Research Article:
Developing A 3D Reconstruction System for Surgical Planning in Neurovascular Surgery

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ABSTRACT

Background and Aim: Neurovascular lesions can cause death or disability. Some of them are operable, but surgical approaches are complicated, and proper access to these lesions is crucial. A few of these surgeries occur during the residency educational program, and residents' experience in operating these lesions may be quite inadequate. Using new technologies like 3D-reconstruction of vascular lesion images may result in better training and improve residents' knowledge and understanding of these operations.

Methods and Materials/Patients: Four senior neurosurgery residents were enrolled in this study. They were taught to use a 3D image rebuilding program (3D Slicer). They were then asked to rebuild a 3D image of every patient lesion, practice different surgical views, and review anatomical structures around the lesion before surgery

Results: All residents mentioned that their knowledge of surgical approaches improved, and they learned more from each operation. Two of them commented that more self-trust during surgeries led to more effective education. Their ability in surgical planning was enhanced too. Attending physicians of these residents believed that this practice improved the residents' skills and educational quality.

Conclusion: New technologies can promote residency educational programs. It seems that working on 3D images of lesions before surgery can boost residents' educational attributes.

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Highlights

- This study shows the 3D Slicer program can enhance the residents' ability in surgery.
- Surgical planning can be more precise with a 3D Slicer program.
- Neurovascular surgery is very sophisticated and needs precise planning

Plain Language Summary

Neurovascular lesions can lead to death or disability. Some lesions can be operated but surgical approaches are complicated, and proper access to the lesion site is very important. Using new technologies like 3D-reconstruction of vascular lesion images may result in better training and improve residents' knowledge of these operations.

1. Introduction

Cerebrovascular diseases are among the leading causes of long-term morbidity and the second leading cause of mortality in the world [1]. These diseases include a wide range of vascular conditions, including ischemic or hemorrhagic brain disease, carotid or vertebral artery stenosis, intracranial artery stenosis, aneurysms, and Arteriovenous Malformations (AVM). In developed countries, there has been a decline in mortality and morbidity from cerebrovascular diseases, but in recent years this decline seems to have stopped, and the prevalence of these diseases has increased in younger adults (35 to 64 years) [2, 3]. Fortunately, great steps have been made in treating these diseases [4, 5]. Treatment of cerebrovascular diseases depends on their causes and other risk factors, and surgeons should usually decide between supportive therapy and surgical treatment [6, 7].

Surgical treatment is considered in cerebrovascular lesions, especially aneurysms and AVM. The appropriate treatment is determined according to the risk factors which include position, size, morphology, presence or absence of thrombosis, multiple aneurysm lobes, and patient's risk factors, such as age, family history, medical history, and history of subarachnoid hemorrhage in the patient or his/her family [6, 8, 9]. Moreover, the surgical treatment of these lesions requires proper access to them [10, 11]. As a result, a 3D model of lesions reconstructed from CT-scan and MRI images can improve residents' knowledge on operating these lesions and enhance the quality of training during surgery.

The 3D model can help surgeons know the shape and borders of the lesion and its anatomical location. There are a lot of 3D reconstructing applications in the market. ITK-Snap, DtiStudio, FreeSurfer, FSL, SPM, OsiriX, BioImage Suite, MIPAV, ImageJ, and 3D Slicer are used for this purpose. Meanwhile, 3D Slicer is a powerful software used for medical and educational purposes [12]. It is a free and open-source program with the ability to add new tools for computer calculations and medical imaging. The program was created by combining several independent projects to illustrate and navigate surgery and to create graphic appearances for users [13].

Functionality, upgradeability, ability to transfer between different platforms, no software license restrictions, compatibility with PACS (Picture Archiving and Communication System), clinical system, and software support are some of the advantages of this program compared with other programs on the market with open-source tools and same goals. There are also various software packages with a set of analytic tools for this program (some of which have even been approved by the Food and Drug Administration (FDA) for certain clinical use) [13]. Unlike similar applications, 3D Slicer is free and does not require specialized equipment. This software is not limited to a specific process or research use because it is very expandable. Other similar programs include OsiriX, BioImage Suite, MIPAV, and ImageJ but they are not open source, and other programmers cannot upgrade them [13]. In this study, we intended to use 3D Slicer software to increase the quality of residents' training for cerebrovascular surgeries.

2. Methods and Materials/Patients

In this study, 4 senior Neurosurgery residents volunteered. First, they were taught how to use 3D Slicer to reconstruct 3D models. Then residents were taught how to extract a 3D image of the cerebrovascular structure using

CT angiography and MR angiography samples and were asked to reconstruct two samples of each on their own.

After ensuring the ability of the residents to reconstruct the 3D models, they were asked to reconstruct the 3D model of any patient's vascular lesion, who were considered for surgical treatment of aneurysm or AVM, before surgery from July 15, 1997, to July 15, 1998. They were also asked to evaluate the 3D model of the lesion, the exact location of the pathology, different anatomical structures around the lesion, the surgical pathway to reach it, and review the surgical approach. They had to practice surgical planning in detail, imagine surgery procedures before the real surgery, highlight the important points at each stage, and conceive the step-by-step operation. During this period, 28 surgeries were performed, and one night before the surgery, at least one resident did this practice and the next day participated in the surgery.

At the end of the study, the residents and attending physicians who performed the mentioned surgeries were given a questionnaire designed for this purpose, and the results were recorded. The questionnaire included questions about the understanding of the processes and learning during the surgery, the ability to plan for surgery, self-confidence during surgery, a better understanding of the surgical site anatomy, and the benefits of this training process for residency training. Finally, the results of the questionnaires were reported.

3. Results

In this study, we investigated the effect of an educational intervention on improving the educational quality of the residency course. Since no specific objective test was designed in this case, the results were expressed subjectively. The duration of this study was one year, during which 28 cases of cerebrovascular surgery were performed. Surgical outcomes of these patients were satisfactory, except for one case of mortality due to post-surgery embolism and 3 cases of morbidity, of which 2 were hemiplegia and 1 ptosis. All 4 residents mentioned that they had a better understanding of the approach to the lesion and learning during these surgeries compared with other surgeries. Two residents also noted an increase in self-confidence during surgery, leading to better and more effective training.

In terms of the ability to plan before surgery, all residents had experienced significant progress in this area, noting that after this training course, they could make more accurate planning with a greater sense of skillfulness.

Furthermore, 3 residents believed that the process increased the quality of education in the training course, especially in the case of rare vascular lesions. It also helped them identify and diagnose the anatomy of the lesions and their surrounding structures that can be useful for any neurosurgeon. All residents believed that at the end of this period, by reconstructing the 3D structure of the lesion in each patient, the anatomy of the surgical site was much more apparent and more accessible. Therefore, less time was required before the surgery to study the anatomy of the lesion's location.

A questionnaire was also obtained from the two attending physicians who performed the surgeries. They both believed that the residents who participated in the surgeries were more skillful and self-confident. Their ability in surgical planning was also much better. Both attending physicians stated that using this method for less prevalent vascular lesions could increase the quality of residency training in neurosurgery.

4. Discussion

In recent years, studies on the use of new imaging technologies in medicine have developed. These technologies have increased the ability to produce 3D images that can be easier and faster for humans to understand [14-17]. This technology is especially important in residency training because surgical training is very difficult, costly, and complex in terms of maintaining ethics, and has many risks for patients and residents [18, 19].

Because of the mentioned limitations, several efforts have been made recently to improve the quality of education by creating simulations outside the clinical situations and especially by using new technologies [20-24]. In a study in China, the impact of using these technologies on the quality of the residents' educational courses was evaluated in a randomized clinical trial. It was found that 3D modeling of spinal fractures makes them easier to understand for medical students who had studied anatomy from textbooks, cadavers, and computer simulators before the study [25].

This study aimed to design a system to improve the residents' training on complex and less common vascular surgeries, better planning of surgery, and improve the quality of residency training in general.

According to the questionnaires filled out by the residents, this process not only makes it easier and more effective for the residents to learn from surgery but also gives them a better understanding of the anatomical structures around the lesion and the surgical approach. It also provides better surgical planning and control and improves surgical outcomes even after the educational course. Recently, the relationships between anatomical learning using 3D image reconstruction software and improved surgeons' performance (after residency) and patient specificity have been reported in several publications [26-28]. The results of our training package are similar. Besides, based on the questionnaires filled out by attending physicians, this process helps educate residents, especially for sensitive surgeries of cerebrovascular lesions with less prevalence, and can increase the quality of the residency training course.

5. Conclusion

Because of the short period of residency and a few patients with cerebrovascular lesions who became candidates for surgery, the number of cases registered in this study was small. No appropriate objective test is available to assess the impact of this training package on improving the quality of residency training accurately. These issues can lead to imprecise conclusions. According to the results of this study, we recommend that this package be studied in a larger group of residents and for a longer period. Designing an appropriate objective test may be useful to test the ability of residents in this particular process and other educational undertakings.

Ethical Considerations

Compliance with ethical guidelines

Informed consent was obtained from all participants.

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Authors' contributions

Conceptualization and design: Amir Saied Seddighi, Afsoun Seddighi, Alireza Zali; Data collection: Shiva Jamshidi, Afsoun Seddighi; Data analysis and interpretation: Hesam Rahimi, Amir Saied Seddighi; Drafting the article: Mostafa Hosseini, Morteza Hosseini; Critically revising the article: Amir Saied Seddighi, Afsoun Seddighi; Reviewing submitted version of manuscript: Amir Saied Seddighi; Approving the final version of the manuscript: Alireza Zali.

Conflict of interest

The authors declared no conflict of interest.

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