Early detection of cerebral berry aneurysms using 3D Volume Rendering in In vivo 5

Munira Jamali\textsuperscript{1} BSc., Dr. Hayder Al-Tukmachi M.D, Dr. Shashi Jasra\textsuperscript{1} Ph.D.

Abstract

Forensic Radiology is currently an integral part of the preliminary procedure of post-mortem examination. As a time and cost-effective measure, a routine medical imaging scan is conducted prior to the autopsy. A commonly encountered cause of death in victims is a subarachnoid haemorrhage which often occurs as a result of a cerebral aneurysm. The key characteristics of cerebral aneurysms involve a weak, bulging artery in the brain that occurs randomly and with no discernible symptoms. The aneurysm may rupture abruptly resulting in brain damage or death. The three current methods of analysis of a Cerebral Aneurysm include Digital Subtraction Angiography, Computer Tomography Angiography and Magnetic Resonance Angiography – all three of which have unique limitations that can be overcome by a software called Invivo 5 by Anatomage. Invivo 5 allows for three-dimensional volume reconstruction and visualization of anatomy not easily seen on standard medical scans. It is a much more effective method to detect Cerebral Aneurysms in their earliest stage when they are smaller than 5mm in diameter and cannot be located on CT scans or MRI’s. This research experiment evaluates the difference in detection of Intercranial Aneurysms with Invivo 5 versus a traditional X-ray in a non-invasive manner. It promises a forensically useful way to verify a cause of death as a result of an aneurysm or disqualify this disease allowing for other possible reasons for death.

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\textsuperscript{1} Forensic Sciences, Faculty of Science, University of Windsor, 401Sunset Avenue, Windsor Ontario
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Introduction

The increasing availability and development of imaging techniques such as Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) has resulted in a growing number of forensic institutes relying on post-mortem imaging as a preliminary examination procedure prior to the internal autopsy. Radiology and Pathology must work in conjunction in the post-mortem investigation to form a new subspecialty: Forensic radiology. Forensic Radiology is used extensively in the post-mortem analysis procedure as well as the identification of remains. It aids in defining cause of death or injury and is traditionally used to accompany a post-mortem autopsy, or as a means of a non-invasive virtual autopsy. Although forensic autopsy is still the reference standard in a morphological forensic investigation, some law enforcement authorities decline autopsies and specifically request post-mortem imaging in cases where there are potential injuries that must be documented. Moreover, some faiths and religions do not tolerate traditional autopsy procedures and in these cases, a virtual autopsy is superior.

Post-mortem imaging includes an unenhanced CT scan as a baseline, a CTA, and MRI and an MRA. MRI passes through the bone and takes pictures of soft tissue, blood vessels and the brain whereas the use of contrast media injections in MRA scans is useful in the visualization of specific arteries and blood vessels and is particularly useful in the evaluation of aneurysms or strokes. This research experiment focusses primarily on the detection and evaluation of cerebral aneurysms in their earliest stage when they are smaller than 5 mm in diameter.

A cerebral aneurysm is a localized degradation of the arterial wall in the brain, that occurs suddenly in 3-5% of the population. The disease is like a heart attack in that there are no warning signs or symptoms until it ruptures leading to an intracerebral or subarachnoid haemorrhage depending on the area of the brain affected - which can ultimately result in brain damage or death. The bulging artery is filled with blood and upon exertion of pressure of nerves or brain tissues it may cause neurological complications.

Although a brain aneurysm is primarily silent, its chief risk is a haemorrhage, and upon detection it must be promptly dealt with. A vasospasm may occur when the blood from a resulting haemorrhage meets the surrounding arteries in the brain. The parent artery narrows due to the leaked blood and this reduces blood flow in important areas of the brain, causing permanent neurological damage. Vasospasms may occur about 3 days after the rupture of the aneurysm and can exhibit deadly
symptoms in patients. Early detection and treatment of an aneurysm is therefore crucial because it may rupture suddenly and without warning.

Early detection and screening of a Cerebral Aneurysm, particularly in cases of a family history of aneurysm is highly recommended and is carried out using imaging technology. The gold standard for evaluation of Cerebral Aneurysms is Digital Subtraction Angiography (DS), which provides high spatial and temporal resolution for detecting details otherwise missed by its competitors: CT scans and MRI images. However, it is relatively expensive and not widely available, and includes the major drawback of high-risk transient, reversible or permanent neurological and non-neurological complications. Magnetic Resonance Angiography (MRA) are the next best option in imaging technology, despite being limited by high cost and difficult evaluation of smaller vessels. Medical examiners endorse MRA’s on the basis that high-quality images on this machine can be obtained if the subject remains perfectly still – which is not an obstacle when analyzing a cadaver. The cheapest and minimally invasive procedure is Computed Tomography Angiography (CTA), of then the easiest and quickest to perform. The use of CT scans for aneurysms is inadequate due to its lack of spatial resolution and ability to localize the aneurysm anatomically.

The ideal technique to evaluate a cerebral aneurysm would be non-invasive, easy to perform, offer high spatial resolution and yield optimal information on the location and size of the aneurysm, as well as the collateral arteries originating from the dome and neck. Invivo 5 Medical Design Suite by Anatomage is an imaging software that promises to solve this problem by allowing for 3D Volume reconstruction and visualization of anatomy not easily seen on standard X-Rays.

The purpose of using Invivo 5 is to use the concept of focus and volume rendering to display both: the aneurysm with enough detail and the vessel network of the brain at the same time. It is worthwhile to recognize that dimensional constraints are the most widely accepted limitation of CTA, i.e. most aneurysms with a dome diameter smaller than 3 mm (referred to as “berry aneurysms”) can often be missed by a CT scan or MRI. The solution is volume rendered reconstruction using Invivo 5. This revolutionary new software allows for 3D reconstructed views of maximum intensity projected X-Rays, and a myriad of personalization tools to interpret the MRI using clipping, taking specific measurements and creating custom nerve pathways.

Materials and Methods

— Invivo 5.4 Medical Design Suite by Anatomage
Adequate Computer System

2 Periodic Brain Scan Images of a patient with Cerebral Aneurysm and 1 normal brain scan for control

Periodic MRI Brain scans of a patient with cerebral aneurysms were compared and analyzed in comparison to normal brain scans. The earliest possible scans of the patient were analyzed using a traditional MRI viewer and Invivo 5, and any anomalies were marked by comparing them to the normal scan – using the highlighting tool in Invivo 5.

Each subsequent scan was used for the detection of the onset of the aneurysm and tracking the increase in size of its dome and neck using the measurement tools. Dr. Hayder Al-Tukmachi and I observed the following characteristics on the MRI scans to locate any lesion in the brain:

1. A deviated mid-line in the brain
2. Size of the ventricles
3. Signs of intracerebral haemorrhage
4. Signs of intracerebral edema

The measurement tool in Invivo 5.4 was used to measure the neck of the berry aneurysm and all the data was recorded in a lab sheet for final comparison to the normal scan. Using the radiologist report accompanied with the medical images, a detailed account of the earliest detection of the Cerebral Aneurysm using the traditional MRI viewer versus the Invivo 5 software was formed.

Results

A berry aneurysm (< 5 mm in diameter) was located at the level of circle of willis in a 68-year-old patient with a history of diabetes and hypertension. The radiologist assigned to the case used a traditional viewer to read CT scans and MRA images. The images were viewed using the Medical Design Suite in Invivo 5.4 by Anatomage to generate a 3D volume rendered image of the vascular network in the brain and measure the size of the aneurysm.

Angiographic examination failed to disclose the aneurysm, although it depicted the subarachnoid haemorrhage with detail, allowing us to explore further arteries for presence of a secondary aneurysm. The following image data shows the cerebral berry aneurysm in one patient as compared to a normal brain scan. Our experiments have shown that the 3D visualization method offers superior diagnostic value in the evaluation of cerebral aneurysms – specifically those smaller than 5 mm in diameter.
Location of Aneurysm using Traditional MRA Viewer

Figure I (a): 2D MRA Image of Berry Aneurysm on Right Anterior Cerebral Artery using a traditional Image Viewer – Frontal View

Figure I (b): 2D MRA Image of Berry Aneurysm on Right Anterior Cerebral Artery using traditional Image Viewer – Dorsal View
Generating a soft tissue profile of MRA images using In vivo 5.4 by Anatomage

Figure II: 3D Volume rendering of MRA Image using Soft Tissue Profile (T2) in Invivo 5.4
Volume Rendering MRA Images of Intracerebral Vascular Network

**Figure III (a):** 3D Volume Rendered Image of Intracerebral Vascular network – Frontal View

**Figure III (b):** 3D Volume Rendered Image of Intracerebral Vascular network – Dorsal View
Location of Aneurysm using In vivo 5.4

Figure IV: Aneurysm is in Right Anterior Cerebral Artery as shown in the image
Figure V: Measurement of neck of berry aneurysm using dimension scale tool in Invivo 5.4
Aneurysm is noted arising from Right Anterior Cerebral Artery just distal of right Internal Carotid Artery bifurcation

- Neck of aneurysm = 1.4 mm
- 1.88 X 2.0mm in dimensions
- Severe narrowing noted at Anterior Cerebral Artery
- Aneurysm is directed inferiorly and slightly anteriorly
Comparison to other imaging

Figure VI: Angiogram for reference with located berry aneurysm and subarachnoid haemorrhage

Discussion

A berry aneurysm was located at the level of circle of willis in a 68-year-old patient with a history of diabetes and hypertension. The following characteristics were observed to locate any lesion in the brain.

1. A deviated mid-line in the brain
   A mid line shift in the brain was not observed likely due to the small size of the aneurysm. The subarachnoid haemorrhage was discovered first, giving clues as to a second aneurysm that may
rupture. The aneurysms at the anterior communicating artery usually are silent until they rupture and thus, there were no prior symptoms in then patient.

2. Size of the ventricles
   Size of the ventricles was observed to have shrunken slightly.

3. Signs of intracerebral haemorrhage
   A subarachnoid haemorrhage was observed in the complementary angiogram but was not visible on the MRI scans. The subarachnoid haemorrhage had caused the patient to have severe headaches and diarrhea for days which led to a hospital visit and the discovery of the second berry aneurysm.

4. Signs of intracerebral edema
   No evident signs of intracerebral edema.

   The MRI scans viewed under a traditional viewer allowed us to generally locate the aneurysm on the right anterior cerebral artery but did not offer any details on the size of the aneurysm or the exact location of it. The Medical Design Suite in Invivo 5.4 combined the dicom images of different segments of the brain into a 3D volume rendered image of the various levels of the brain to determine the relation between the right anterior cerebral parent artery and the surrounding nervous structures. It allowed us to yield optimal information on the location of the aneurysm, size of its dome and neck and any anomalies as well as any dilation or narrowing of the arteries. Upon clipping of the surrounding nerve pathways, we were able to see the aneurysm in three-dimensional view with maximum detail and measure it to 1.88 x 2.0 mm in dimensions, as well as a 1.4 mm diameter at the neck of the aneurysm. We were also able to observe severe narrowing at the anterior cerebral artery.

   Invivo 5.4 automates the volume rendering and texture mapping processes that must be conducted manually by radiologists prior to visualization of the MRI scans. It has interactive tools that can calculate the size of vessels directly within the viewer. If magnetic resonance imaging scans accompanied with a contrast media injection can be used within a 3D viewer such as Invivo to evaluate aneurysms, the need for an invasive technique such as Digital Subtraction Angiography will be greatly reduced. Currently the gold standard in evaluating cerebral aneurysms, DSA provides extremely high spatial and temporal resolution. However, due to its invasive nature it may cause irreversible neurological complications. Since it is difficult to create a 3D model out of tomographic slice images, the technique of volume rendering in Invivo 5 is an ideal method for the preliminary reconstruction of the vessels. Although surface rendering techniques are often performed manually in clinical settings to achieve the same result, it is a highly time-consuming process which does not prove as effective.
A variety of customization tools provided by Invivo 5.4 allow the user to edit variables such as light sources and tissue profiles. Several built-in manipulators can alter a lesion or a vessel within the 2D space. Moreover, the analysis of the angiographic volume data set is largely interactive and can be viewed under individual clipped planes to virtually cut off parts of the nerve pathways that are irrelevant to the observer. This allows for more focussed viewing within certain orientations. Viewing windows may also be alternated to display the structures closely within a zoomed area as well as a distant point. A total of 6 windows can be displayed at one point in time, including the global overview of the skull.

Our experiment has shown that the 3D volume rendering visualization method is far superior to the traditional 2D viewer and offers more diagnostic value. It allows us to delineate the sac, the dome and the neck of the cerebral berry aneurysm as well as the adjacent vasculature. The ability to manipulate 2D images in real time based on personal customization of the software makes the process of diagnosing and evaluating a cerebral aneurysm less time consuming and much more convenient. The perception of depth and the opaque vessel structures allow the radiologist to make more informed decisions about the type of surgery to perform. The entire data set of dicom images is loaded into the Invivo Medical Design Suite, and the viewer may rotate or zoom the 3D reconstructed structure to inspect the details. Additionally, the distance, area and volume measurement tools allow the viewer to measure any lesion to scale by placing markers within the three-dimensional space. A data set with known measurements in a normal brain scan was applied first to ensure the precision of the software. The proposed treatment method for the aneurysm can be determined based on the measurements i.e. either treatment with a platinum coil or clipping. The surgery usually requires expensive equipment, which can be ordered after confirming the best possible method for removal of the aneurysm.

Conclusion

A faster, and more convenient method of visualization of Cerebral Berry Aneurysms in their earliest development stage is shown using the Medical Design Suite in Invivo 5.4 by Anatomage. Using the volume rendering and focus based texture mapping feature in this software, magnetic resonance scans with contrast media injection are visualized and manipulated in a three-dimensional space. The aneurysm can be located optimally with Invivo using the high spatial and temporal resolution available in the software, and the size of its dome and neck can be estimated using the measurement tools. These tools can be an effective means of pre-operative preparation and decisions especially due to the time constraint that is present in patients with cerebral aneurysms.
In vivo 5.4 is vital in detecting aneurysms in their earliest stage in high-risk asymptomatic patients, for example with a family history of aneurysms, genetic disorders associated with aneurysms or elderly patients with atherosclerosis. When compared to a traditional MRI / CT viewer, Invivo provides more detail on the location and measurement of the lesion and may even allow for 3D printing of the intracerebral vascular network before the surgery. It may also be beneficial in medical education to practice on a 3D printed module of the brain and explore different routes of surgery. Our experiment has demonstrated that Invivo 5.4 acts as a superior tool to diagnose a small aneurysm before complications may occur.
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References


