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Evaluating the effectiveness of integrating radiological and cross-sectional anatomy in first-year medical students – A randomized, crossover study

R. Rajprasath, V. Dinesh Kumar¹, Magi Murugan, Bhavani Prasad Goriparthi, Rema Devi

Abstract:

CONTEXT: Radiological anatomy (RA) knowledge is essential for the current-day clinical practice due to the rapid development in imaging technologies. As there is a long interval between learning RA in the 1st year and applying it in their clinical disciplines impedes their functional understanding, this study has been planned to provide the students with a right mix of anatomy and radiology in order to promulgate deeper medical comprehension.

AIM: This study aimed to evaluate the effectiveness of integrated RA in honing the radiological reasoning abilities in 1st year medical students and to develop critical thinking skills through small-group, case-based learning experience.

METHODOLOGY: All the students of 2017–2018 batch were randomized equally into study group and control group. The study group was exposed to the interactive RA module followed by posttest. The control group was exposed to traditional teaching and then given posttest. The groups were flipped for successive regions of anatomy. Feedbacks were obtained by both quantitative and qualitative methods.

STATISTICAL ANALYSIS: Posttest scores were compared using Student's *t*-test. Feedbacks were analyzed using descriptive statistics.

RESULTS: The posttest scores were significantly higher in the study group when compared to the control group. Nearly 92% of the students felt that the integrated module made them learn better and 44% of the students felt that it helped them to apply the knowledge in clinical context.

CONCLUSION: For the present millennial-generation students, integrated RA lectures help develop their critical thinking and help in the subsequent clinical years.

Keywords:

Cross-sectional anatomy, integrated radiology, radiological anatomy module

Department of Anatomy,
Pondicherry Institute
of Medical Sciences,
¹Department of Anatomy,
Jawaharlal Institute of
Postgraduate Medical
Education and Research,
Puducherry, India

Address for correspondence:

Dr. V. Dinesh Kumar,
Department of Anatomy,
Jawaharlal Institute of
Postgraduate Medical
Education and Research,
Puducherry - 605 006,
India.
E-mail: dinesh.88560@gmail.com

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Introduction

Anatomy teaching, being one of the oldest components of medical education, has always been the subject of debate. As postulated by Fink and Parmelee,^[1] anatomy as a discipline faces three daunting

challenges in the modern medical education. First, being a content-laden subject, the frontiers of anatomy expand over time. Second, students should be trained to apply the anatomical details in various clinical contexts and third, the learning process should promote other skills such as critical thinking. In other words, the rapid

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development of imaging technologies and techniques for minimally invasive surgery has transformed the knowledge of anatomy required for clinical practice.^[2] In addition, a long interval between visualizing the structures in anatomy and revisiting them later in clinical disciplines impedes a functional understanding. We felt that providing students with a right “mix” of anatomy and radiology could be of immense help in promulgating deeper medical comprehension and hence the present study.

In the recent trends, the need for satisfactory comprehension of radiological anatomy (RA) has been more pressing.^[3] Unfortunately, RA remains as the “gray area” which lacks the explicit teaching from both disciplines, i.e. anatomy and radiology. This is reflected in a study^[4] which suggests that as few as 25% of medical school graduates are confident in their appraisal of chest X-rays. Similarly, another study^[5] pinpoints that in gross anatomy, apart from teaching anatomy by cadaveric dissection, atlases should be integrated with radiology for achieving better learning outcomes.

Most students lack experience in mentally reconstructing three-dimensional objects from various two-dimensional perspectives.^[6] This disables them to relate cross-sectional radiographic images with the structures seen in the cadaver and illustrations given in the textbooks. The ability to identify the spatial orientation of the organs in the cadaver requires the switching of dimensionality and application of learned anatomical details. For example, the proximity of the liver and the right kidney becomes more apparent when a student appreciates the cross-sectional imaging of the abdomen.

Regarding radiological reasoning abilities, two systems of thinking process have been described.^[7] System 1 is an automatic and intuitive thinking process, primarily based on instantaneously noting similarities between something observed in images and prior examples stored in memory. System 2 involves more deliberate and analytical thinking which require deliberations over other differential considerations. RA teaching in most institutes includes showcasing few radiological images at the end of each regional anatomy sessions. This disjointed provision of information leaves medical students with a deficiency of radiological reasoning skills. In contrast, an effective RA module should achieve the temporal connect and complementary flow of knowledge in both anatomy and radiology.^[8] This could prune the system 2 thinking in 1st-year students and help them in analyzing the images in an effective way. The Royal College of Radiologists had outlined that universities should prepare medical students with the “necessary knowledge and skills to routinely arrange and correctly interpret basic radiological investigations^[9] and

recognition of normal anatomical structures is the basis for attaining that.” Marker *et al.*^[10] found that students had performed poorly when asked to label structures and interpret radiological images without any prior teaching.

Upon reviewing the traditional method of RA teaching in various institutes of India, we felt that both instructional and assessment methods were grounded on memorization rather than on reasoning. This impairs the knowledge transfer from the cadaver into skills of interpreting medical images as seen later in clinical practice, which requires analyzing stacks of cross-sectional images. To keep in pace with the evolving demands of medical image interpretation, we had developed an integrated RA module^[11] at our institute. The main aims of our module were (1) to present anatomy using multiple formats and enable the students with the power of “visualization,” (2) to drive the students to learn using classic radiological case vignettes, and (3) to promote self-assessment of students’ abilities in a safe environment using a formative assessment. We had observed a palpable positive response among students as evident from the Kirkpatrick’s first level of evaluation of teaching–learning methodology.^[12] However, we could not document the actual learning outcomes of our module and figure out the imparted benefits in analyzing radiological images.

The traditional approach adopted at our institute mostly involved structure identification in X-rays and single-method study habits. Some studies^[13,14] have shown that these approaches make the students adopt superficial memorization approaches, resulting in inferior long-term recall. The present study aims at evaluating the effectiveness of our module in honing the radiological reasoning abilities in 1st-year medical students using a mixed-methods approach. Other goals of our program are (1) to enable the students to identify normal anatomy in radiographic images, (2) to develop critical thinking skills through small-group, case-based learning experiences, and (3) to familiarize the students with basic imaging modalities. Further, we aimed at formulating the number of hours required for an optimal RA teaching in an already overcrowded curriculum.

Methodology

We presented the proposal to the institutional research and ethics committee and obtained clearance. Following the standard recommendations for carrying out educational researches in medical students, we distributed a subject information sheet to all 150 students for getting their informed consent. During that process, we had narrated the overview of the study and defined the roles of all participants.

Study design

We had used a randomized crossover design which gave an equal exposure to all students and evaluated the intervention using a mixed-methods approach. Quantitative methods and posttest assessment were used to generate the evidence of effectiveness, and qualitative methods were used to capture the reaction of students toward the intervention. All the 150 students of the 2017–2018 batch were randomized equally by lottery method into study and control groups. The groups were flipped in successive sessions. The overview of the study design is depicted in Figure 1.

Description of the intervention

In addition to the traditional gross anatomy teaching, we planned to impart the integrated RA module.^[11] The innovative intervention included structured teaching of radiological and cross-sectional anatomy of four regions (lower limb, abdomen and pelvis, thorax, head and neck). The content of each sessions was based on the must-, should-, and desirable-to-know clinical conditions related to the prescribed university syllabus. All sessions were handled by the principal investigator.

Content of a session

The framework was built in four tiers. In the first tier, the study group students were exposed to annotated X-rays, computed tomography (CT) scan, and magnetic resonance imaging. In the second tier, problem-solving exercises were given to the students where they had integrated clinical conditions with RA and had correlated the sectional anatomy with radiological images. In the third tier, focus was laid upon identifying spatial relationships and clinical significance (e.g. sciatic nerve compression in the posterior dislocation of hip). Following that, in the last tier, posttest questions (image-based practical anatomy paper) were administered to the students.

Each PowerPoint presentation was based on Mayer’s multimedia principles.^[15] Text and pictures were placed close to each other and presented simultaneously (coherence, multimedia, and spatial and temporal contiguity principles). Key points were highlighted (signaling principle), and the contents were delivered in a narrative and conversational manner (modality and personalization principles).

The control group underwent traditional small-group RA teaching, with one faculty member assigned to a group of 25 students. In this method, the students were exposed to few X-ray images and CT images in X-ray lobbies discussed by a faculty. At the end of small-group teaching, they answered the same posttest questions used for the study group and the answer sheets were collected. Following this, the control group students had their integrated module-based teaching similar to the study group.

Analyzing the effectiveness of the module

Evaluation of the module was done at two levels: (1) student learning gains (Kirkpatrick level 2) from the innovation by posttest comparisons and (2) student reaction (Kirkpatrick level 1) to the innovation by nominal group technique.

Image-based practical anatomy paper, i.e. posttest questions, consisted of ten questions in each domain of regional anatomy. Each question was constructed in a twofold fashion; the first subquestion focused on identification, and the second subquestion focused on spatial relationship/clinical relevance. Questions were prepared by a blinded investigator who is unaware of the content of the module. To compare the effectiveness of our integrated module over the traditional small-group teaching, comparison of posttest scores was made by using Student’s *t*-test.

Students’ reactions were recorded on an individual basis, by giving a quantitative response sheet containing items generated from a pretested and prevalidated questionnaire.^[16] We had modified few items based on the learning objectives of the module, and seven subjective statements used were cross-checked by three anatomists who were not involved in the survey process. The students were asked to rate the statements on a Likert scale scoring from 1 (strongly disagree) to 5 (strongly agree) on the last day of the module. Feedback was evaluated by summing the scores for each of the items.

In addition, we had used the nominal group technique to obtain the group responses of the students. We asked the students to discuss upon the following two probe questions: (1) the effects of newer intervention over the traditional small-group teaching and (2) enlisting

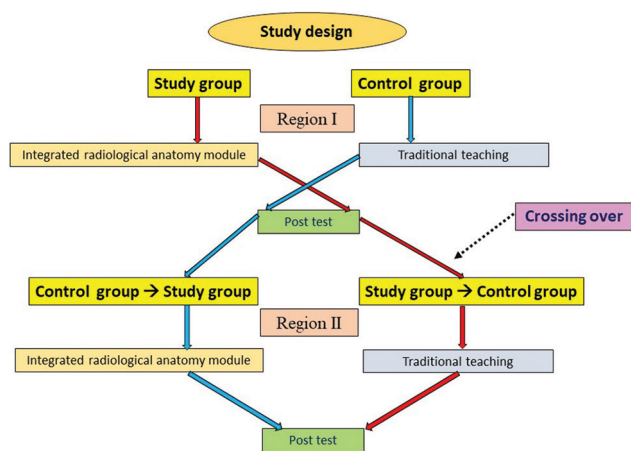


Figure 1: Description of overview of the study design

the ways in which the newer module had developed their reasoning skills in clinical conditions given in the module. The students were divided into groups of 15 students, and they processed the provided evaluation items. The students came up with individual responses which were rationalized later after collaborative discussion with peers. At the end of the discussion, the top five responses were boiled down in each subgroup. We collected the responses from each subgroup and negated the overlapping responses.

Results

Posttest scores' comparison between the study group (75) individuals who were exposed to the integrated teaching module and the control group (75) individuals exposed to the traditional teaching is shown in Table 1. The mean scores were significantly higher in the study group than that of the control group.

Individual perceptions of the students on the effectiveness of the integrated RA module are summarized in Table 2, 3 and 4. Most of the students have agreed that the integrated module was effective in meeting the learning outcomes, in applying their anatomical concept in clinical context, and in familiarizing with radiological images. The integrated module was useful to a great extent to 52% of students and 42% of the students felt it useful to some extent [Figure 2].

Table 1: Posttest score comparison between study and control groups

| Region | Mean score (out of 20)±SD | | P |
|---------------|---------------------------|----------------------|-------|
| | Integrated teaching | Traditional teaching | |
| Lower limb | 12.57±2.44 | 9.86±2.83 | 0 |
| Abdomen | 12.22±4.37 | 7.52±3.75 | 0 |
| Thorax | 12.19±3.66 | 7.97±3.24 | 0 |
| Head and neck | 12.31±3.25 | 10.77±2.82 | 0.013 |

SD=Standard deviation

Table 2: Perceptions of students on the effectiveness of radiological anatomy

| Questions | Likert scale (1 - Strongly disagree; 5 - Strongly agree) | | | | | Mean |
|---|--|---|----|----|----|------|
| | 1 | 2 | 3 | 4 | 5 | |
| Meeting radiological learning outcomes | | | | | | |
| RA learning was useful in helping me to identify and describe normal radiological features | 0 | 0 | 11 | 34 | 55 | 4.44 |
| RA learning was useful in helping me differentiate normal anatomy from abnormal ones | 0 | 1 | 15 | 41 | 43 | 4.26 |
| Application and contextualization of anatomical knowledge | | | | | | |
| RA learning helped me apply my knowledge of anatomy in a clinical context | 0 | 3 | 11 | 42 | 44 | 4.27 |
| RA learning helped me identify areas of anatomy where my knowledge and understanding are insufficient | 1 | 4 | 22 | 38 | 35 | 4.02 |
| RA learning helped me revise anatomy | 1 | 2 | 22 | 40 | 35 | 4.06 |
| Introduction to and experience of RA | | | | | | |
| RA learning helped me become familiar with radiological imaging | 1 | 2 | 12 | 32 | 53 | 4.34 |
| RA learning has increased my interest in learning anatomy | 0 | 6 | 21 | 31 | 42 | 4.09 |

RA=Radiological anatomy

Results of nominal group discussions

Merits of the integrated RA module (top five responses after collation and arranged according to frequency) were as follows:

1. Better visualization of structures in different formats
2. Explanation of clinical aspects helped in better understanding
3. Easier to integrate with prior gross anatomical knowledge
4. Marking structures using "dotted lines" with adequate enlargement was more helpful
5. More engaging and interesting.

Demerits of the integrated RA module (top responses after collation and arranged according to frequency) were as follows:

1. Not able to revisit the material after class hours
2. Time available for group discussion was not adequate
3. Too many new information provided in single session is difficult to grasp
4. Not being included in conventional assessment lessens the importance.

Merits of the traditional radiological teaching (top five responses after collation and arranged according to frequency) were as follows:

1. Allows room for clearing doubts then and there
2. Easy to concentrate as information is provided in smaller amounts
3. Offers real-time exposure to X-rays
4. Handling X-rays individually
5. Ramification of discussion is possible.

Demerits of the traditional radiological teaching (top five responses after collation and arranged according to frequency) were as follows:

Table 3: Students' perceptions regarding the positives about the integrated radiological anatomy module

| Positives about the module |
|---|
| "Helped in applying theoretical knowledge in an applied way" |
| "We could find out what we are missing in traditional RA teaching" |
| "PowerPoint® helped in better identification of structures in normal X-ray and differentiate from abnormal ones" |
| "Annotations in X-ray were helpful in guiding us" |
| "The module was interactive and since we had our knowledge being tested it was beneficial" |
| "Exposure to clinical-based questions would help us in solving clinical scenarios in future" |
| "Gave different views of structures which we encounter during dissection" |
| "After undergoing the module, learning from X-rays mounted in lobby gave more meaning" |
| "Learning structures in X-ray one by one was much useful. The visual memory gained by this would help in retaining the information for a longer time" |
| "Coupled with osteology and dissection, it gave better understanding" |
| "Cross-sectional images with marking/highlighting of structures were interesting and easier to understand" |

RA=Radiological anatomy

Table 4: Common reflections of students on the reasons for incorporating the integrated radiological anatomy module in the anatomy curriculum

| Integrated RA module should be incorporated in anatomy curriculum? why? |
|--|
| It made learning anatomy easier and better understandable |
| It would be helpful in future practice as we need to interpret X-rays, CT scan, and MRI scan |
| Better appreciation of bony landmarks was helpful in gross anatomy as well |
| Helpful in better understanding of relation to structures and better recall |
| Learning RA from books was not easy and module helped me a lot |
| Helps in better engagement because of clinical orientation |
| Interaction during sessions offers better clarity and different ideas |

CT=Computed tomography, MRI=Magnetic resonance imaging, RA=Radiological anatomy

1. Crowded and not audible
2. Not able to demarcate the structures properly
3. Not able to exactly follow the areas pointed by teacher
4. Lack of exposure to a variety of imaging modalities
5. Absence of integrating with clinical knowledge.

Discussion

Bohl *et al.*^[17] pointed out that "Any teaching methodology that places anatomy in a clinical context and improves student awareness toward anatomy's clinical relevance is likely to improve student acquisition of relevant anatomical concepts." Similarly, Johnson *et al.*^[18] postulated that a modernized anatomy curriculum which integrates the benefits of traditional lectures with radiological imaging, computer-assisted learning, and problem-based learning would be of great benefit for the

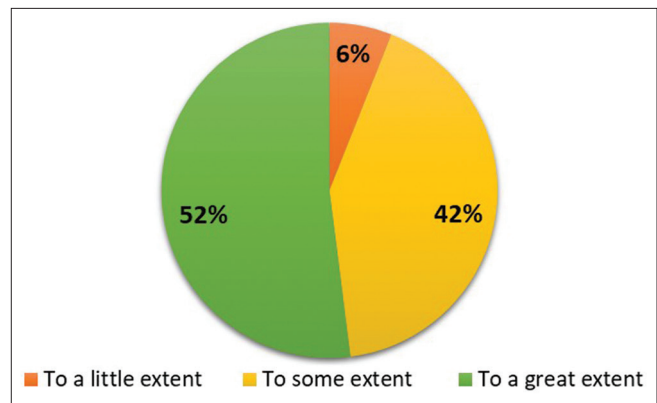


Figure 2: Students' reflection on the usefulness of the interactive radiological anatomy module than traditional teaching

students. In the past, our department typically delivered RA teaching, which entailed informal practical sessions whereby students in groups of ten were rotated in groups to visualize the available X-rays. Even though it can be considered as a primitive asynchronous team-based learning model and does not require additional resources, the outcomes were variable.

A study by Mirsadraee *et al.*^[19] found that 90.5% of medical educators were of the view that radiology should be taught in conjunction with anatomy dissection. Similarly, it has been said that understanding the benefits of radiological competence is quintessential prior to clinical practice.^[20] In the present study, 89% of the students (mean = 4.44) gave a strong agreement to the fact that RA was useful in identifying and describing anatomical structures in radiological images and 84% (mean = 4.26) of the students agreed that it was useful in helping them to differentiate abnormal anatomy from normal ones, which indicated the self-perceived increase in radiological reasoning abilities. Our results were similar to a prospective study by Murphy *et al.*^[21] where 98.7% of the respondents felt that radiology-aided anatomical learning was useful and 96% wanted more radiological teaching linked with normal anatomy dissection. In addition to this, various studies^[10,22-24] have shown positive perception about integrating radiology in anatomy teaching.

Upon asking about the contextualization and application of anatomical knowledge in various dimensions, 86% of the students felt that this module helped in applying the learned content in clinical contexts and by answering the probe questions, 73% of the students found the areas in which their anatomy knowledge was insufficient and 75% felt that it is useful for revising the knowledge gained through lectures and dissection as well. This could be explained by the fact that visuospatial addition, which is usually not offered by the prosection specimens, is provided by radiological images and *vice versa*; learners' spatial ability needs to be strengthened

to fully understand the radiological images.^[25] In addition, cross-sectional images can be navigated through different planes, and this would highlight the areas where students are insufficient in their anatomical knowledge. As reported in earlier studies,^[6,26] we could also envisage that, students, when posed with questions containing cross-sectional images, had the initial confusion followed by clarity upon discussion. We could suggest that with the transition from static images to digital images, providing access to various sectional planes by comprehensive modules will be of great help to students in gaining the much-desired visuospatial abilities.

Nearly 85% of the students (mean = 4.34) perceived that the module helped them to become familiar with the imaging modalities. This is similar to a previous study^[27] where the mean score of agreement was 3.8. We can consider that the delivery of anatomy knowledge in this format would have increased the inclination of students toward imaging modalities and would have positive influence on their radiological reasoning skills.^[23,28,29] Nearly 73% of the students (mean = 4.09) expressed that the module has increased their interest in learning anatomy, as such. Marker *et al.*^[10] posited that digital radiology-based anatomy lectures were well received by students, and this aided them in anatomy exam preparation as well.

In addition, various factors in the module such as interactive dialogs within small groups^[30] as in think-pair-share technique and novelty factor due to the new electronic learning format were well received by the students. However, the execution of the module makes a lot of difference in enabling the students to gain maximum learning outcomes. In the present study, all sessions were conducted by the principal investigator and to our best level, "Socratic" method of asking a series of questions, with the intention that the student reaches the desired knowledge in the process, was used. If the session had been a typical didactic one or if the session is completed in a limited time period, outcomes would not be so optimal. In the nominal group discussion, some students pointed the benefits they had gained from the module and traditional method, where they had time to hoist the X-ray films in the lobby and scrutinize the unlabeled ones.

Limitations

We would also like to mention about few potential limitations of the present study. The results of the study, which are primarily from a single medical college, could not be generalized because of the differences in the curriculum, students' abilities, and teaching standard. Overall, the students perceived that a right mix of traditional and modular methodology would be

of extreme benefit. Hence, it could not be ascertained that the module can be used as a stand-alone method of instruction. Rather, it can better be used as an adjunct to the existing framework. Another challenge we had faced in the due course was regarding the number of cross sections to be displayed. Even though providing students with labeled cross-sectional images was beneficial, slide presentation, as a medium, has its own contingencies.^[31] If the number of cross sections had gone more than the perceivable limit of students, the main purpose of the study would have gone unachieved. Finally, it was not feasible to measure the increase in visuospatial abilities across the module. The documented change in the visuospatial abilities, particularly after interpreting cross-sectional images, would have added value to the results.

Conclusion

Radiological imaging has become a quintessential part of medical practice in the current era. Hence, having adequate knowledge about RA is essential, and if it is learned with concurrent dissection, the knowledge will be retained for a long time. Compared to the traditional lobby-based teaching, the integrated RA module was perceived to be effective by majority of the students. Based on these, we could conclude that the integrated RA module has yielded better outcomes compared to the traditional method and also helped in honing the spatial and applied anatomical knowledge of the students' right from the preclinical year of medical education. Further studies, regarding the transferability of radiological reasoning abilities to different educational contexts, such as case-based learning scenarios and measurement of knowledge decay shall be planned to evaluate the long-term effects of the module.

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Conflicts of interest

There are no conflicts of interest.

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