Comparative analysis of various CT scans using the “Superimposition” feature from the Invivo 5.4 software by Anatomage

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Abstract

Magnetic Resonance Imaging (MRI) and Computer Tomographic (CT) scans have paved a way to more in depth and non-invasive analysis of the human body for pathological purposes. As our world delves further into the digital age, so should our medical imaging technology. The Invivo 5.4 software by Anatomage is advancing this journey in medical imaging to create even more forensic potential. The software was used to analyze two abdominal CT scans and two cranial CT scans depicting the brain to gain further insight into their conditions and potential prognoses. The “superimposition” application in the program is used to place the pre-condition scans along the same plane as the scans containing the patient’s diagnosis; this provided clarity and accuracy in determining the nature of the conditions, found to be an abdominal hemorrhagic cyst and inflammation and degeneration of the brain caused by multiple sclerosis, respectively.

Key Words: medical imaging, pathology, Invivo, superimposition, multiple sclerosis

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Introduction

Imaging has become a crucial aspect of the medical field, aiding in the diagnosis, observation, and treatment of a plethora of medical conditions. Approximately 120 years ago, a German scientist named Röntgen brought about the invention of the x-ray, revolutionizing the way we approach medicine by allowing bones and metal to be seen in a non-invasive manner. This technology proved its effectiveness when Marie Curie put it to the test during World War I, saving the lives of many soldiers inflicted with metal wounds and shattered bones (Scatliﬀ & Morris, 2014). Fast forwarding to over a century later, imaging has only increased exponentially in effectiveness and utility. Ultrasound was brought about to be used for the same gynecological purposes it is used for today, followed by computed tomographic scanning (CT). Magnetic Resonance Imaging (MRI) and Positron Emission Tomography (PET) are also among the imaging techniques used today in the healthcare profession. These technologies have their own realm of advantages and disadvantages. (“Developments in medical imaging – timeline”, n.d.). CT scans are a combination of multiple x-ray images taken at various angles to produce sliced images of the desired structure. This radiological technique is more informative than a simple x-ray image, but comes at the price of radiation exposure (“CT scan”, 2018). MRI scans produce images by creating a strong magnetic field that throws the body’s protons out of equilibrium, and records the various characteristic responses to this event; the speed and amount of energy it requires for these protons to return to the proper position is recorded by the machine. This movement of energy depicts what kind of cells (tumourous, benign, etc.) exist within the patient’s body and where they are located (“Magnetic Resonance Imaging (MRI)”, n.d.). While both are non-invasive techniques, they both come with their own disadvantages.

Invivo 5.4 Medical Design Suite is a software that allows viewing and modification of DICOM files, typically received from doing MRIs and CT scans. Along with easy viewing ability, the program adds a new portfolio of tools for professionals, students, and others to analyze these images with. DICOM (Digital Imaging and Communications in Medicine) is an official file format used exclusively for handling and storing medical images. The images produced from CT and MRI scans are often two-dimensional slices which can be very useful, but also limiting when the issue being observed is complex and/or invades multiple structures of the body. MRI scans are three-dimensional, but without the right viewer there is still a limit on the structures you will be able to see for diagnosis, as well as a lack of supplementary tools to improve the scans and the resulting image.
Invivo 5.4 has many useful features to maximize the effectiveness of a scan, which are commonly stress-inducing experiences for patients, particularly children. These features include volume rendering, superimposition, and 3D analysis, among others. Each feature provides a variety of image depictions such as soft tissue, bone, teeth, and combinations of soft tissue and bone. The superimposition tool combines the volume render features with a side-by-side visual of two chosen images. This will be the feature that my research focuses on, comparing normal against afflicted patient scans of both the abdomen and the brain.

Cysts are categorized as abnormal sacs or cavities containing fluid. They are often accompanied by pain symptoms in the region of inhabitance. Abdominal cysts are complicated, rare, and often require invasive surgery to be removed. This process is meticulous as the bursting of the cyst inside the body will allow the abnormal fluid to be spilled within the abdominopelvic cavity, potentially causing adverse effects (Mullaney & Dsouza, 2017). As commonly occurring as cysts are, there is a great need for a better method of diagnosis and preparation for extraction surgery, and better imaging technology to observe the manifestation of the cyst as there are many variations of the condition. Cysts may contain stones, clear fluid, bile, and even cancerous tumours; each of these cases must be treated differently (Chen, Lee, Yeung, Chan, Jiang & Sheu (2010).

Inflammation of the brain is a severe symptom which is indicative of a variety of conditions in a patient. It is a common symptom of dementia, epilepsy, multiple sclerosis, and more (Ekdahl, Claasen, Bonde, Kokaia, & Lindvall, 2013). There are particular regions of the brain in which damage will indicate a specific condition. Multiple sclerosis is a chronic neurodegenerative disease that targets the central nervous system, including the brain and the spinal cord. Patients with this condition experience their own bodies mistakenly attacking the myelin sheath that surrounds their nerve cells, removing the barrier that aids in the conduction of the electrical pulses between the brain and the rest of the body (“Multiple Sclerosis – Brain Foundation”, n.d.). This debilitating disease causes loss of motor function, vision and memory loss, and loss of sensation, among other symptoms. These symptoms correspond to specific regions of the brain that control the respective regions of the body; degeneration in the primary motor cortex, occipital lobe, and the limbic system (“The Diencephalon”, 2015).

Using the Invivo 5.4 superimposition tool to overlay unaffected with affected scans will make it easier to show the extent of the condition and the specific areas affected, helping professionals reach a diagnosis and helping communicate the situation to patients who may not have prior knowledge of what is considered a “normal” scan. I expect that Invivo 5.4 will provide professionals with a different perspective of the affected area and may offer alternative insight into the issue.
Materials and Methods

- Invivo 5.4 Medical Design Suite by Anatomage
- Microsoft Computer System
  CT scans were accessed from online servers providing anonymized DICOM files ("The Cancer Imaging Archive (TCIA)", n.d.).

- 1 CT scan file of Patient 1 presenting with normal abdomen
- 1 CT scan file of Patient 2 presenting with hemorrhagic abdominal cyst

For Case 1, the two abdominal scans were compared using the Superimposition tool from the Invivo 5.4 program. The scans were accurately overlaid using the landmarks feature to properly register the abdominal regions together. The images were preset to the “Soft [Tissue] & Bone 1” and “Soft [Tissue] & Bone 1 Colour2” volumes.

The feature that was observed to conclude that a hemorrhagic cyst was the plausible diagnosis was the lack of soft tissue in the cystic region representing the fluid-filled sac. The measurement tool built into the superimposition feature was used to outline the irregularly shaped cystic region and display an approximate volume.

- 1 CT scan file of Patient 3 presenting with a normal brain
- 1 CT scan file of Patient 4 presenting with inflammation of the brain

For Case 2, the process outlined in Case 1 was repeated, along with minor adjustments to the “3D Volume Toggle”, moved slightly towards the “Superimposed” end to allow the normal structures to be visible through the opaque tissue of Patient 4. The features observed to identify the condition of Patient 4 were:
- size of ventricles, particularly the lateral ventricle
- cerebellum shape and inflammatory characteristics
- each distinguished lobe (ie. temporal, frontal, etc.) regions

Results

The image features including orientation, colour, and volume registration were adjusted through the Invivo 5.4 program to allow the best possible viewing experience.
CASE 1

A cystic region measuring approximately 87.14 mm² was observed in the lower right quadrant of Patient 2 after superimposition with the normal abdominal cavity of Patient 1. In axial view, the lack of soft tissue is clearly visible, depicting the assumed hemorrhagic cystic structure. Patient condition of hemorrhagic cyst was indicated for Patient 2 through the online server through which the DICOM files were obtained.

CASE 2

Three anomalies can be observed after superimposition of Patient 3 and Patient 4 brain scans; degeneration of primary motor cortex, and inflammatory obstruction of both the cerebellum and the diencephalon which houses the limbic system; particularly the anterior horn of the lateral ventricle. Patient 3 and Patient 4 information regarding the results of this scan were provided by the online server through which the DICOM files were obtained: normal brain and the brain of an acute MS patient.

Figure 2: (CASE 1) Frontal view of both Patient 2 (left) and Patient 1 (right) abdominal scans in the Invivo 5.4 Superimposition “Registration” screen. Four blue (left) and four red (right) points representing registration landmarks.
Figure 1: (CASE 1) Axial view of abdomens of Patient 1 and Patient 2 overlaid by landmark registration, with highlighted cystic region in the upper right section of image, representing lower right quadrant in the individuals.
Figure 3: (CASE 1) Enlarged axial view depicting an 87.14 mm² measurement around the cystic region of the abdomen of Patient 2.

Figure 5: (CASE 2) Axial view of the normal brain of Patient 3.
Figure 4: (CASE 2) Axial view of the brain with inflammation of Patient 4, showing blue contrast to differentiate from normal scan.

Figure 6: (CASE 2) Axial view of Figure 4 and Figure 5 superimposed using Invivo 5.4 Superimposition tool.
Discussion

With the Superimposition feature in the Invivo 5.4 software, each pair of patient images were successfully superimposed to reveal the expected medical conditions: a hemorrhagic abdominal cyst, and inflammation and degeneration of brain tissue by way of multiple sclerosis. Using the integrated features including landmark registration and volume rendering, I was able to successfully superimpose two abdominal images from two different individuals, the normal one serving as a “control” image on which to base any abnormal findings. The ability to assign landmarks to the photos and accurately superimpose them adds the ability to compare scans from different individuals. This aspect of the superimposition feature is quite useful when physicians are attempting to conduct comparative analysis on an anomaly that has struck suddenly, or simply for an individual with a poor previous imaging history. This is incredibly useful in the forensic field, since individuals who have passed may have little to no medical history, or no one to communicate their past medical experiences. However, it is always most beneficial to remain consistent in order to best control interfering variables that may impact results.

Invivo 5.4 is a great tool with which oral surgeons can plan future dental implants, comparing before and after images. Pre-surgery and post-surgery comparisons would be made much easier with this software, allowing the surgeon and more importantly the patient to clearly see what was wrong before, the adjustments that have been made to solve the problem, as well as the positive results. The software is very user friendly and creates images that are easily communicable to patients with a lack of medical knowledge who may be perplexed about their medical situation.

Medical imaging is an ever-evolving field of medicine with many life-saving advantages, however it is not a flawless system. The process of an MRI or a CT scan can be intimidating for some, particularly those who suffer from claustrophobia, or general anxiety related to medical procedures. There is also an economic disadvantage that occurs when individuals without health coverage are not able to access these resources frequently, if at all (Al-Damegh, 2016). According to the United States Census Bureau, “8.8 percent of people, or 28.5 million people,” in the United States do not have any health insurance (US Census Bureau, 2018). These factors are important to consider when dealing with medical technologies because accessibility and simplicity is crucial to success. Invivo 5.4 provides a virtual anatomical suite in which there are a plethora of tools available for doctors and other professionals to manipulate the images they have taken and observe the case for longer in more detail than when the patient is under the CT scanner. This way, extensive study can be performed with no financial liability to the patient which often accompanies multiple or long scans, as well as a shorter time of imaging which will reduce patient anxiety. While there is still much room for improvement, Invivo 5.4 is a step in the right direction.
While the software has many advantages, there are modifications that can be made to maximize the potential of Invivo 5.4. If doctors are depending on this software to make decisions that will affect human lives, trials and tests must be conducted on large sample sizes to qualify the software for dependable reporting. Some aspects of my research that caused errors included: DICOM files from indirect sources, use of a trial-and-error approach, and limited archive of scans to observe. Since the DICOM files were not directly from a CT scanner, nor were they of patients whose medical history or other important details were disclosed, my research was quite limited. I approached the project with a trial-and-error plan, uploading many scans and making the necessary adjustments to display a clear visual image of the problem area. Had I used scans from a primary source, I would have been more confident in my findings. Furthermore, with focused testing and certification according to national guidelines and procedures, Invivo can develop into a prodigious technology used by physicians everywhere (Medical Device Testing, Certification & Auditing, n.d.). This research has only begun and will continue to grow in order to preserve the quality of care that every patient deserves.

Acknowledgments

I would like to thank the University of Windsor Forensic Science program for providing me with the opportunity and the Invivo 5.4 by Anatomage software to conduct my research, as well as my family and friends for supporting me in this endeavor.
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