers. This structure promoted in-class discussion and offered the opportunity to address particularly difficult concepts. Finally, the activity was readily summarized to help the students bring closure to the content.

The scenarios and metabolic and ABG variables were chosen to encompass the session learning objectives and cover significant disruptions of both physiological and biochemical systems so as to enhance content integration. We chose this dynamic delivery approach for several reasons. First, without a prescribed connection between ABGs and metabolic lab panels, it is not realistic to use a lecture-based approach to capture all the metabolic shifts that could occur as a result of an interorgan acid-base disturbance. Second, the goal as defined by the objectives was to analyze clinical data, and this format allowed us to achieve that goal. Finally, for M1 students, the overarching goal of our curriculum is to enhance problem-solving skills to generate physician-thought leaders, and in doing so, a large component of our delivery is in an active classroom setting. So, the active classroom approach allowed us to meet programmatic and session-level objectives.

This activity not only integrates acid-base and metabolic homeostasis but also incorporates multiple physiological systems in order for M1 learners to appreciate interplay between these factors early in their preclinical education. As such, the activity differs from current *MedEdPORTAL* submissions on similar topics that target M3-M4 learners for mixed acid-base disorders² or focus on single electrolyte imbalances³ or a single system.⁴ Throughout the course of this workshop, students were asked to generate a holistic view of the patient presentation and to rationalize laboratory data associated with each case. The incorporation into the M1 year contributed to the overall positive student performance and was well received by learners. The activity represents a unique opportunity for the undergraduate learner to explore systems-based interactions while having the chance to explain the fundamental basic science mechanisms leading to a disturbance.

Methods

The Virginia Tech Carilion School of Medicine (VTC SOM) has a class size of 42 students per year, and the curriculum is divided into four main disciplinary domains: basic science, clinical skills, research, and interprofessionalism. In the M1 year, the content in each of these domains is delivered in an organ systems–based approach across four 10-week blocks. Basic science content within each block is delivered primarily in large-group sessions (which can adopt a variety of pedagogies) and problem-based learning. The problem-based learning sessions are mandatory, while the large-group sessions (in which this activity is delivered) are not. Below is the breakdown of course titles and content across the four blocks within the basic science domain:

- Block I: Functional Biology of Cells and Tissues—genetics, cellular biology, immunology, genetics, basic histology, and muscle and bone physiology and development.
- Block II: Human Body I—anatomy, physiology, histology, and development of the cardiovascular, respiratory, and hematological systems.
- Block III: Human Body II—anatomy, physiology, histology, and development of the endocrine, renal, gastrointestinal, and reproductive systems.

- Block IV: Biology of the Nervous System—anatomy, physiology, histology, and development of the nervous system.

The activity has been delivered to three classes at two medical schools, but analysis of outcomes has only been performed on its final iteration and most recent delivery at VTCSOM (week 8 of block III in the M1 academic year 2017-2018). We delivered this learning activity in a multipurpose classroom space. Prior to this, students had received instruction in basic pathway biochemistry and respiratory, gastrointestinal, endocrine, and cardiac physiology. Students had also received a pair of hour-long instructional periods covering the basics of acid-base balance in the context of respiratory and renal physiology, respectively. To facilitate integration of systems and clinical knowledge, we implemented this 2-hour activity as a capstone session to engage students and have them consider several aspects of a patient presentation including linking the patient presentation (case scenario) with appropriate laboratory results (ABGs and abbreviated metabolic lab panel). A facilitator guide (Appendix A) is provided. We divided the class into groups of six students (according to their established problem-based learning teams that were consistent throughout the block) and gave each group four patient case scenarios, five sets of ABGs, and five sets of abbreviated metabolic lab panels. We then instructed the groups to match each scenario with an ABG and a metabolic lab panel and told them that there was only one best solution to the clinical puzzle and that one set of ABGs and one metabolic lab panel should not be used. We delivered materials (Appendix B) electronically and as individual sheets of paper (with one case component per sheet) so that the groups could work around a table and organize the data. We provided associated PowerPoint slides (Appendix C) containing the correct answers for the four patient case scenarios only after the activity.

After this brief introduction to the objectives, activity, and expectations, groups were allowed to work on the problem for 35-45 minutes. Students could use any external or text-based resources to help solve the clinical puzzle, and faculty circulated to answer questions and address concepts. Following this allocated time, the whole class addressed each case sequentially. Initially, all groups simultaneously declared choices for matched ABGs and metabolic values for the case. Full-class discussion followed. It involved asking groups to provide rationales for the choices they had made for the variables within the ABG and metabolic values. In this full-class setting, we also asked groups leading questions so we could determine the students' level of understanding from their explanation of the relationship between physiological and biochemical processes and the patient presentation. The questions were generated from ad hoc discussions we had had with individual groups during the 35-45 minutes of circulating through the class. These discussions had revealed confusion or a lack of understanding. We chose this method over formalized, pre-prepared questions so class time would be used to address poorly understood concepts rather than concepts students had mastered. Before moving onto the next case, we gave a brief summary to encompass the current case's major concepts.

To assess the activity, we used both qualitative and quantitative metrics. Our summative assessment for each block was standardized to a multiple-choice exam with questions purchased from the National Board of Medical Examiners (NBME) question bank. We selected 13 questions that best encompassed the content of the activity, aligned with the learning objectives, and addressed broad concepts of system interactions. These questions mapped to various United States Medical Licensing Examination categories, including protein-calorie malnutrition, digestion and absorption, drugs to alter gastrointestinal motility, tubular reabsorption/secretion, acid-base balance/renal mechanisms, diuretics/antidiuretic drugs, peptide hormones, and pancreatic islets. Student performance on the 13 selected NBME questions was used to assess the effectiveness of the activity. Individual student performance on specific questions could not be assessed due to NBME testing regulations. Qualitative assessment was performed on open comments made on faculty evaluations or end-of-block evaluations, allowing us to determine overall student satisfaction with the activity and any arising themes.

Results

Of the 42 students in the M1 class at VTCSOM, 18 participated in the activity; this level of attendance was consistent with the M1 year overall.

The block III exam consisted of 122 questions spanning the endocrine, gastrointestinal, renal, and reproductive systems. The average student grade for the 13 activity-related questions was $80.92\% \pm 6.28\%$ versus $78.32\% \pm 3.59\%$ for all other block material ($p = .607$, t test). While this increase for our students was small (2.6%), it was three times larger than the gap seen nationally for the same questions ($77.31\% \pm 6.90\%$ vs. $76.47\% \pm 3.01\%$, $p = .845$, t test).

Review of faculty evaluations provided positive commentary for the activity. Students perceived it to be engaging as it “contained many opportunities to apply and integrate knowledge from block III and previous blocks.” Students responded positively to the inclusion of “application problems that helped integrate pathology,” reporting that the activity was “helpful in synthesizing what they have been taught in multiple blocks.” No negative comments surrounding the activity were reported in either end-of-block evaluations or individual faculty evaluations.

Discussion

Integration of systems is often not approached in the M1 year despite its significant contribution to normal homeostasis and involvement in numerous pathologies. This activity represents a rigorous applied task requiring M1 students to integrate information across several physiological systems and incorporate knowledge of metabolism to generate an understanding of common pathologies. The approach implemented here also allowed for classroom discussion to reinforce or address student misconceptions regarding individual systems as well as their integration. Based on the assessment results and open commentary, students made positive progress in their ability to integrate how changes in metabolism influence physiological adaptations and vice versa. This is a very high-level objective, and its true outcomes need to be evaluated in the M2 year to look at longitudinal retention of knowledge as our students progress into their pathological systems-based M2 curriculum.

The structure of the activity required students to analyze clinical data to determine dysregulation of both metabolic and physiological pathways, which was a deliberate function of how the activity was generated. Additionally, the ability of students to appreciate the relevance of laboratory values (blood glucose, BUN, albumin, lactate, and ABG) and how to interpret these values to make a clinical diagnosis was well assessed by the NBME questions chosen. Performance on these questions showed a positive impact by the activity (albeit small). The in-class activity focused on discussing the various physiological derangements that could lead to the presentations of hypoglycemia, hyperglycemia, or metabolic/respiratory acidosis and metabolic/respiratory alkalosis; however, the activity did not include all potential disease presentations that might lead to such derangements. Specifically, the activity did not address specific genetic contributions to acid-base disturbances. In subsequent iterations, the activity could be expanded to include a sickle cell crisis to better incorporate genetic factors.

Our delivery of the activity involved a respiratory physiologist and a biochemist; however, the incorporation of a clinician or pharmacologist could broaden the activity's scope. The format lends itself well to the inclusion of other content, such as pharmacology, that could also be integrated into the exercise or through the discussion. We have made some suggestions for integration of additional content in the facilitator guide, but the activity could easily be expanded on or altered by adopting alternative scenarios. It is important to keep in mind that we developed the activity for M1 learners and thus focused heavily on basic concepts of metabolism and respiratory, gastrointestinal, and renal physiology. By altering the scenarios or adding additional laboratory values, the session could easily be expanded for M2-M4 learners (e.g., by incorporating anion gap, pharmacology, or patient management plans).

In summary, although summative assessment did not illustrate a significant performance increase, this could be due to the inclusion of assessment metrics from all students rather than addressing performance specifically with the subset of students who participated in the activity. Both qualitative and quantitative measures suggest that the incorporation of the activity can be a positive addition to a curriculum. Future iterations will include formative NBME-style assessment so that additional comparisons can be made regarding outcomes of the activity.

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Disclosures

None to report.

Funding/Support

None to report.

Ethical Approval

Reported as not applicable.

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Received: August 23, 2018 | **Accepted:** November 24, 2018 | **Published:** January 10, 2019