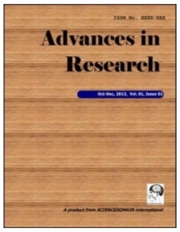

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Vascular Segmentation of Cerebral AVM

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Authors' contributions

This work was carried out in collaboration between all authors. Authors Shashi Mehta and Manjunath Ramachandra guided the project and reviewed the manuscript and Y.Kiran Kumar designed the study, wrote the protocol, and wrote the manuscript, managed the literature searches, collection of samples. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Aim: A Cerebral Arteriovenous Malformation is an abnormal connection between arteries and veins, where arteries shunt directly into veins with no intervening capillary bed which causes high pressure and hemorrhage risk. The success of treatment by embolization in interventional Neuroradiolgy is highly dependent on the accuracy of the vessels Visualization.
Place and Duration of Study: Philips electronics India Ltd.
Methodology: Wavelet based segmentation
Design: In this paper, we have done segmentation of feeding arteries and NIDUS using 3DRA for cerebral patients, using various preprocessing steps of image and used wavelet for reconstruction and segmentation of the image.
Conclusion: The doctors can analyze and decide the mode of clinical diagnosis/ treatment based on our segmentation results.

Keywords: AVM, NIDUS, 3DRA, Segmentation.

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1. INTRODUCTION

Intracranial Arteriovenous malformations (AVM) constitute usually congenital vascular anomalies of the brain. AVMs are composed of complex connections between the arteries and veins that lack an intervening capillary bed. A brain AVM (BAVM) is a set of abnormal vessels comprising feeding arteries; draining veins and a collection of arterialized veins called the Nidus.

AVM's consist of networks of large caliber vessels yielding an alternate pathway for blood flow with high flow/low pressure characteristics. As a result AVM's steals the blood supply away from capillary beds juxtaposed in parallel with the AVM. In the brain, such shunts reduce the blood supply to normal neuronal tissue perfused by the parent vessel which is shared with the AVM, resulting in varying degrees of cerebral ischemia and central nervous system breakdown. The arteries have a deficient muscularis layer. The draining veins often are dilated and tortuous due to the high velocity of blood flow through the fistulae.

The AVM "Nidus", without feeders or veins, is measured in currently used predictive models and grading systems. The Spetzler-Martin AVM classification [1] stratifies the malformation according to its largest diameter, i.e. <3, 3–6 and >6 cm. The middle group may for example contain lesions with diameters of in between 1x 1x3 cm up to 6x6x6 cm, corresponding to volumes between 0, 5 cm^3 and 113 cm^3 as shown in Fig. 1. In a radio surgical outcome model or for volume comparison a more exact measurement is necessary.

The Gamma Knife® radio surgery outcome model defines AVM volume as being within the prescription isodose line, not the same as the "true" Nidus, but a reasonable approximation.

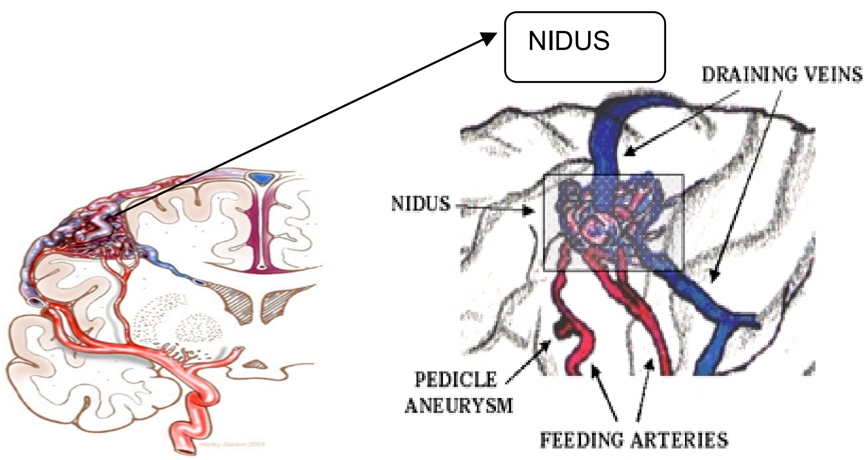


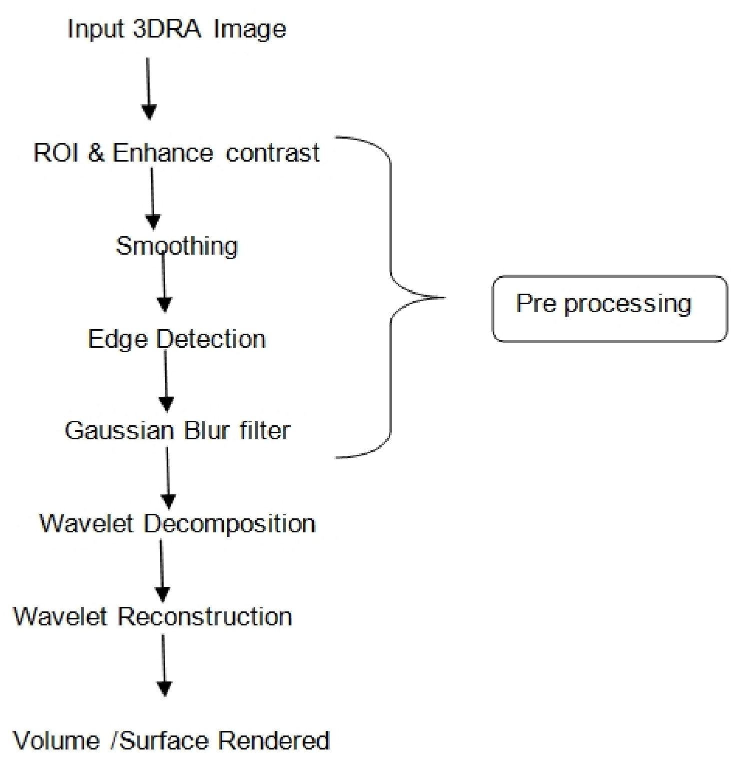
Fig. 1. AVM in Brain

The literature shows the various models using Mechanical, Electro-Mechanical, and few Electrical Models for AVM "NIDUS".AVM Nidus volume is a predictor of the outcome of AVM surgery [2,3,4] and radio surgery. The impact of AVM size upon the results of endovascular treatment seems to be less clear. A recently published study [5] based on a material of 2262 AVM patients showed that the annual risk for presenting with hemorrhage increases with the volume of the malformation. Thus volume data should influence therapeutic decisions in the individual patient, be used in the assessment of the efficacy of any therapy and when comparing patient outcome.

It is essential to precisely locate the position of vessels and also to track the vessels entering and leaving the malformation, as well as their radii and bending angles before treatment. The problem statement is very complex as the NIDUS is very complex structure which varies from every patient and imaging modalities also used for this purpose. Many imaging techniques have been developed for this purpose. Conventional catheter angiography (CCA) is used at the end of follow-up to confirm complete occlusion [6], while for intermediate controls Magnetic resonance angiography (MRA) with time of flight (TOF) or phase contrast techniques or computed tomography angiography (CTA) are usually used [7,2,3]. Digital subtraction angiography (DSA) with 3-D rotational angiography (3DRA) remains the standard technique [4], providing substantial additional information on BAVM angioarchitectural [8,9]. In this paper, the feeding arteries and NIDUS segmentation is performed with unique methodology, which is implemented in MATLAB.

2. MATERIALS AND METHODS

The following flowchart 1 shows the methodology to segment the 3DRA dataset, which is obtained from Philips Allure Unit. The processing steps are applied to all the images and it is reconstructed to get the final segment image.



Flow chart 1.0

Flow chart 1

1. The input 3DRA image is used as the input volume of the Brain AVM (BAVM).

2. 3D ROI is drawn for the Vessel Deformed region, automatically propagated to all the slices, by applying interpolation technique.
3. Preprocessing techniques are applied to the ROI by performing enhanced contrast, smoothing algorithm and edge detection algorithm based on intensity.
4. The filtering is applied to remove the noise; we have used various filtering techniques – Mean, Median, Convolve and Gaussian Blur, FFT.
5. The filtered image is segmented using the wavelet – db4, and decomposed for 3 levels to get outputs of LLL, HHH, LHL, HHL details information.
6. Each decomposed image is reconstructed and combined to produce final output. This way, we assess the lower and higher level of details of the image, to segment larger and smaller vessels.
7. The reconstructed output is rendered using the rendering techniques – Surface Renderings and Volume rendering is displayed as the final output

3. RESULTS AND DISCUSSION

The Feeding arteries and NIDUS is segmented using the proposed approach and results are shown in the below Figs. 2 and 3. The Fig. 2 shows the segmentation of the image in 2D Plane, where as Fig. 3 shows the volume rendered image.

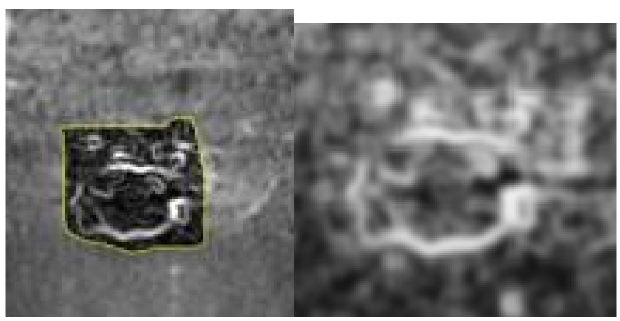


Fig. 2. Segmented Arterial & NIDUS

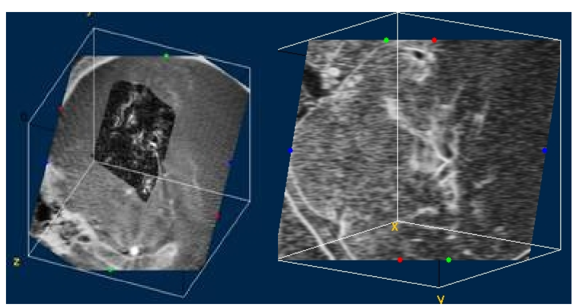


Fig. 3. Volume Rendered Arterial and NIDUS

The results shows that NIDUS segmentation of BAVM provides the insight of the path of vessel propagation in a complex shape and also to segment smaller vessel segmentation, feeding from various arteries and draining from the multiple veins, the results tries to address the segmentation of complex feeding arteries and veins.

The proposed algorithm is also compared with DSA image, where for the same patient, we have DSA and 3DRA image. The drawback with 2D image is that we will not get the depth details of the image, which is less accurate result than 3DRA segmentation results. The Figs. 4 and 5 shows the DSA image segmentation.

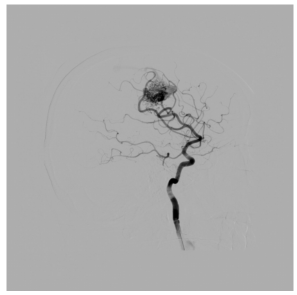


Fig. 4. DSA image

Fig. 5. Segmented Image

The proposed solution is verified with 17 patients of 3DRA and following are the metric analysis:

Sample size	17
Correlation coefficient r	0.9896
Significance level	P<0.0001
95% Confidence interval for r	0.9705 to 0.9963

The clinical interpretation of the results shows that for a total of 17 patients, the significance level of algorithm tolerance range is less than 0.0001 and confidence factor shows the algorithm validation portion, is that is best suited for complex vessel segmentation of NIDUS.

The main advantage of this research work is that the proposed solution help to segment complex loop vessels combinations, which helps to find the clinical parameters for the doctors that, will assist doctors to take clinical decision.

4. CONCLUSION

This research work solves the complex vessel segmentation approach for NIDUS, throws a light of segmenting the complex vessels with clustering loops. This approach will help Doctors for the diagnosis and treatment analysis using the clinical parameters. The challenge of the segmentation is automatic segmentation of NIDUS loop vessel with fine tuning the path is a problem, for which we are working on it.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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