

Rembrandt's Anatomy Lesson of Dr. Tulp Revisited: Advancements in Teaching Anatomy and Neurobiology in an Integrated Medical Curriculum in the 21st Century.

Orien L Tulp

University of Science Arts and Technology, Montserrat.
Einstein Medical Institute, N. Palm Beach, FL, USA

Frantz Sainvil

University of Science Arts and Technology, Montserrat.
Einstein Medical Institute, N. Palm Beach, FL, USA

Hailin Wu

University of Science Arts and Technology, Montserrat, BWI.
East-West College of Natural Medicine, Sarasota, Florida

Rolando Branly

University of Science Arts and Technology, Montserrat, BWI.
East-West College of Natural Medicine, Sarasota, Florida

Abstract

The recent challenges in anatomy and neurobiology education in medical curricula have imposed a curricular redevelopment in delivery and content, incorporating modules in virtual anatomy and neurobiology, didactic lecture and enhanced cadaveric dissection in a state-of-the-art teaching and learning environment. The combined approach engaged active student participation at each phase of the course, incorporated clinical perspectives, emphasized valuable diagnostic and surgical techniques and procedures, and minimized noxious exposure to formaldehyde by using unembalmed cadavers in a laminar airflow environment. Finally, the objectives of emphasizing the importance of proficiency in anatomy knowledge in clinical medicine were accomplished well within the allocated one semester time frame, in a timely, cost and resource effective manner, and with demonstration of competency to standard during post laboratory examinations.

Keywords: Cadaveric Dissection, Prosection, Anatomy, Virtual Dissection, Clinical Integration

OVERVIEW

The events of the past years have placed greater demands on innovation and creativity in medical education than ever before. The role of anatomy as a core course in the medical curriculum, where it has been a traditional element of the first year of the course structure for many years is undergoing much needed transition in many institutions around the globe based on a variety of factors. With great advancements in educational technology and in the overall content and complexity and an increasing greater emphasis on a clinically oriented focus of

basic medical sciences in recent decades, the necessity for broad changes and topic integration are progressing. While fewer clock hours typically remain available for gross anatomy instruction in the developing curricular models of the 21st Century, the necessity and clinical importance for the subject content has not diminished. If anything, the overall content has not only maintained its criticality in importance but has also increased in its complexity in application. There exists therefore a need to condense such courses in shorter time frames to the extent possible by making more efficient use of resources including computer integration, simulation, 3-D modeling, and problem-based learning (PBL) approaches and to present the course content in the most imaginative and cost-effective manner possible. It is also essential to accomplish these objectives without having to extend the duration of the years of study to complete a primary medical or graduate qualification or graduation from medical or graduate school beyond the current 4 to 7 years, depending on the country and institution where the program may be offered. To accomplish this, didactic lectures are oriented along organ system-based settings for each phase of the lectures, incorporated with a virtual anatomy system such as Anatomage® or similar virtual instructional assist. Lecture discussions and demonstrations include topics in Pathophysiology, Medical Biophysics, discussion and practical demonstration of meridians and acupuncture points where appropriate and preclinical introduction to selected clinical procedures. The culmination of the dissection ends with each student being able to demonstrate the above procedures to standard, and with a complete functional small group surgical dissection of an unembalmed cadaver. The anatomic content is reinforced and revisited in subsequent years in Clinical Anatomy, Pathophysiology, and Pathology modules prior to entry to the clinical years. With careful attention to planning and curriculum, one can fulfill the needs of tomorrow's medical practitioners, surgeons, physicians and biomedical scientists; with careful attention to content and need, and the undeterred will and motivation of a dedicated faculty and staff, the emerging educational technologies now available can help to meet and attain the challenge and will enable the students of today and tomorrow to master the field of anatomy and neurobiology like never before.

INTRODUCTION

Emerging Global Changes in Medical Education have increased the pressures to increase the content and efficiency of delivery in medical education in many subject areas to keep pace with advances in scientific discovery of new therapeutics and emerging diseases without losing sight of the many significant albeit often historical advances in clinical medicine accomplished in recent decades. Some have questioned the future directions of traditional education in Anatomy as a declining field of study, its significance and importance to clinical practice prevail.¹⁻⁵ Although ever changing advances in technology have occurred and traditional approaches have presented new challenges, the core specialties including surgery and radiology in particular continue to remain heavily dependent upon a solid mastery of anatomy.^{3,5} These pressures often occur with simultaneously shrinking budgets, limited faculty, and challenging resources, including decreases in available cadaver donations and changing perceptions of need in medical education across the globe.^{7,8} This has generated a shift towards a greater emphasis on molecular biological than physical aspects of medical practice.²⁻⁵ The recent coronavirus pandemic added an additional extraordinary burden to the mix by forcing compromise in classroom participation, and further impacted on cadaver availability due to specimen safety concerns, all without easy solutions.² The greatest challenge however may be progressive schedule reallocations with ongoing decreases in available clock hours that can be allotted to the cadaveric dissection experience, combined with experienced faculty shortages as retiring

faculty may not always be replaced with the same disciplines, talents, experience and specializations as in the past, or at the same rate as institutional needs become obligated to adjust to a changing classroom, a shrinking budget, and progressive changes in the laboratory and educational environment, all while contributing to needed improvements in the overall quality and content of medical education.⁸⁻¹⁰

RECOMMENDATIONS FOR A SUCCESSFUL OUTCOME IN ADVANCED LEVEL CADAVERIC DISSECTION

Every successful anatomy experience should best start with an investigation of the desired objectives and desired outcomes, and supported with a well thought out plan to achieve the objectives deemed important for the lesson and dissection experience.¹¹⁻¹⁴ In planning such an experience, consideration should be given to a) the level of prior education and experience of the intended audience; b) the availability of suitable cadavers, dissection tables, instructional staff and availability of additional resources deemed necessary for a successful experience; and c) the group or class size undertaking the dissection laboratory. Securing the availability of adequate resources requires significant preplanning. Specific points one might entertain developing the plan are Included but are not limited to the items summarized below.

Is There a Critical Endpoint in Anatomy Course Duration and Content?

Historically traditional Gross Anatomy courses were once spaced over a 2 to 3 semester experience, staffed with dedicated faculty and assisted by surgical residents and graduate assistants (themselves often in training) to assist a faculty member in course delivery, and modelled to provide the future physicians and surgeons with a comprehensive knowledge of cadaveric anatomy.^{1,3,6} Those assets Institutions were once accustomed to are now often pared down to a mere one semester bloc of instruction but with the same or greater projected endpoint in terms of expected academic content and stated course outcomes. These adjustments appear to have thereby necessitated shortcuts such as demonstrations, prosections, and abbreviated labs compared to the more extensive and time-consuming dissections of yesteryear. The graduated physician is still expected to have mastered the same or greater grand level of knowledge of anatomy, physiology and neurobiology as in the past, and one can be assured, the 'board exams, such as the USMLE in the USA or equivalent comprehensive assessment in other jurisdictions.¹⁰ The qualifying exams when taken, as well as the senior resident mentor, will likely expect no less than the same amount of the detailed knowledge-base likely needed to navigate the most complex procedure one might encounter in the theatre. In addition, one can be assured that the 'board exams' will be certain to cover the same body parts and physiologic processes on those written examinations that one may have missed or inadvertently forgotten along the intervening years between the in-course experience and the ultimate qualifying examinations for entry into the advanced training years.^{15,16} In addition, a shortage of qualified and experienced instructors in the field of human anatomy, physiology and neurobiology has been reported and is likely to continue to be present in the future, as abundant opportunities for graduate training in this field appear to have been lacking. Moreover, in recent years as the emphasis had been shifting toward cellular and molecular biology oriented topics, and with what many may perceive as more exciting fields of study, particularly in the gross anatomy side of the profession. The cumulative impact of these changes in the delivery of anatomy education appears to have led to a lack of qualified instructors in some of the more basic and rudimentary elements of the curriculum.¹⁻³

Necessity is the 'Mother' of Invention: Anatomy Budgets May Facilitate the Way to Improvement.

As academic budgets and class times become readjusted, class size considerations can become a hot topic, as the larger the class size, the more cost effective it can become for the Institution to conduct the class, especially for lecture type instruction. Small class sizes and laboratory expenses can become cost-prohibitive if the number of enrolled students per session is too small, and most institutions have well established lower limits that typically border around a certain single- or double-digit number that essentially revolves at least in part around cost recovery for offering elective and other course modules. For the most effective student- to-faculty ratio in medical instruction however, those lower numbers simply often do not work very well in many scenarios, and anatomy lab is one of those scenarios where a closer faculty to student ratio may be more effective but less economically feasible in the overall anatomy laboratory dissection experience.¹⁴

Anatomy Essentials are Best Incorporated Early in the Medical Curriculum.

Anatomy lecture and lab is traditionally a first-year course in medical education, where class lecture sizes are of necessity large, historically often 100 to 200 or more students in a lecture session. For laboratory exercises however, small group instruction is much preferred to large group demonstration, such that everyone around the dissection table can more easily participate and more effectively visualize the details of the specimen.^{11,13-14} In such settings there can also be greater student-faculty interaction, particularly in pointing out the fine detail of particular or individualized findings that may be present in the cadaver and which are often unique to a particular cadaveric specimen. It is valuable to have an experienced mentor, preferably one with prior surgical experience, such as a retired or senior surgeon or pathologist who can readily identify and discuss specific pathologic teaching points along the way during the dissection.^{11,14} As such, it presents a more effective teaching and learning situation, with freer inhibited participation and with more student-instructor interchange resulting in less perceived student hesitation or perceived instructor intimidation. In smaller settings such as are described here there can be better and more effective attention paid to the uniqueness of each cadaver and the more individualized teaching points that it may present. It is also always useful to have both a gross anatomy reference, a pathology reference and a whiteboard readily available nearby during dissections, such that spontaneous discussions may ensue where students and the instructor assigned to the table may become engaged in creative discussions about the subtopic at hand. The ready availability of reference resources may further encourage instructor-student shared exchanges and thus enhance the dissection experience. Availability of appropriate supporting resources enables one to research topics of interest that may arise during a dissection procedure, rather than to delay such topics until after the moment has passed and interest has cooled. The whiteboard may be used to aid in the discussion, or perhaps for example to outline a surgical approach for a particular surgical procedure, then during the dissection, undertake such a procedure as part of the regional dissection, thereby adding a valuable clinical focus to the dissection. The uses for a readily available whiteboard adjacent to a dissection table are virtually unlimited and can add much to a dissection exercise. The use of cellphones are typically prohibited in a dissection laboratory, with the exception of the camera use restricted for preapproved instructional purposes only and where one is careful to not photograph the cadaver *per se* for identification purposes. However, taking a picture of the whiteboard notes or specimen details should only be attempted for educational purposes and with the prior express (preferably written) consent of the author or relevant instructor

whereby some forms of recording for later instructional purposes or topic review may be undertaken.¹⁴

Establish a Clinically Oriented Focus.

Establishing a clinical focus during anatomic instruction is important and as a general observation likely contributes to greater potential for content retention of subject matter by the student.^{11,14,17} It is usually beneficial to introduce some clinical procedures to the cadaver prior to the commencing the dissection per se, where such incorporation may offer the distinct advantage that it may provide an orientation to the subject, contribute to instructional realism and can cause no harm. It is essential that all unembalmed and lightly or fully embalmed cadavers be safety tested and care taken to conduct the lab in a deemed safe environment, such as state-of-the-art dissection laboratory facility equipped with adequate laminar-flow ventilation to minimize unwanted distraction during the often-condensed duration of the planned laboratory experiences.¹⁸⁻²⁰ Prior to the dissection, important sensitivity instruction should be given, including acceptable respect, clinical PPE attire including surgical scrubs and gowns, proper dissection instrumentation and surgical techniques and attention to expected personal demeanor from all in attendance during the dissection.^{13,14} Clinically oriented procedures one might consider incorporating include such items such as:

1. Surgical attire and conduct in an anatomy theatre is typically similar to that of a surgical theatre, including surgical setup, instrument tray, instrumentation technic and supporting resources;
2. Surgical draping of the cadaver, regionally specific to the anatomic dissection under discussion;
3. Demonstration of an endotrachoscopy, bronchoscopy or other instrument assisted visual examination procedure.
4. Introduce and practice multiple suturing techniques: These are easily performed on fresh unembalmed cadavers and can yield a great additional value-added dimension to the dissection; suturing human skin tends to generate a different sensation to the student than occurs with other materials
5. Time permitting, when the dissection progresses, remove the lungs intact and connect to a heart lung apparatus and demonstrate the physiologic elasticity of the respiratory system, and then demonstrate and examine the tissues for environmental injury such as smoking, drowning, forensic indications, etc. including examination of selected tissues under a dissecting microscope;
6. Endoscopy of internal structures such as gastrointestinal, uterine, or other structures or and organs with an endoscope adds a dimension seldom available prior to a clinical setting, and is an educationally rewarding experience likely to further reinforce long term recall to the student;
7. Injection of a simple dye into cardiovascular and neural networks to better visualize such structures such as cardiac vessels and neural pathways that may be of interest. Simple dark colored food dyes are inexpensive any may be utilized as a substitute to more expensive tissue dyes for visualizing vasculature for classroom demonstrations should the tissue dyes be unavailable. As an added benefit, the dyes often reveal partial cardiovascular occlusions or other lesions that become excellent teaching points and which otherwise may otherwise may escape observation during the small or larger group dissections;

8. Demonstration of surgical palpation, as the sense of touch in the surgeon's hands and fingers become an important extension of his visibility, for anatomic features that the surgeon cannot see directly. The palpation of individual organs becomes an important part of the dissection, as much as how one holds the instruments, removes tissues, or obtains biopsy specimens is an important component of presurgical theatre. The opportunity to obtain biopsy specimens for integrated histologic evaluation adds an additional valued dimension to the dissection experience and may help the participating students to determine the likely cause of death of the cadaver.
9. Numerous reports attest such as suturing, ultrasonography technique and other surgical and clinical procedures are improved when first practiced on fresh cadavers over plastic models or live patients (refs), and which when performed in unembalmed or lightly embalmed cadavers reflect observations more typical of those which may be observed in live specimens.²¹⁻²⁶ Professor Smith, of Brighton and Sussex medical school once reported that when one presses a knife into human flesh, the sensation subtly and uniquely changes compared to that of other species or artificial tissues as the knife penetrates and travels through its incision. With each cut of the knife, it facilitates the creation of a valuable learned sensation and teaching point in surgical technique.⁷ To slice into a human artery in contrast, one may feel a bit of springback due to the elasticity of the structure, while dissection of veins tends to result in a more passive or flat surgical response and do not produce the same springback sensation, and nerves a response intermediate to the forgoing examples. Acquisition of such skills early in one's medical career can bring greater satisfaction to the surgeon or emergency room physician throughout their subsequent career, and hopefully reduces the likelihood of a future medical or surgical mishap at an inopportune time where it could potentially result in a dire outcome.^{14,16,17}
10. The dissecting laboratory should be equipped with adequate laminar flow air circulation, regardless of the type of cadaveric specimens used so as to minimize any potential untoward effects of formaldehyde or other noxious chemicals or odors. This is especially important when students are expected to spend long hours over many days in the presence of the cadaver or cadaveric specimen.^{3,6-8} During the dissections, which typically last for several days only on each fresh cadaver, key surgical and medical procedures that are likely to be needed during forward clinical years are demonstrated on each cadaver, including insertion of chest tubes, spinal taps, Intubation, topical and cosmetic suturing, endoscopy surgical techniques, 3-D imaging, biopsy techniques, meridians and point location among other valuable instructional points that may contribute to greater potential for retention.¹⁴

Cadaver Availability is Important.

The availability of cadavers is a highly valued and often scarce resource in medical education.¹ Prior to the dissection, important sensitivity instruction is preferably given, including acceptable respect for the cadaver. The proper donning of clinical PPE attire including surgical scrubs and gowns often begins in the anatomy lab; proper dissection and surgical technics and attention to expected personal demeanor are emphasized during the dissection.^{13,14} During the dissections, which may typically last for several days to a week on each fresh cadaver, key surgical and medical procedures that are likely to be needed during forward clinical years three and four are demonstrated on each cadaver, including insertion of chest tubes, spinal taps, Intubation, topical and cosmetic suturing, endoscopy, 3-D imaging, surgical technique, point

location and others. The culmination of the dissection ends with each student being able to demonstrate the above procedures to standard and having completed a complete functional surgical dissection of the cadaver. The anatomic content is reinforced and revisited in subsequent years in Clinical Anatomy, Pathophysiology, and Pathology modules with continued as needed access to the virtual anatomy program, prior to entry to the clinical years. In a condensed time-frame, with limitations in resources it may seem to remain a challenge to adequately incorporate the quality and content of anatomic education fully needed and essential to retain anatomic proficiency and ensure competency in anatomy education. However, with careful attention to planning, one can fulfill the needs of tomorrow's medical practitioners, surgeons and physician biomedical scientists but with careful attention to content and need the will and undeterred motivation with the emerging educational technologies now available to attain the challenge will enable the students of today and tomorrow to master the field like never before.

Incorporation of Surface Anatomy Modules.

The early incorporation of surface anatomy and body painting modules into the laboratory is a highly useful technic which has shown value in identifying key anatomic landmarks, and in determining a number of outward clinical features that are important in descriptive clinical anatomy.²⁷⁻³¹ Findings of surface anatomy instruction and demonstration, when applied to diagnostic criterion and to the art of physical diagnosis and clinical medicine via anatomically correct terminology may enhance the student's long term retention. The role of surface anatomy is often covered in Clinical Anatomy, covered in Year two of the USAT MBBS and MD curriculum.¹⁴ Living and Surface anatomy includes multimedia, body painting, and living anatomy which are useful for demonstration of body movements, body mechanics and thus have many applications to clinical and physical medicine. Indeed, the dynamics of conducting routine and targeted physical examination are perhaps the most commonly used clinical application of surface anatomy in clinical medicine in all specialties.^{2,31-32} The study of Living and Surface anatomy is included in numerous anatomy programs, where it plays an increasingly important and well accepted role and contributes to a student's understanding of physiologic aspects of musculoskeletal anatomic functions. Body painting, including marks placed by indelible marking pens is an inexpensive and easily mastered approach to define variations in physical features and is well accepted by students as an effective instructional technique, and one in which students can often participate. An indelible line or mark is only 'skin deep' and can easily be superimposed when an error occurs, while a mark or premature cut made by a scalpel blade not so much, and when misplaced can complicate later steps and including deeper layered tissues in the dissection. Study of surface anatomy often incorporates body painting as a useful tool to enhance physiologic implications thus enhance a student's understanding of the relationships between muscle groups, kinesiology and body movements and has proven beneficial adjunct to anatomy understanding and musculoskeletal physiology^{29,30} Peer physical examinations may sometimes be considered a useful tool in conducting living and surface anatomy sessions and assessment of clinical biometry, but many medical students may feel uncomfortable in such settings, thus the use of anatomic models or professional subjects more accustomed to such examinations is preferred, especially when sensitive body parts that may be at stake are under discussion, and are often preferred in such sensitive settings. Addition of a course or module in clinical anatomy as the student enters year two of basic medical sciences can augment the introductory course content in anatomy and can

enhance critical preclinical dimensions to the overall long term retention factor for anatomy which will be very beneficial when the student enters the clinical years.

Formaldehyde Vs Fresh Cadavers, Carcinogenic Risk of Cadaver Preparation.

Use of lightly preserved vs unembalmed vs Embalmed cadavers: Which provides the best anatomical resource? The preparation of the cadaver becomes an important consideration for the type of laboratory one intends to conduct.¹⁸⁻²⁰ For dissections of shorter durations, of one week or less, unembalmed cadavers maintained in a cool, well ventilated environment often work very well and in our experience are to be preferred.^{13,14} For dissections or prosections of up to one to 3 months duration, lightly embalmed cadavers in a cool, well-ventilated environments with intermittent cooling during times when the cadavers are not in use and where the formaldehyde is diluted to “~half strength” may be used.¹⁸⁻²⁰ For traditional dissections of longer duration, embalmed cadavers usually via formalin remain the specimen of choice among most anatomists as they may be preserved for many months to years at conventional cool (~65-68°F) room temperatures if kept with a moist formaldehyde cover. In our experience the fresh cadavers were most preferred by students however, as the absence of the formaldehyde not only minimizes any potential carcinogenic or other health related risk, and the smell renders them more compatible with student acceptance both in and outside of the laboratory. In addition, dissection of unembalmed cadavers enables the scheduling of longer durations of laboratory periods often extending of up to 8 hours in a single day, whereas with formaldehyde embalmed cadavers, labs are limited to approximately 2 hours, one or two times a week, thereby making them not only less cost effective but more drawn out and longer to accomplish with a corresponding loss of momentum in the longer scheme of events. Recently developed computer assisted virtual learning with the Anatomage® and similar systems enables students to attain a greater depth of anatomy and neurobiology when combined with the small group short term dissection with greater retention than in the past, as they can return to the virtual system for refresher and self-study after the dissection without penalty, as they prepare for the medical ‘board’ exams of their choice. In addition, the above circumvents the potential longer term health risks of formaldehyde exposure which have been proposed elsewhere.^{14,18-20}

Achieving Competency in Anatomy

Competency in the teaching of anatomy requires considerably more than just structure identification that a student might gain from a textbook reading and/or review of an anatomic diagrams or limited study with virtual anatomy resources. While it has often been said that if ‘a good picture is worth a thousand words’ then a good cadaver is more likely worth more along the value of a textbook or encyclopedia full of words. The more complex interrelationship with the innervation and interrelationship with adjacent structures in health and disease, identification of major vascular and neural networks, both virtually and cadaveric, and how specific therapeutic agents might impact on those actions can be demonstrated, could hardly be covered in a picture. An encyclopedia, probably more likely, but, finally, demonstration to standard of the principles of the lesson in small group settings via cadaveric instruction helps to demonstrate the teaching points of the day, and the uniqueness of the individual cadaver, and correlate with the text and whiteboard references described above. An inquisitive instructor and with 6 or 8 enthusiastic students there is little that is likely to be omitted from the lessons of the day. The uniqueness of each individual cadaver will often add the subspecialty discussion to the mix. Such as “what caused the left hip osteoporosis?” or “why

did we find extrarenal arteries only in this cadaver?" "Is this what bone cancer looks like?" "is this a cyst or a tumor?" there is no end to the questions that may surface during a small group dissection that may add greater dimension and instructional value to the exercise.¹⁴ It's almost like it can be a preface to the first day in clinic. Except maybe it is, and the patient is always likely to be cooperative.

New Technology Presents Opportunities for Change and Can Fill a Need and Opportunity for Fresh New Ideas.

In recent years there has been a dramatic decrease in cadaver donations, coupled with increased costs of available specimens.¹⁻⁵ Thus, the opportunity to incorporate emerging developments in educational technology resources in not only the pedagogy of teaching, but also in developments in teaching and learning techniques brings new challenges and opportunities to the anatomy lab.^{14,23,33} Technological change is ever on-going in all aspects of education, at all levels from primary to post-graduate, higher education instructional methodology. In your grandparent's generation, the invention of computers may only have been a dream in someone's imagination, while in the past four decades they have made major inroads if not superhighways into every aspect of higher education. If we accept the computer assisted virtual dissection of man and animals that is now possible with some of the current computerized programs as a new starting point in medical education. In the last century, Our professors would seldom allow a then new-fangled device called a tape recorder in the lab or classroom; now multimedia is expected to be included in virtually all levels of education, where it can bring about a more comprehensive and greater retention of examined materials and concepts on virtually any topic. A student can truly reach for the stars or whatever horizon they may envision now in whatever discipline they may choose, as those once seemingly distant vistas are a lot closer due to innovations in educational technology than ever before: now those once distant realizations are closer than just the number of gigabytes needed to access and bring them to fruition.

RESULTS

Modernization of Anatomy and Neurobiology Instruction at the USAT Department of Anatomy.

The Anatomy dissection program developed progressively over a period of 5 years to its present state. The program was developed under the oversight of the Miami Anatomic Research Center, who provided the extensive resources needed to develop the program. From the outset, only unembalmed safety tested cadavers were used and maintained in a cooled and well-ventilated dissection parlor equipped with stainless dissection tables, fully equipped sterilized instrument trays, protective gowns (PPE) and such other items as necessary, including a portable whiteboard dedicated to the room. Prior to the onset of each laboratory session, proper respect was offered for the cadaver. Prior to the dissection instruction, students trained on an Anatomage® table as part of their didactic anatomy lecture course, depicted in Figure 1 below. In Figure 1, a photoshot of student participation on an Anatomage module, where the images are also shown on the larger screen adjacent to the Anatomage® table. Both students and faculty can manipulate the images, and have the opportunity to confirm the identity of the structures depicted to further enhance the importance and retention of the content of the modules. In addition, students can return to the Anatomage® Table for audit, followup and reinforcement throughout their academic experiences' years during designated times through both basic science and clinical years.

In Figure 2, a rendition of the Anatomy Lesson of Dr Tulp, a renowned anatomist³⁴ is depicted, and in Figure 3, a typical group of USAT students is depicted undergoing a mentored cadaveric dissection, during which all participants cooperate and take an active part in the dissection process. Each dissection table can accommodate a maximum of 10 to 12 students, although for planning purposes most sessions limit each table to 8 students. In Figure 2, a lumbar laminectomy is being performed as one of the dissection modules with individual student participation. When unique or remarkable findings are discovered during a dissection, the participants of all tables have the opportunity to join in the observation, dissection and discussions pertaining to the anatomic findings. In Figure 4, a group session is depicted undergoing a cardiac massage, again with maximum student participation. In additional modules, endoscopy or bronchoscopy is routinely performed during the first hour of the dissection process.

Figure 5 depicts a 3-D printing apparatus, during dissections a small body part can be dissected and placed in the apparatus, which then can print a replica of the body part. Anatomic structures commonly printed include any easily dissected small bones included mandibles, phalanges and others. Overall the mastery of staged anatomic instruction enables students to better appreciate and reinforce the clinical manifestations of the anatomy, physiology and neurobiology with carryover to the clinical years and beyond. Anatomy teaching hours have become significantly compressed in recent years to yield room for additional topics in molecular biology and numerous other topics now included in medical basic sciences, many of which have a connection to basic functional anatomy. As a likely result of the innovative emphasis placed on this and other topics during medical basic sciences, student test scores on the basic sciences and clinical sciences pre-licensing examinations have trended upwards with virtually all applicants finding success in their pursuit of post graduate residency training in the USA and other nations.

SUMMARY AND CONCLUSIONS

Clearly, your grandfather's anatomy lab is not here anymore, but it hasn't gone out entirely with the discarded debris, and although it is not likely to return any time soon in its earlier format, the fundamentals, importance and need for mastery of the instruction in gross anatomy remain and haven't changed. The early process has provided the fundamental basis developed over hundreds of years, since Dr Nicholaes Tulp's early demonstration of human dissection as artistically recorded in the 'Anatomy Lesson of Dr. Tulp' (ca 1600)³⁴ followed by the evidence of early anatomical dissections of the Holden Chapel at Harvard University in the US.³⁵ Today's anatomy dissection and modularized learning programs, including computer assisted virtual anatomy programs for human and animal anatomic study enable anatomy instruction to be more meaningful and longer lasting than ever before. The old adage has often been stated, "necessity is the mother of invention" and which rings truer today than ever before. With new and developing technology in the form of virtual anatomy, biophysics, fiber optics, and electronic media applications. One can simulate neurophysiologic and biophysical phenomenon with predictive accuracy at the molecular level and apply fiberoptic visualizations and 3-D printing exercises not previously adaptable to the anatomy laboratory to supplement the age-old dissecting instruments of yesterday's lab. This may include computer assisted photography, radiographic imaging, introduction to surgical techniques and procedures, all focused to better prepare the student of today for the clinical experience and demands of tomorrow. Neurophysiologic pathways can be modeled, and virtual dose related

pharmacologic alterations predicted. In small group discussions, students can discover the uniqueness of each cadaver, relate them to live situations and examples, and engage in healthy and productive discussion with the participating faculty and in attendance, and with computer assisted library resources available as needed. The anatomy laboratory of the 21st century is an evolving program, which will continue to evolve and develop as technology advances and will continue to present an exciting and dynamic opportunity for tomorrow's medical student to not only master the skills for today but to build on and to develop the skills for a stronger tomorrow. No single approach by itself is likely to be as effective as the combined approach using new and developing multimedia approaches.

In summary and conclusion, the student Mastery of Gross Anatomy remains a fundamental core course in medical education, and must be mastered for an optimal medical education. The USAT Modular High Yield approach has incorporated numerous innovations in the delivery of medical education and has transformed a previously unpopular experience into an effective module that is now based on capitalizing on the neurotransformative educational philosophy of watching, learning and doing. This has been accomplished by using Anatomage® anatomic virtual illustration in combination with aesthetically presented fresh unembalmed cadavers to increase individual participation, and by enhancing content retention via incorporation of multidimensional technological advances in teaching, learning and memory throughout the basic sciences years. This pedagogical approach was established to help the student form a foundation for lifelong learning including elements and clinical aspects of both allopathic and Traditional Chinese Natural Medicine (TCM). By incorporating advances in the delivery mode of anatomy education designed to enhance participation, improve techniques of delivery, insure faculty competency, and enhance retention of the principles of anatomy from a functional clinical and pathophysiologic viewpoint, USAT has markedly improved the individual student skill set and anatomy retention of material taught during the Medical Basic Sciences and preclinical curricula such that the basic principles may be more effectively retained and applied during their continued career development.

Acknowledgements.

The authors are grateful for the assistance of the many faculty and staff of the Miami Anatomic Research Center for support and assistance in developing the above program for anatomy dissection for USAT medical students, many of whom entered the program with advanced certifications and degrees, seeking career advancement in the medical professions.

References

1. Drake, RL, McBride, JM, Lackman N, Pawlina W 2009. Medical Education in the anatomical sciences: The winds of change continue to blow. *Anat Sc Educ*. 2: 253-259.
2. Bowsher, D 1976. What should be taught in anatomy ? *Med Educ*. 10:132-134.
3. Eng-Tat Ang, Kapil Sugand, Mikael Hartman, Choon-Sheong Sheon Seow, Boon-Huat Bay, Peter Louw, G., Eizenbeg N, Carmichael SW 2009. The place of anatomy in medical education. *AMEE Guide no 41. Med Teach* 31:373-386.
4. Ang, E-T, Sugand, K, Hartman, M, Seow, X-S., Bay, B-H, and Abrahams, P. Singapore's anatomical future: Quo Vadis? *Anat Sci Educ* 5: 234-240. (2012) <https://doi.org/10.1002/ase.1286>

5. Habicht, J K, Kiessling, C, and Winklemann, A. Bodies for Anatomy Education in Medical Schools: An Overview of the Sources of Cadavers Worldwide. *Acad Med*. 2018 Sep; 93(9): 1293–1300.
6. Satheesa N Periya. Teaching Human Anatomy in the Medical Curriculum: A trend Review. *IJAR* 5(4) 445-448. 2017.
7. Claire Smith. Water, water everywhere: The pandemic has caused a shortage of cadavers. *The Economist*, Britain, May 8th 2021 edition.
8. Periya S N. Teaching anatomy in the medical curriculum: a trend review. *Int. J. Adv. Res.* 5(4), 445-448 ISSN: 2320-5407
9. Drake, RL. McBride, JM, LackmanN Pawlina W 2009. Medical Education in the anatomical sciences: The winds of change continue to blow. *Anat Sc Educ.* 2: 253-259.
10. Shiffer, C D, Boulet, J R, Cover, L J, and Pinsky, W W.. Advancing the Quality of Medical Education Worldwide: ECFMGs 2023 Medical School Accreditation Requirement. *J Med Reg* 103: (4) 9-16. 2019.
11. Tulp¹, OL., Ortiz-Bustillo- M, Einstein, GP., Sainvil, F., Konyk- CM., and Branly, RL. Innovation in Functional Anatomy Education: The Anatomy Lesson of Dr Tulp from the past to the Present. *Proceedings, Abstr A7749, EB2018, the FASEB Journal, 33 S1, 2018.*
12. Agu, A. The Dissecting Room Experience: A Factor in the choice of organ and whole body donation-A Nigerian survey.
13. Tulp, OL, Sainvil F Einstein GP, Scrianka, A, Branly, R, Wu, H, and Awan, AR. Incorporation of virtual enhancement in anatomy, physiology and clinical pathology instruction in medicine and veterinary medicine basic sciences. *FASEB J* 36(S1).
14. Tulp, OL., S ainvil, F., Wu, H.,Feleke, Y . Einstein, GP., and Branly, R. Modernization of Anatomy and Graduate Medical Education from the Past to the Present. *[Experimental Biology] FASEB J* 35: S1, 2021
15. Leung KK, LU KS, Huang TS Hsieh BS 2006. Anatomy Instruction in medical schools: connecting the past and the future. *Adv Health Sci Educ Theory Pract* 11: 209-215.
16. Anastakis, DJ, Regehr, G, Reznich, RK, et al: Assessment of technical skills transfer from the bench training model to the human model. *Am J Surg* 1999;77:167–170.
17. Keim Janssen, SA, VanderMeulen, SP, Shostrom, VK, Lomneth, CS: Enhancement of anatomical learning and developing clinical competence of first-year medical and allied health profession students. *Anat Sci Edu* 2014;7:181–190.
18. Kalanjati, VP, Prasetiowati, L, Alimsardjono, H: The use of lower-formalin-containing embalming solution for anatomy cadaver preparation. *Med J Indones* 2012;21(4):203–207
19. Whitehead MC, Savoia MC. Evaluation of methods to reduce formaldehyde levels of cadavers in the dissection laboratory. *Clin Anat.* 2008 Jan;21(1):75-81. doi: 10.1002/ca.20567.PMID: 18058900 [Switzerland]
20. Ocel, J, Natt, N, Tiegs, R, Arora, AS: Formal procedural skills training using a fresh frozen cadaver model: a pilot study. *Clin Anat* 2006;19:142–146.
21. Prasad, N, Kumar, S, Manjunath, R, Bhadauria, D, Kaul, A, Sharma, R: Real-time ultrasound guided percutaneous renal biopsy with needle guide by nephrologists decreases post-biopsy complications. *Clin Kidney J* 2015;8:151–156.

22. Reed, AB, Crafton, C, Giglia, JS, Hutto, JD: Back to basics: use of fresh cadavers in vascular surgery training. *Surgery* 2009;146:757–763.
23. Keim Janssen, SA, VanderMeulen, SP, Shostrom, VK, Lomneth, CS: Enhancement of anatomical learning and developing clinical competence of first-year medical and allied health profession students. *Anat Sci Edu* 2014;7:181–190.
24. Are, C, Lomneth, C, Stoddard, H, Azarow, K, Thompson, JS: A preliminary review of a pilot curriculum to teach open surgical skills during general surgery residency with initial feedback. *Am J Surg* 2012;204:103–109.
25. Meek, M, Meek, J, Hollowoa, B, Li, R, Deloney, L, Phelan, K: Lightly embalmed cadavers as a training tool for ultrasound-guided procedures commonly used in interventional radiology. *Ac Rad* 2018;25:1503–1509.
26. Hoyer, R, Means, R, Robertson, J, et al: Ultrasound-guided procedures in medical education: a fresh look at cadavers. *Intern Emerg Med* 2016;11:431–436.
27. Asad, M R, and Nasir, N. Role of Living and Surface Anatomy in Current Trends of Medical Education Vol-1 Issue-2 2015 *IJARIE-ISSN(O)-2395-4396*.
28. Finn GM. Twelve tips for running a successful body painting teaching session in freshman gross anatomy. *Med Teaching* 32:887-890. 2010.
29. Finn GM. McLachlan JC. 2010. A qualitative study on the student responses to body painting. *Anat Sci Educ*. 3:33-38
30. Nanjunundaiah K, Chowdapurkar S 2012 Body painting: a tool which can be used to teach surface anatomy. *J Clin Diagn Res* 6: 1405-1408.
31. Collett T Kirvell D Nakorn A McLachlan JC 2009. The role of living models in the teaching of surface anatomy: some experiences from a UK medical school. *Med Teach* 31: e90-e96.
32. Bickley, L S, Szilagyi, PG, Hoffman, RM, and Soriano, R P.(authors). In: Bate's Guide to Physical Examination and History taking., 12th ed. Lippincott Pubs. 2020.
33. Hoyek et al. Effectiveness of three-dimensional digital animation in teaching human anatomy in an authentic classroom context. *Anatomical Sciences Education* (2014).pp 1-8 [shows 3 -d digitl animation adds to cognitive retention by end of course].
34. The Anatomy Lesson of Dr. Nicolaes Tulp, 1632, by Rembrandt
35. Hodge, C. Non-bodies of knowledge: Anatomized remains from the Holden Chapel collection, Harvard University (2013) *Journal of Social Archaeology*.13(1). DOI:10.1177/1469605312465692. Corpus ID: 163338535



Figure 1. The Anatomy Lecture of Dr. Nicolaes Tulp (Rembrandt, 1632)



Figure 2. The Anatomy Lecture and Demonstration of Dr. Tulp, CA. 21st Century.



Figure 3. Small Group Dissection, depicting a cardiothoracic examination and dissection.



Figure 3. Virtual anatomy laboratory.