Intracranial aneurysms: reproduction of the surgical view using 3D-CT angiography

Dimitrios Siablis\textsuperscript{a,}\textsuperscript{*}, George C. Kagadis\textsuperscript{b}, Maria T. Karamessini\textsuperscript{a}, Dimitrios Konstantinou\textsuperscript{c}, Dimitrios Karnabatidis\textsuperscript{a}, Theodore Petsas\textsuperscript{a}, George C. Nikiforidis\textsuperscript{b}

\textsuperscript{a} Department of Radiology, School of Medicine, University of Patras, Rion GR 26500, Greece
\textsuperscript{b} Department of Medical Physics, School of Medicine, University of Patras, Rion GR 26500, Greece
\textsuperscript{c} Department of Neurosurgery, School of Medicine, University of Patras, Rion GR 26500, Greece

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Abstract

Our purpose was to describe a technique for simulating the surgical view of ruptured intracranial aneurysms, using volume-rendering techniques in spiral computed tomography (CT) angiography data. The 3D (three-dimensional) rendered images were assessed by a team consisted of four radiologists, one neurosurgeon and one medical physicist. The resultant ‘surgical view’ image was standardized in space using a three-dimensional coordinate system, which allowed for its reproduction in the operating theatre. The surgical views are a potentially useful tool for the surgical planning of intracranial aneurysms.

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1. Introduction

The successful surgical treatment of intracranial aneurysms impedes by numerous obstacles, one of which is the correct anatomical radiographic illustration of the pathology. Although digital subtraction angiography (DSA) remains the gold standard in aneurysm detection, computed tomography (CT) angiography (CTA) takes precedence in the era of image post-processing and can demonstrate the aneurysm characteristics. The term ‘surgical view’ refers to a reproduced 3D CTA image, which simulates the ideal surgical view. While the term and the exact method for its production have not been clarified by previous authors, it is of value since it has been utilized to facilitate aneurysm clipping [1–3]. If a technique had the potential to simulate the surgical field of view before surgery, a clear operative field could be achieved by the neurosurgeon.

In this study we examined the region of the anterior communicating artery (ACoA), as it is one of the most common sites for intracranial aneurysms to occur, as well as the middle cerebral artery (MCA) bifurcation [4]. The objective of this report is to illustrate a technique that tries to replicate the intra-operative view of ruptured intracranial aneurysms.

2. Materials and methods

Thirty-four patients with ruptured intracranial aneurysms in the ACoA and MCA were included in our study group. Their age ranged from 15 to 76 years (mean age 49). There were 16 men and 18 women. The presence of the aneurysm(s) was certified by both CTA and DSA. Written informed consent was obtained from the patients and the study protocol was approved by the local ethics committee. Of the 38 aneurysms found, 24 were located in the ACoA and 14 in the MCA bifurcation. Four patients possessed two aneurysms each and were treated accordingly. All patients were surgically treated by clipping the neck of the aneurysm(s), through a pteri-
A basic axis for orientation was standardized in a fixed device (Mayfield device) during surgery. The entry and exit points corresponded to points standardized around every axis (X, Y and/or Z) for patients with an AcoA or MCA aneurysm. After applying this technique in a total of 24 AcoA and 14 MCA aneurysms, we found some rotation values around which our patients’ optimum values ranged (Table 1) (Figs. 1 and 2). We were able to demonstrate the cerebral arteries simulating the position of the head during surgery in a way that would be familiar to the neurosurgeon. Produced images could be rotated at any desired angle that the neurosurgeon would prefer. Aneurysms’ characteristics provided by the VRT surgical view were validated by the neurosurgeon’s intraoperative findings. Specifically, aneurysm’s projection, neck size, sack size, presence and orientation of adjacent arteries were in accordance to the information provided by the VRT view.

3. Results

The total time needed to reproduce and manipulate the whole compilation of VRT images, using the proposed technique ranged between 10 and 20 min.

We tried to find the optimum values of rotation around every axis (X, Y and/or Z) for patients with an AcoA or MCA aneurysm. Acquired CTA data were transferred to a DICOM server through a high bandwidth (gigabit) LAN (local area network). The studies were then selected from the server by the medical physicist responsible for image processing.

Spiral CT data sets were processed on a high performance image processing workstation under Microsoft Windows XP, running Analyze PC 5 (AnalyzeDirect, Lenexa, USA) and custom-made software. Volume rendering techniques (VRT) were applied to all patient datasets. Much attention was paid on the parameters set on VRT in order to find the optimum values. The threshold technique had a lower threshold of 110–130 HU, since we preferred not to exclude the bony structures from the three-dimensional images.

A virtual coordinate system was applied to the reconstructed image of the patient’s head and served as a basis for the objective calculation of aneurysm topography. It consisted of three-coordinate axes and it was utilized in order to replicate the same position in the operating room. On every axis the entry and exit points corresponded to points standardized in a fixed device (Mayfield device) during surgery. A basic axis for orientation was X-axis, which was defined by a virtual line that is crosscutting the base of the nasal bone to the external occipital protuberance and can easily be established and serve a supplementary role. After the application of the set of coordinates, VRT images were rotated around every axis (X, Y and/or Z) in order to find the optimum orientation for each patient. This meant the simultaneous complete exposure of the aneurysm neck; clear of surrounding vessels if possible. A consensus in reviewing image findings for each aneurysm and the anticipated surgical view was reached by team collaboration of radiologists, neurosurgeon and the medical physicist. In the operating theatre view the patient’s head was fixated with the Mayfield device, applying the set of coordinates given in the three axes by the ‘surgical view’ image. Each aneurysm possessed a unique orientation (given in degrees on each virtual axis), e.g., patient in Fig. 1: X-axis, 115°; Y-axis, 0°; Z-axis, (−160°), in a way that would assist the neurosurgeon to simulate the operating theatre view (Fig. 1).

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The application of the proposed technique was feasible in all cases.
Discussion

CTA has been the primary tool for many authors in the investigation of intracranial aneurysms and in the crucial decision making regarding surgical treatment or endovascular embozilization [3,6–11]. Currently, the growing demands for aneurysm surgery require a team effort for achieving precise knowledge of aneurysm characteristics and for ensuring the desired patient outcome. The potential of CTA to demonstrate not only the lumen of the vessels, but also their walls is of immeasurable value for the detection, morphological characterization and treatment of intracranial aneurysms. The radiologist has to collect suitable image data and in cooperation with the neurosurgeon and medical physicist reconstruct the ideal view of the aneurysm in proximity to the anticipated ‘surgical view’.

The objectives of this article were three-fold:

1. To objectively clarify the term ‘surgical view’.
2. To assess the clinical merit resulting from the production of a special view during image post-processing.
3. To demonstrate the capabilities of 3D image processing, which results under team cooperation.

The definition of the term ‘surgical view’ has not been yet illustrated, although it has been used by some authors as an additional tool to assist safe aneurysm clipping. In 2001, Matsumoto et al. performed surgery based solely on CTA results and reported that ‘surgical simulation images’ were helpful for making decisions on the most appropriate surgical approach [3]. Another study by Futami et al. has found that 3D CTA could provide ‘preoperative simulation views’, using a cut-along-trace function, in order to facilitate complete clipping [1]. In a recent study by Tomandl et al., it has been stated that the possibility of simulating the ‘intraoperative view’ prior to surgery is often helpful [2]. Schmid-Elsaesser et al. have proposed a neuro-navigation technique based on CTA data in order to optimize the surgical approach of aneurysms located in ICA, ACoA and MCA [12]. They have shown that a major advantage of 3D CTA data is to produce ‘operative views’ of unruptured aneurysms. Satoh et al. have suggested that CT angiograms can provide an ‘operative view’ in perspective, similar to the operative view [13].

The term ‘surgical view’ refers to a reproduced 3D image resulting from the post-processing of CTA source data. The reason for its production is to simulate the intraoperative view of an aneurysm and to help the neurosurgeon to conceptualize its morphological features before surgery. Whether the surgical view produced by the proposed technique and the operating theatre views are in proximity depends on the adopted standard points of reference. We tailored the proposed virtual coordinate system in operating theatre conditions, in order to reproduce objective and comparable images in all of our patient series.

In general, neurosurgeons follow common rules for the surgical approach of aneurysms and during surgery they may reassess the available angle of view before insertion of the clip applicator, in order to improve their field of view. Especially with ACoA aneurysms, a great deal of flexibility will be required in planning the final clip application. Since there are so many vessels that need to be identified and preserved during the dissection and clip application, the three-dimensional configuration of these arteries in relationship to the aneurysm dome, has to be taken into account when planning surgery.

Using the proposed technique we were able to show the cerebral arteries simulating the position of the head during surgery, in a format familiar to the neurosurgeon. Images can be rotated at any angle desired by the neurosurgeon (usually 30–45°), simulating the intraoperative view [14].

The morphological features of an aneurysm include the location, orientation, shape of the sac, size, neck, the presence of wall calcification, its relationship to near bony structures and surrounding vessels, and whether other branches stem out from the sac. Each one of these features has a unique importance possessing a different weight in every aneurysm. In addition, the radiologist may pay more attention to a feature other than the neurosurgeon’s estimation. CTA has the advantage to provide the simultaneous luminal and mural imaging of the cerebral vasculature and coexistent aneurysm(s). This, of course, is not obtained by a single image but by both the source data and the VRT images. As a result the radiologist must try to maintain all the valuable information and provide them to the neurosurgeon, which has the authority to evaluate them for the therapeutic approach. The medical physicist is responsible for image post-processing, which is balanced between the detailed demonstration of vascular anatomy and the clinical request. Consequently, team approach (radiologist, neurosurgeon and medical physicist), is preferable for the enhancement of CTA post-processing capabilities.

The results of our study support the conclusion that simulating the surgical view is feasible and not time consuming. The cumulative advantages of CTA imaging with team collaboration for the reproduction of the surgical view are of great importance for the optimization of surgical approach.

Conclusion

The growing success of CT angiography is the result of the evolutionary development of imaging software and hardware, which provides, among others, the ability to reproduce a preoperative surgical view.

The potential ability to create a vascular map by means of noninvasive techniques with the ‘surgical view’ is very useful especially for complex cases such aneurysms of the ACoA or MCA. Preoperative simulation of the surgical view is feasible and facilitates aneurysm surgery.

The cooperation between the radiologists, the neurosurgeon and the medical physicist is mandatory for the favorable outcome.
References


