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Creation of virtual patients from CT images of cadavers to enhance integration of clinical and basic science student learning in anatomy

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Abstract

Objective: The goal of this study was to determine whether computerized tomographic (CT) images of cadavers could be used in addition to images from patients to develop virtual patients (VPs) to enhance integrated learning of basic and clinical science.

Methods: We imaged 13 cadavers on a Siemens CT system. The DICOM images from the CT were noted to be of high quality by a radiologist who systematically identified all abnormal and pathological findings. The pathological findings from the CT images and the cause of death were used to develop plausible clinical cases and study questions. Each case was designed to highlight and explain the abnormal anatomic findings encountered during the cadaveric dissection. A 3D reconstruction was produced using OsiriX and then formatted into a QuickTime movie which was then stored on the Tufts University Sciences Knowledgebase (TUSK) as a VP.

Results and Conclusions: We conclude that CT scanning of cadavers produces high-quality images that can be used to develop VPs. Although the use of the VPs was optional and fewer than half of the students had an imaged cadaver for dissection, 59 of the 172 (34%) students accessed and reviewed the cases and images positively and were very encouraging for us to continue.

Introduction

Virtual patients (VPs) have been found to be an important addition to the curriculum in medical schools permitting one to prepare students for actual patient contact before they begin their experiences in the clinical setting (Huang & Caughey 2004; Virtual Patient Reference Center, AAMC 2007, 2008; Ellaway 2008). With the development of The Visible Human project by the National Library of Medicine (1986) (McNulty 1997; Spitzer & Whitlock 1998), detailed high-resolution computerized tomographic (CT) and magnetic resonance imaging (MRI) images of the normal anatomy of a young male and female were now available to examine prior to the actual dissection and to anticipate findings seen in the dissecting room.. In view of the successful development of VPs and the detailed images from the Visible Human Project, we sought to determine the feasibility of using CT images of cadavers to create VP prior to their dissection. Our goals were to determine whether such images would be of sufficient quality for detailed radiologic analysis and would they yield sufficient abnormal and pathological findings to allow for the development of virtual cases (VPs). The ultimate goal of this approach is to better integrate basic and clinical sciences and to improve student learning in human anatomy in preparation for their clinical years. In this article we describe the results of a feasibility study.

Practice points

- One needs a team consisting of basic and clinical scientists to create the case history that is essential to the development of a Virtual Patient (VP).
- Care must be taken to ensure that sufficient permission has been given to use the computerized tomographic (CT) images for educational purposes.
- CT Images from an embalmed cadaver are of high resolution and can readily be constructed into a VP.
- The DICOM images from a CT can be configured into a 3D volumetric reconstruction using the open source program OsiriX on a Macintosh.
- The created VPs can be stored on a server as a movie or as Jpegs and made accessible to all.

Methods

Pilot study

All the cadavers used in this study were obtained through the Anatomical Donation Program at Tufts University via the Instrument of Anatomical Gift for a Massachusetts Medical School. To determine if the images in an embalmed bodies

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were useful and of high quality, we obtained CT images of a body within 12 h of death. Embalming was then performed immediately by the infusion of fluids through the common carotid artery. We then CT imaged the same body several weeks later and noted that the images in most regions were of high quality and similar to what those obtained shortly after death and without embalming. We further noted that a 1 min infusion of air, after the conclusion of embalming, enhanced the visualization of the arterial system.

CT imaging

Thirteen embalmed bodies were imaged. They were each enclosed in a body bag without any metallic fasteners and imaged on a Siemens Somatom Sensation dual energy 64 detectors computer tomographic system. Each body was embalmed via a canula inserted into the right common carotid artery. At the end of the infusion of the embalming fluid, air was introduced to demonstrate the arterial tree.

CT protocols

The system was setup to image the length of the torso, abdomen and lower extremities in one scan and the head and neck in a separate scan. Main detector energy was set at 120 KV and the Field-of-View at 380 mm. Rotation of the gantry was set at 0.5 s and collimation at 2 mm slice thickness in the axial plane on the scanner workstation (Leonardo). Image reformatting was performed in the coronal plane using a 3 mm × 3 mm pixel size. Images were stored in three image sets: standard soft tissue, lung and bone windows.

OsiriX protocols

OsiriX Imaging System is an open source DICOM viewer for Macintosh computers running on operating system (OS) 10.5 (Leopard) or better. DICOM images from each cadaver's CT scan are imported into the OsiriX database. In OsiriX, the data can be viewed as the CT scan, or it can be converted into 3-dimensional representations of the data. This is done by the analysis of the change in densities in the data, allowing the user to assign different colours to each set of densities. The finished product can be exported to either still images (JPEGs) or to a movie using QuickTime. The user can define the path that the camera should use to fly through the body; this allows the creation of custom movies that enable the user to decide the important highlights of the body for the students to focus on, as well as a logical progression through these points. After the movie is created, the user can add labels, shapes, outside images, changes in colouring, etc. into the movie to create a clearer informative guide for the students.

VP protocols

The CT images were collected and then reviewed by a radiologist who then sent his observations to a clinician, in our case a professor of medicine who based upon his clinical experiences developed a plausible case with appropriate questions and answers and URL listing appropriate cross references. The VPs were made available to the medical students by placing them on the server at Tufts University in Boston and then made accessible too.

Results

Six of the 29 cadavers (45%) used in the first-year Anatomy Course were imaged. The CT images were of high quality and were comparable to those obtained in living patients and available in the Visible Human Project. An average of six abnormal and pathological findings was found per imaged cadaver (range, 2–12 findings). Some major findings were directly associated with the reported cause of death (e.g. large right cerebral hemispheric infarction in a patient with a reported a cause of death of left-sided stroke), numerous others were unanticipated (e.g. large abdominal aortic aneurysm in a patients with Alzheimer's Dementia as the cause of death) and many other entities were detected (e.g. hip replacement, pleural and pericardial effusions, ascites, metastatic lesions, arterial grafts and unreported surgical procedures including cholecystectomy, hysterectomy, and vascular shunts). These CT findings were critical for the completion of the case history, and with a 3D reconstruction were used to create the VP. What follows are an example and a summary of a case that was created from a cadaver after combining the cause of death and the results of the radiological analysis.

Case AA. Patient AA was an 82-year-old man who was originally presented for medical evaluation with left-sided headache that had been present for several weeks. The headache was worse in the morning and was increased with coughing. The patient was subsequently hospitalized for a generalized tonic-clinic seizure. A diagnosis of glioblastoma was made and the patient underwent treatment. He subsequently presented with the loss of consciousness and was found to have evidence of increased intracranial pressure.

Questions

(1) What surgical procedure did the patient undergo as primary treatment for his glioblastoma? What may have led to his loss of consciousness and increased intracranial pressure. *Answer: The patient underwent a left temporal craniectomy. There is evidence for a large left temporo-parietal parenchymal hematoma with blood in the posterior horn of both lateral ventricles producing a mass effect.*

(2) During his final hospitalization fever was noted and purulent discharge was noted from the nares suggesting a possible diagnosis of maxillary sinusitis. Can you identify anatomic and radiographic evidence suggestive of this diagnosis? *Answer: There is fluid in the maxillary sinuses. The fluid could be blood, a sterile exudate or an infected collection (e.g. sinusitis).*

Conclusions

We conclude that CT scanning of cadavers is feasible and the high-quality images obtained can be used to develop VPs.

Students were given the option of reviewing each VP and answering the questions developed for each case even though they were not required to review the cases. Nonetheless, 59 of the 172 (34%) students accessed and reviewed the cases and images. The students indicated that the images were readily accessible at home via the internet or in the university library and that they clearly showed many anatomical and pathological features, and they also encouraged us to keep developing the VP from our cadavers. This year we included images from these cases in our gross anatomy exams, and a majority of our students now reviewed the cases. Focused discussions with students indicated that another limiting factor included the large volume of required content for the Human Anatomy Course.

We are currently expanding this work to determine the effect of such VPs on student learning. Imaging all cadavers and making the CT images at the 'bedside' in the Anatomy Lab may further engage students in this integrated approach to learning. Development of a database of VPs, to compare and contrast with images from the Visible Human and in normal patients, may further enhance the integration of clinical and basic science learning in human anatomy.

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Notes on Contributors

STANLEY JACOBSON, PhD, is Professor of Anatomy and Cellular Biology, Tufts University School of Medicine, Boston, MA. He was in charge of the selection and dissection of the cadavers and collected digital images for correlation to the CTs during the actual dissections.

SCOTT K. EPSTEIN, MD, is Dean for Educational Affairs and Professor of Medicine, Tufts University School of Medicine and Tufts Medical Center, Boston, MA, and he wrote up the cases.

SUSAN ALBRIGHT, BA, is Director of Tufts University Science Knowledge Base (TUSK), Tufts University School of Medicine, Boston, MA, and is in charge of placing the developed VP onto the Tufts server, TUSK.

VERONICA COPPERSMITH, BS, prepared the 3D reconstructions from OsiriX and is an applicant to medical school.

JEFFREY GRIFFITHS, MD, MPH, TM, is an Associate Professor in the Department of Public Health and Family Medicine and added in the relevant public health issues for each cadaver.

JOSEPH OCHIENG, MD, is Chairman of Anatomy, Makerere University School of Medicine, Kampala Uganda, collected images from patients in Uganda that will form a portion of our population of VP.

JOSEPH F. POLAK, MD, MPH, is Professor of Radiology Tufts University School of Medicine and Tufts Medical Center, Boston, MA, and the radiologist on this project and he directed, and interpreted all the scans.

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