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# SPECIALIZING ANATOMY - DEVELOPING AN INTEGRATED RADIOLOGICAL ANATOMY MODULE FOR THE FIRST YEAR MEDICAL STUDENTS

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## ABSTRACT

**Introduction:** Introducing radiology in the pre-clinical curriculum can enhance anatomy education. The need of the hour is a transparent vertical pathway that can be logically followed through the preclinical and clinical years of training. The aim of this paper is developing an integrated radiological anatomy module and evaluating its effectiveness.

**Methodology:** Imaging anatomy used for teaching included normal radiography, MRI and CT scans. These techniques were incorporated into teaching for the first year medical students. At the end of the year, students were asked to rate the effectiveness via closed ended questions.

**Results:** 50 (41%) students graded 3/5, 42 (34.4%) students graded 4/5 when asked about the extent to which sectional anatomy can positively influence the learning process of CT and MRI in future and 52 (42.6%) students graded 3/5 followed by 43 (35.3%) graded 4/5 when asked about the perceived utility of the module.

**Conclusion:** the results show that the module has its own positive effects in majority of the students. Further standardization and refining of the module has to be done to elucidate its short and long term outcomes.

**KEY WORDS:** Anatomy Curriculum, Radiology Education, Medical Imaging, Sectional Anatomy.

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## INTRODUCTION

The rapid development of technologies and techniques for minimally invasive surgery has transformed the knowledge of anatomy required for clinical practice [1]. The practical skills such as endoscopy and laparoscopy in gastroenterology, interventional procedures in cardiology and radiology require a competent knowledge in anatomy to manoeuvre the instruments. The reduction in the anatomical curriculum has led to growing concerns among medical educators, clinicians, as well as medical students that the anatomical knowledge of new medical graduates may not be adequate [2,3]. A change in the medical curriculum with innovative ways is thus required to ensure that students have the knowledge and skills necessary to function as qualiûed new clinicians.

The ongoing ‘‘anatomy debate’’ has polarized educationists between the so-called ‘‘traditionalists’’ who favour cadaveric dissection and the ‘‘modernists’’ who favour newer teaching modalities, such as problem-based learning and computer-assisted learning [2]. An integrated exposure of students to cadaveric specimens, radiographic images and clinical case scenarios improves the student’s understanding of anatomy, stimulates study and increases interest [4,5].

Radiology teaching in most universities is sporadic in nature. The lack of proper integration and variable teaching methodologies can only have a negative impact on the interpretation of radiological images which is mandatory for any undergraduate student. The ad-hoc teaching of radiological imaging by clinicians during various clinical postings seldom have documented objectives or goals for the students. This lacunae demands a committed framework for integrating radiology teaching in medical education. The need of the hour is a transparent vertical pathway that can be logically followed through the preclinical and clinical years of training.

The next question which lies in front of us would be regarding the right time for inception of radiology teaching in undergraduate curriculum. A study has suggested that integrating radiology and anatomy can reinforce learning during anatomical dissection [6]. The Royal College of Radiologists has made it clear that radiology image interpretation is central to ensure accurate patient management. Furthermore, it suggests that radiology images offer a powerful tool in supporting the learning process of anatomy and pathology, as well as in improving the understanding of disease and treatment response [7,8]. The 'eye of medicine' is a resource with the potential to fill such gaps between basic sciences and clinical medicine. It can provide the future doctors with a succinct and true-to-life view of the normal as well as the disease processes in a non-invasive manner [9,10]. Rengier et al., had stated that "three-dimensional imaging and post processing helps to understand difûcult anatomical structures and topographical relations in a better way" [11].

Regardless of the choice of speciality, almost every future doctor would utilize diagnostic imaging in patient care [12]. It is high time to realize that integration of radiology into medical curricula, especially basic science courses, may not only provide medical students a practical acquaintance with the normal human processes but may also build an enduring foundation for the clinical years [12]. The increasing demand of radiology in clinical medicine warrants its reflection in continual curriculum review process.

A study recommends the usage of cadaveric cross-sectional prosections as an adjunct to improve spatial anatomical knowledge among students and to improve the ability to accurately interpret the radiological imaging [13]. With the growing body of 3D information, the modern day call is looking for new pedagogical techniques that accomplish anatomical understanding in less time, but the challenge still remains for students to build and operate within internal mental models of complex biological structures [14]. The inclusion of sectional anatomy training in medical school curricula has been found to have a great impact on subsequent CT interpretations [15]. Thus, inclusion of sectional anatomy can provide a different perception of the structures which the students had perceived using their "tactile" sensation in routine cadaveric dissection.

The non-invasive and interventional procedures require a greater appreciation of anatomy from a different perspective [16]. With the decline in the amount of time devoted to teaching anatomy in medical school curricula, the ability of the students perceive and internalize the spatial relations of the organs also has reduced. This learning outcome, which is much needed by the surgeons, radiologists and interventionists has to be addressed. Providing laparoscopic view of internal abdominal organs either in the form of early clinical exposure programs or video presentation can help the students to learn anatomy from a clinical perspective.

The main emphasis we had placed in our teaching module is "visualization". Visualization, in the context of anatomy, can be defined as creating a mental picture of anatomical structures that is easily recalled. It is a powerful tool in learning anatomy since the complex spatial organization of the body across three dimensions is best represented visually [17].

## METHODOLOGY

The integrated radiological anatomy module was designed to be delivered at the end of each session of regional anatomy. By this time, students would have acquired the orientation of viscera and bones from the dissection and lecture classes. At the end of each section of the regional anatomy course (upper limb, lower limb, abdomen & pelvis, thorax, head & neck and neuro-anatomy), imaging anatomy session was

**Table 1:** The integrative radiological anatomy module.

| Region | Framework of the lecture | Objectives specified |
|---|---|---|
| 1. Upper limb, pectoral region and axilla (1.5 hours) | a. Introduction to principles of X-ray<br>b. Plain X-ray of shoulder joint<br>c. Plain X-ray of arm and elbow<br>d. Plain X-ray of forearm and carpal bones<br>e. Age-estimation by carpal bones<br>f. X-rays of shoulder dislocation, clavicle fracture, supracondylar fracture, Colle's fracture<br>g. Basics of ultrasound introducing knob techniques, different types of echogenicity<br>h. USG images of muscles in the shoulder region<br>i. Image of rotator cuff tear<br>j. Introduction to mammography<br>k. Normal breast and breast carcinoma in mammography | At the end of the demonstration the student should be able to<br>Identify the bones and their orientation in X-rays<br>Identify common abnormalities related to these bones<br>Determine the age using carpal bones<br>Identify orientation of muscles and tendons in ultrasound<br>Understand the differences in appearance of normal and pathological breast in mammography |
| 2. Lower limb (1 hour) | a. X-rays of hip joint, knee joint, ankle joint, foot stressing on the landmarks for identifying fractures<br>b. Images and classification of fractures involving hip and hip dislocation<br>c. Interactive sessions challenging students to identify different types of fractures<br>d. MRI of knee joint and orientation of intra-articular ligaments<br>e. Arteriogram of lower limb emphasizing on branches of femoral artery and popliteal artery | At the end of the session the student should be able to<br>Identify the orientation of bones and name different types of fractures<br>Identify the orientation of structures in MRI of knee<br>Get orientation regarding the vasculature of lower limb |
| 3. Abdomen and pelvis (2 hours) | **Session 1**<br>a. Plain X-ray of abdomen<br>b. Comparison of and identifying structures in X-ray<br>c. Plain X-ray pelvis<br>d. X-rays of paralytic ileus, gallstones and renal stones and the basis of their appearance<br>e. Introduction to barium studies, procedure and subtypes<br>f. Labelled images of barium swallow, barium meal, barium meal follow through, barium enema<br>g. Image of double contrast studies for small intestine<br>h. Image of cholecystogram<br>i. Principles, procedure and images of different phases of intravenous pyelography<br>j. Image of renal calculi and hydronephrosis<br>k. Principles, procedures and image of hysterosalphingography.<br>**Session 2**<br>Basics of sectional anatomy, CT scan and difference in appearance of solid and luminous organs were explained.<br>Triplet images at 5 different levels were displayed. It contains<br>a. Unlabelled CT sectional image at a particular level (eg: L1)<br>b. Unlabelled schematic illustration of section at that particular level<br>c. Unlabelled image of cross section from atlas<br>Following this, an interactive session challenging the students to identify the structures of the CT image shown first was conducted.<br>This was repeated at 5 different levels. | At the end of the session the student should be able to<br>Identify the structures in plain X-ray of abdomen and pelvis<br>Identify common clinical conditions like gallstones, renal calculi and ileus<br>Get orientation of barium studies and ability to identify different parts in it.<br>Get orientation of cholecystography, intravenous pyelography and hysterosalphingography.<br>At the end of this session, the student should be able to<br>Identify disposition of viscera at different levels.<br>Identify the level at which section is taken by analysing the disposition of viscera.<br>Identify the differences in the appearance of various viscera. |
| 4. Thorax (1.5 hours) | a. Plain X-ray Postero- anterior view of thorax<br>b. Differences between different views of thorax<br>c. Stepwise interpretation of chest X-ray<br>d. Identification of different lobes and broncho-pulmonary segments<br>e. Cardiothoracic ratio estimation and reading of structures forming cardiac silhouette<br>f. Images of pleural effusion, cardiomegaly, tetralogy of Fallot, pulmonary tuberculosis<br>Following this, sectional anatomy of thorax was taught using the same methodology followed as in abdomen and pelvis. | At the end of the session the student should be able to<br>Identify the structures in plain chest X-ray<br>Identify basic clinical conditions from normal X ray<br>Identify disposition of viscera at different levels.<br>Identify the level at which section is taken by analysing the disposition of viscera. (especially sections of heart in CT scans) |
| 5. Head and neck (1.5 hours) | a. Plain X ray postero-anterior view of skull<br>b. Plain X ray Water's view showing paranasal sinuses<br>c. Plain X ray lateral view showing cranial fossa and other landmarks<br>d. Plain X ray lateral view showing airway and cervical spine<br>e. Images showing Le Fort fracture types, cervical spine fractures and sinusitis.<br>Following this, sectional anatomy was taught in three different planes<br>(Coronal -1; sagittal – 1; axial – 6; skull base – 1; middle ear and mastoid sinuses -1; spaces of head and neck – 4)<br>This is followed by interpreting CT sections at these levels. | At the end of demonstration, student should be able to<br>Identify various structures in all three prescribed X ray views of head and neck.<br>Identify all paranasal sinuses and contrast it from plain X ray showing sinusitis.<br>Identify the structures met during dissection in CT sections.<br>Identify the boundaries of spaces of head and neck. |
| 6. Neuro-anatomy (1.5 hours) | In the first half of the session, series of images of cross sections of the brain (coronal – 5; transverse – 7; sagittal -2) with animated labelling were displayed.<br>Following this cross section images without labelling was displayed. Students were asked to write down the structures corresponding to the numbers marked.<br>MRI images were displayed and students were asked to identify the structures which they had seen in sections. | At the end of the session students should be able to<br>Identify the various structures of brain at all possible levels.<br>Identify the disposition of ventricles and structures related to them.<br>Identify the 'digital analogue' of them in CT images. |

scheduled. Didactic practical sessions encompassing X-ray films, CT sections and MRI were conducted via PowerPoint presentations in the anatomy department, Pondicherry Institute of Medical Sciences, Puducherry. These sessions could be better co-ordinated as a radiology-anatomy meet where both radiologists and anatomists can give a double-pronged approach towards the objectives. If the co-ordination couldn't be established, the anatomist himself can conduct the session, after introducing the basics of radiological techniques. Special techniques like MRI, ultrasonography and mammography nevertheless requires the contribution of radiologist, as it could be difficult for an anatomist to explain.

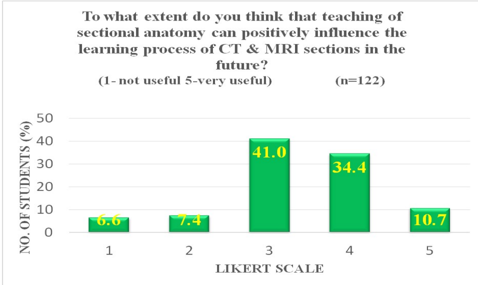
The schedule totals up to 9 hours. It involves both teaching of sectional anatomy and correlating with radiological images. The schedule itself includes self-assessment exercises for students which helps them to ensure their understanding. Besides covering normal imaging and sectional anatomy, the module also include some pathological images, each shown within its clinical context.

At the end of the academic year, students were asked to grade the effectiveness of the imaging anatomy schedule. The responses (n=122) were recorded in an anonymous feedback. For questions which involves rating of the module, a five-point Likert scale (ranging from 1-strongly disagree to 5-strongly agree) was used to express the opinions of the students. The variables were summarized using mean, median, minimum and maximum. No identifying information was collected, and subject participation was purely voluntary.

## RESULTS

Responses were collected from 122 students at the end of the yearly academic schedule and after the completion of the university theory examinations. When asked about the extent to which sectional anatomy can positively influence the learning process of CT sections and MRI in future, 50 (41%) students graded 3/5, 42 (34.4%) students graded 4/5 and 13(10.7%) students graded 5/5. Figure 1 summarises the respondents' evaluation for the question.

**Fig.1:** Perceived utility of sectional anatomy in learning process of CT &MRI sections in the future (n=122).




The next question was about the perceived utility of the integrated radiological anatomy schedule in positively influencing the identification and orientation of the structures in radiological images. 52 (42.6%) students graded 3/5 followed by 43 (35.3%) graded 4/5. Figure 2 summarises the participants' percipience for this question.

**Fig. 2:** Perceived importance of integrated radiological anatomy in positively influencing identification and orientation of structures in radiological images (n=122).

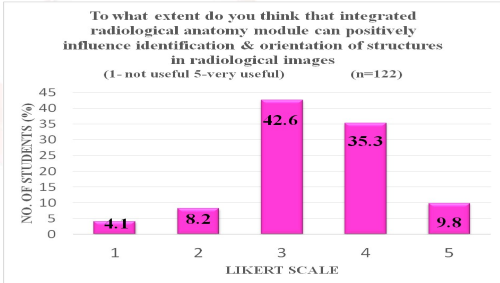



**Fig. 3:** Transverse section of abdomen displaying anatomical structures.

**Fig. 4:** Roughly corresponding axial image of the abdomen obtained via computed tomography which is manually labelled and sequentially displayed during the interactive session. The unlabelled axial image was displayed prior to Fig 3 (shown above).

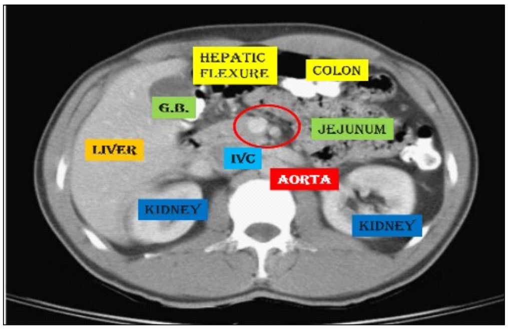
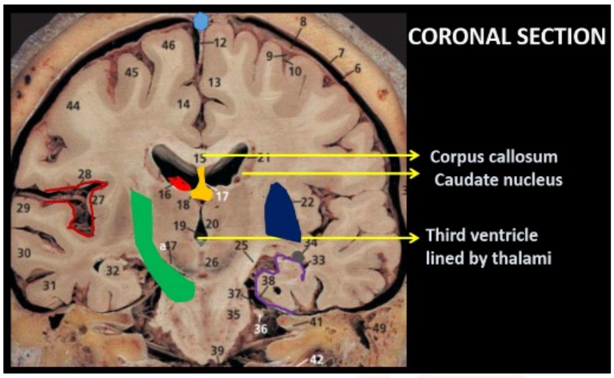


**Fig. 5:** Sample screen capture of the neuro-anatomy session showing a coronal section of brain. Similar images in all possible coronal and transverse sections were displayed. The areas shaded in this picture were sequentially displayed for facilitating face to face interactive session.




## DISCUSSION

Gogalniceanu P et al., [18)] had stated that, "Future doctors will need to conceptualize anatomy from the perspective of angiography, ultrasound imaging, computed tomography, laparoscopy, and endoscopy". Unfortunately, the reduction of both in the gross anatomy teaching hours and its context, has led to a serious review of the way in which anatomy is taught [19]. Reports suggest that less than one third of the new residents in surgery have adequate anatomical knowledge [20]. This demands for a re-engineering in the undergraduate curriculum which accommodates innovative methodologies and thereby widening up the conceptual understanding necessary for the future clinicians.

It has been emphasized that the primary aim of an anatomy teaching module is to teach medical students to understand and visualize the structure of the human body using the various tools available to the clinician, ranging from touch for physical examination to more modern methods, such as imaging modalities [21,22]. Gross anatomy teaching which involves dissection involves learning in all three dimensions. Nevertheless, students often fail to appreciate arbitrary planes and structural relations in the course of such laboratory work [23].

The policy makers in the curriculum committee should balance the needs and limitations of the present generation learners, who need a "modernized" and clinical oriented anatomy to be taught in a shorter duration. This calls for moving towards competency based education, which is being implemented widely in the universities across the world. The curricular philosophy also prescribes a convergence of teaching modalities by all the disciplines contributing to the course, as these are of necessity directed at achieving a common goal of producing a competent "generalist" doctor instead of attaining expertise in each discipline [24]. Apart from dissection skills, this reform should enable the students acquire the skill of three-dimensional visualization. On the other hand, contextualizing learning with clinical cases assists in the storage of knowledge in memory so that it is available for reasoning in subsequent clinical situations [25]. As Bohl et al., [26] had pointed out, "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".

Mirsadraee et al., [27] conducted a study in which he sought review opinions of medical educationists from various specialities. 90.5% of the participants had agreed that radiology teaching should be taught in conjunction to anatomy dissection. 95.2% had suggested that radiology anatomy should be placed into undergraduate curriculum. All the participants had unanimously agreed that cross-sectional imaging taught via CT sections and MRI, followed by plain radiographs played an important role in linking radiology with anatomy [27].

An integrative radiological anatomy module was developed bearing all these facts in mind. Imaging anatomy is here provided as an "adjunct" tool to routine cadaver based teaching. In many medical schools in North America and Europe, have introduced radiology at the preclinical phase of the medical curriculum [28,29]. A survey of 21 British and Irish universities performed in 2002 showed that the majority of medical schools are delivering anatomy content via integrated curricula involving radiology [30]. In India, most universities have radiology incorporated in the first year anatomy syllabus, but the space for that is shrunk owing to the competition among other subcomponents of anatomy education.

A simultaneous application of dissection, radiological film material, clinical cases and the achieving of clinical skills lead to a significant improvement of the understanding of anatomy [31]. As said by Schober et al., [32], "the transmission of information into long-term memory and the rapid recall in a clinical situation depend crucially on the conditions under which the information was learned". The above said statement was confirmed by a study by Erkonen WE et al., [33] where lectures were designed to integrate diagnostic imaging with anatomical structures. They found that when the students were followed up 14-17 months, 74% gave correct answers. They concluded stating that, "this high level of long-term retention documents the effectiveness of integrating diagnostic radiologic images into normal gross anatomy instruction" [33].

This could also be an example for level-appropriate teaching of the clinical reasoning process in human anatomy [34]. For example, on comparing a normal X-ray image with an image showing Colle's fracture, a student can reach a morphologic diagnosis. This was used in a problem-based learning format in few sessions (eg: classification of hip fractures; identifying the nerve potentially damaged in posterior hip dislocation). This was intended to promote an orderly fashion of thinking to connect the morphologic diagnosis with clinical presentation in later years. Further active involvement of students by correlating and recalling the knowledge gained from traditional gross anatomy classes, clinical relevance and repetition are suggested as favourable factors for learning [35].

Elizondo-Omaña et al., [34] divided the clinical reasoning into five basic and three superior abilities. The basic skills includes identiûcation, description, comparison and deûnition. In our module, the student needs to identify the region, describe the structures seen in a step-wise manner (eg: chest X-ray), compare normal images with pathological images and finally arrive at the morphologic diagnosis. As an adjunct, we also had small group teaching sessions with X-rays mainly where individual teachers helped the students to interpret them in a systematic approach.

In our module, we intended to provide a solid foundation for medical imaging, as lectures covered relevant radiological techniques and views coupled with sectional anatomy. Harden (36) argues that curricular integration can be viewed as a ladder, with discipline-based teaching ("isolation") at the bottom of the ladder and full integration ("trans-disciplinary teaching") at the top. An ideal integrated curriculum should involve interdisciplinary teaching, interdisciplinary faculty collaboration and building curricular links [37]. In most of the sessions we had tried our level best to facilitate interdisciplinary teaching amalgamating sectional and imaging anatomy.

At the end of the module, we tried to evaluate the effectiveness, by asking students to what extent the session has improved their understanding of radiological images. These questions addressed Kirkpatricks' first level of learning i.e. to what degree participants react favourably to the learning event [38]. Majority of the students graded 3/5 and 4/5, depicting that they can appreciate the relevance of the module. Our findings were in concordance with another study [39], where between 57% and 60% of students agreed or strongly agreed that radiology lectures helped them learn effectively, producing a mean Likert rating of 3.4 to 3.6. Also in the same study (39), between 75% and 87% of students agreed or strongly agreed that the cross-sectional sessions were a helpful introduction to the interpretation of medical imaging of thorax, head and neck, with a mean Likert rating of 4.0 to 4.2. Similarly, 72% to 77% of students agreed or strongly agreed the cross-sectional practical sessions helped them to better understand the imaging modalities of CT, MRI and ultrasound, with a mean Likert rating of 3.9 to 4.0 [39]. In another study [11], students felt that three-dimensional imaging and post-processing helped to better understand difficult anatomical topics and topographical relations. Students felt that modules combining anatomy and radiology gave long term benefits [11].

The introduction of imaging anatomy in tandem with regional anatomy schedule presents one of the great opportunities for vertical integration of anatomy throughout undergraduate medical curriculum. Longitudinal integration of the anatomical sciences in the curriculum is widely supported by clinicians from all disciplines [40].

**Limitations of the study:** One of the drawbacks of the present study is the inability to compare the knowledge of the students before and after the sessions. Therefore, we are unable to make an assessment of whether integrated radiological anatomy module had improved the students' understanding of human anatomy or medical imaging. This could have been better established by a better study design involving two different student population and measuring the differences in the ability to interpret radiologic images. The scope for including image based questions wasn't there in our present assessment pattern. This made 'internalization' of our module varying according to students' interest. We were not able to collect sufficient data pertaining to these 'varied percipience'. As mentioned earlier, effective co-ordination with radiologist was seldom achieved which had truncated their contribution towards the module. But this shortcoming was overruled by placing our emphasis on sectional anatomy and achieving an effective linkage between radiological images and sectional anatomy.

Curricula where the use of medical imaging was integrated with cadaveric anatomy led to a demonstrated improvement in students' performance in anatomy and radiology (41). Many medical schools in western countries have devoted nearly 20% of their practical classes for radiology teaching. Despite of the fact that, we were unable to measure the effectiveness, we can hypothesize that students have gained image-specific anatomy knowledge. In further coming years, the desired short term and long term outcomes of our module should be tested using different hypotheses.

## CONCLUSION

Our intention, by developing an integrated radiological anatomy module, is to inculcate the basic skills in interpreting radiological images, right from the first year of medical education. This could help the students to better understand the spatial relationships between anatomical structures and also the usage of different imaging modalities. Its right time for anatomy to get evolved from the years where radiological anatomy was confined to a few hours of displaying X-rays in the lobby. With the reduction in the time available for gross anatomy education, it becomes mandatory that the curricula should be re-engineered to prepare the students to meet common demands of various specialities, which forms the basis for vertical integration as well.

**Conflicts of Interests:** **None**

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