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Case Report

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Giant Frontal Meningioma – Applying Radiant to Reconstruct 3D Images for Preoperative Prognosis and Surgical Planning

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Giant intracranial meningioma; RadiAnt; 3D images; Meningiomas; Ramban GSS Score

1. Abstract

Meningiomas are the most common primary Central Nervous System (CNS) tumors and giant frontal intracranial WHO grade I meningioma is a fairly common practice in the neurosurgical center in developing countries. However, giant meningiomas raise challenges for surgeons, due to the size of the tumor, prominent vascularity, entangling, limited visualization, and cerebral edema. Objective. RadiAnt to reconstruct 3D images of the tumor to support preoperative planning and prognosis brings enormous value. It does not only help prevent an accidental blow to precious structures, but it is also very simple and practical. A case report. a 74-year-old woman showed up in the clinic complaining of an increasing headache and confusion. Her headache had presented for quite a long time, but it tended to increase in intensity over the last 6 months and did not respond to pain relievers. We used RadiAnt to reconstruct 3D images of the tumor to better figure out the size, shape, and relation of neighbors, as well as its relative position on the skin. The patient then underwent resection microsurgery, and postoperation went well with no major complications. Conclusion. RadiAnt DICOM Viewer shows up as a free, simple, and accessible tool with great potential for 3D rendering. The resulting detailed preoperative understanding of the nature of the lesion, as well as the surgical view obtained from simulation of the perspective of intraoperative positioning, will enable the surgeon to achieve better outcomes from the surgery itself.

2. Introduction

Meningiomas are the most common primary Central Nervous System (CNS) tumors, they account for more than a third of all primary brain and spinal neoplasms. Up to 39% of meningiomas are asymptomatic and slowly grow in size throughout patients' life [1], some of them can be silent until becoming giant as one in our case. Even though the majority of leptomeninges tumors are benign [2], their large size, as well as their location in the CNS system, can be threatening factors to not only the patient's neurological functions but also her being.

In cases of symptomatic tumors or asymptomatic but large and expanding tumors, surgical resection is indicated, if feasible. However, the surgery for giant intracranial meningioma is terrifically challenging due to the size of the tumor, prominent vascularity, entangling and limited visualization, and cerebral edema. Thus, invasive treatment raises a huge concern about damaging adjacent vital neurovascular tissues.

In such a context, the utility of reconstructed 3D images for preoperative planning and prognosis brings enormous value. It does not only help prevent an accidental blow to precious structures, but it is also very simple and practical, especially for residents.

3. A Case Report

A 74-year-old woman showed up in the clinic complaining of an increasing headache and confusion. Her headache had presented for quite a long time, but it tended to increase in intensity over the last 6 months and did not respond to pain relievers. Besides, she noticed confusion lately. Clinical examination found a weakness in the right side of the body, muscle strength decreased to 4/5 in the right arm and right leg. Otherwise, there were no significant abnormalities.

Various subclinical indications were made. Other than slightly high blood glucose, all biochemical tests were normal. CT Scan result showed a large hyperdense lesion on the left frontal lobe, causing a space-occupying effect, suspecting meningioma. MRI was immediately performed, the results illustrated that left frontal lobe parenchyma had a space-occupying lesion sized #72x53x63mm, multi-arch margin, fairly well-defined, heterogenous signal, slightly increased on T2w (Figure 1E), isointense on T1w (Figure 1A), limited diffusion, strongly enhanced, heterogenous after injection (Figure 1B,1C,1D); The mass caused severe edematous and displacement effect: compress bilateral lateral ventricles, push the midline shift right by #15mm, cause supratentorial parenchymal herniation, plus extensive edema of the left hemisphere; Inside the mass, there were hypointense dots on SWI; outside, in the peripheral region of the lesion, it was a cystic structure with no diffusion restriction (Figure 1E); Drug infiltration with mild thickening of adjacent meninges; Dilated peripheral veins of the mass, draining into the cavernous sinus vein. Radiographic results highly suggested a Giant Intracranial Meningioma (GIM) in this woman. These imaging investigations warn us of a large mass with prominent vascularity and insensitive location to neighboring anatomy. Our mission was to find a way that provide us wide visual field, simultaneously, to plan out the vessels and structures we might see during the operation. Hence, we used RadiAnt to reconstruct 3D images of the tumor, Thanks to it, we could better figure out the size, shape, relation of neighbors, as well as its relative position on the skin. Then, we were more than ready to deal with the challenging GIM.

The patient then underwent resection microsurgery, in which we opened frontally and removed the tumor. The operation went well with no major complications. We sent tissue specimens for pathological examination. The patient was kept in-patient for further monitoring, fortunately, no postoperative complications were present, and the postoperative CT scan images show excellent recovery (Figure 3). She recovered well, her headache decreased significantly, muscle strength improved. Two weeks after the surgery, we received histology results: the patient's tumor was fibrous meningioma (WHO grade I), and no malignancy pattern showed (Figure 2). The patient was discharged home with a care and surveillance plan.

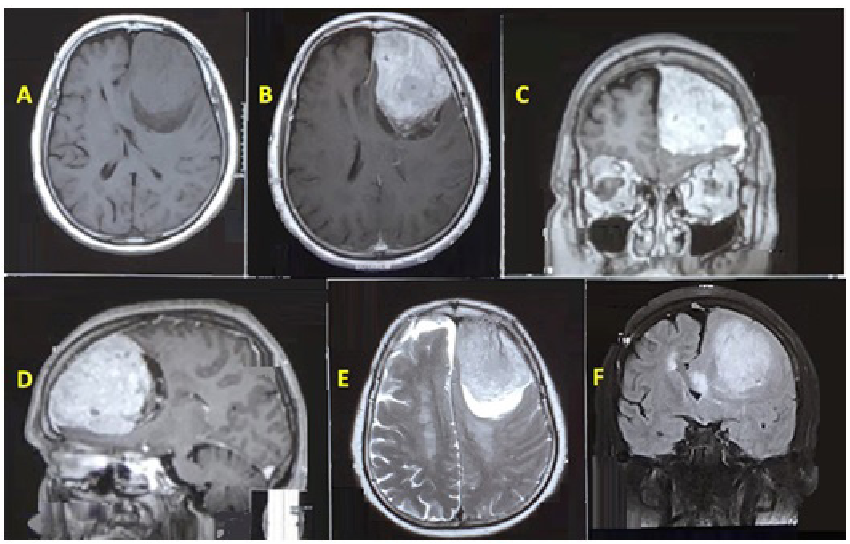

Figure 1. (A) Isointense meningioma on axial non-contrast T1W; (B), (C) and (D) strongly enhanced mass on axial, coronal, and sagittal contrast T1W, respectively; (E) slightly hyperintense tumor on axial T2W; (F) hypointense mass on FLAIR

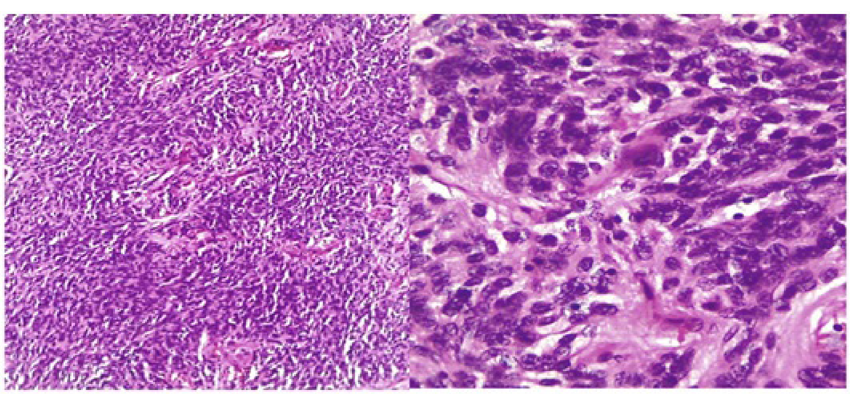

Figure 2: The histologic finding of patient's fibrous meningioma: Left panel – 10x microscopic; Right panel – 40x microscopic

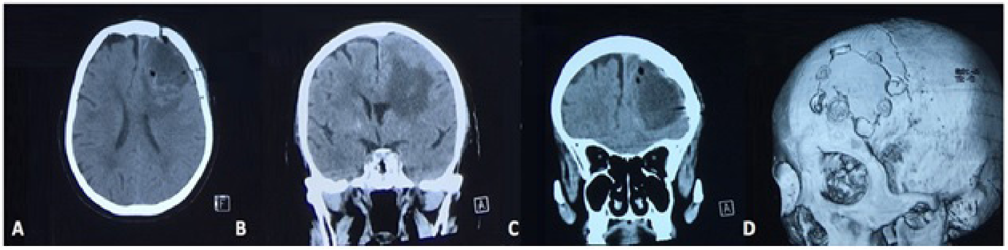

Figure 3: (A) Postoperative axial CT; (B) and (C) postoperative coronal CT; (D) 3D reconstructed image of the skull postoperatively

4. Discussion

4.1. Demographics

Meningiomas are the most common primary central nervous system tumors, as many as 3% of autopsies on adults over 60 years of age reveal a meningioma [2 3]. Incidence peaks at age 45, whilst the median age of diagnosis is 65, the possibility increases with age [1-3]. Besides, meningiomas are also more common in women, with the ratio two to threefold higher than in men, this tendency may be explained by the relation with the estrogen [1-3]. Among meningiomas, brain one's account for up to approximately 90%, and the rest belongs to spinal meningiomas, interestingly, in the spinal group, the female to male ratio is even higher, roughly nine to one. According to a population-based study, 80-85 percent of meningiomas are WHO grade I, and about 15-18 percent are WHO II and III [4]. Studies have demonstrated some risk factors for the appearance of meningiomas, including Ionizing radiation (typically in doses used in radiation therapy for malignancy); Neurofibromatosis 1 and 2; Hormonal factors (low-dose estrogens and progestins, or high-dose cyproterone) [5, 6].

4.2. Pathology

Meningiomas can grow intracranial or within the spine, they are thought to arise from arachnoid cells, which reside in the arachnoid space. They are classified according to the World Health Organization (WHO) schema, which is based upon morphologic criteria, into three groups [1-3, 7] (Table 1).

While WHO grade I meningiomas are benign, WHO grade II and III tumors are significantly more likely to have malignant and/or invasive characteristics. Consequently, local recurrence following the initial treatment, and, ultimately, the overall survival rate of grade II and III meningiomas are poorer compared to grade I tumors. Thus, this grading system correlates with the outcome and as the consequence, has a considerable impact on treatment planning.

Table 1: WHO classification of meningiomas (1)

Grade I	Meningothelial, fibrous/ fibroblastic, transitional, psammomatous, angiomatous, microcystic, secretory, lymphoplasmacyte-rich, metaplastic.
Grade II	Atypical, clear-cell (intracranial), chordoid
Grade III	Rhabdoid (sarcomatous), papillary, anaplastic.

4.5. Clinical Presentation

Meningiomas can arise from anywhere along the leptomeninges. Symptoms produced depend on the location of the mass and its size. To be more specific, meningiomas involving the optic pathways can produce visual change, for example, a meningioma located para sellar of sub frontal can cause Foster-Kennedy syndrome. A cerebellopontine angle meningioma can lead to sensorineural hearing loss. Or mental status changes with apathy and inattention may result from surprisingly large sub frontal or sphenoid ridge meningiomas. Apart from that, seizures, independently, can be seen preoperatively in about 30% of patients diagnosed with intracranial meningioma, this symptom can be explained as the mass displacing brain parenchyma, causing seizures. The risk of seizure increases associated with non-skull base location (eg, convexity and parasagittal/falcine tumors) and those with peritumoral edema [2].

Besides, as many as 39 percents of meningiomas show no symptoms at all (ie., asymptomatic). These tumors often grow slowly over a long period of time, some might reach incredibly large, and are discovered incidentally on neuroimaging or at autopsy [1-3, 8]. A systemic review and meta-analysis of incidental findings on brain MRI in nearly 20.000 people conducted in 2009 showed that meningioma was the most common incidental tumor, accounting for 0.29 percent in MRI [9]. Another study performed by Nakasu et al in1987 told us that roughly 3 percent of autopsies on adults in their 60s and above-unveiled meningioma [3].

4.6. Neuroimaging

Both CT scans and MRI are used as contributors for meningiomas diagnosis with some characteristic appearance. On MRI, a typical meningioma is an extra-axial, dural-based mass that is isointense or hypointense to gray matter on T1 and isointense or hyperintense on T2w images. There is usually strong, homogenous contrast enhancement after gadolinium injection. Most meningiomas, 60-72%, show "dural tail" sign. On CT scan, the typical meningioma is a well-defined extra-axial mass that displaces the normal brain parenchyma. They are smooth in contour and sometimes calcified or multilobulated. Isodensity with the normal surrounding brain may make diagnosis difficult on a non-contrasted scan, but intravenous contrast administration results in uniformly bright enhancement.

4.7. Diagnosis

A definitive diagnosis of meningioma and classification requires histologic confirmation. However, imaging investigations often provide a tentative diagnosis that might be sufficient for empiric treatment when obtaining tissue for pathologic confirmation entails too high a risk of causing further neurologic deficits [2]. History and physical assessment should also be performed since they can provide useful information suggesting meningiomas, such as predisposing to radiation, having familial NF1 or 2, or schwannomatosis.

4.8. Management of Giant WHO Grade I Meningioma

Depending on WHO grades, meningiomas treatment is recommended differently, In this article, we purposely focus on management for WHO grade I meningioma as the patient presented in the case report. Patient-specific factors, such as the presence or absence of symptoms, age, comorbidities, and location of the tumor in relation to adjacent critical brain structures are all important factors in determining the optimal treatment. Considering these characteristics, initial management may include observation, surgery, surgery + radiation therapy, and radiation therapy alone. The Ramban GSS Score gives us a scoring system for favoring surgery or not, in which Ramban GSS Score greater than 16 favors operation (Table 2).

The goal of surgery is to completely remove the mass if feasible because total removal of meningioma and its adjacent dura can be curative [2, 10]. However, surgeons must bear in mind that the utmost management of choice requires a balance between the definitive treatment of the tumor and conservation of essential neurologic functions (ie., avoidance of iatrogenic neurovascular damage from tumor removal) [11]. Nonetheless, that requirement is genuinely challenging due to the mass size, location, prominent vascularity, entangling and limited visualization of surrounding neurovascular structures, and excessive cerebral edema. Especially in cases of giant intracranial meningioma as in ours, we report a case in which the patient tumor was more than large with size #72x53x63mm, located in the frontal field, right in front of the motor gyrus and supplied by plenty of vessels. Such a situation poses a request for having more advanced imaging tools to offer surgeons a better view of the tumor preoperatively so that they can have a finer plan and prognosis.

Table 2: The Ramban GSS Score.

Admission parameter	1 point	2 points	3 points
Size	> 5 cm	3-5 cm	<3 cm
Neurological deficit	Progressive	Stable severe	None, minor
Karnofsky performance scale	<50	60-80	90-100
Tumor location	Falcine, parasagittal, foramen magnum	Tentorial, posterior fossa, jugular foramen	Convexity, intraventricular, sphenoid wing, tuberculum sellae, cavemous sinus, optic nerve.
Peritumoral edema	Severe	Mild	None
Diabetes mellitus	Not controlled	Medically controlled	None
Hypertension	Not controlled	Medically controlled	None
Pulmonary disease	Severe	Mild	None

4.9. Radiant Dicom Viewer: Preoperative Planning Tool in Meningioma Dissection Neurosurgery

Correct and detailed preoperative planning is one of the most essential prerequisites of a successful surgery and this skill takes years of experience to develop and master. The difficulty comes from transforming 2D, black-and-white images into 3D images in surgeons' minds, in relation to the patient's position, with neurovascular structures in close-by locations. Fortunately, with modern technology development, nowadays, there are imaging tools and software that help facilitate this process. They help create 3D images, or even 3D models, simulating both the targets and the surrounding normal anatomical structures, thus providing doctors outstanding assistance for preoperative strategy (12-16). Specific to meningioma, two separate studies, conducted by Samer ZA et al in 2021 and by Xin Zhao et al in 2013, came to the similar conclusions that the 3D technique corresponded extremely well with the surgical observations, it provided better detection of the meningioma, tumor-related anatomical structures, furthermore, 3D supplied information vital in the selection of optimal head position and surgical approach [15, 16]. With that in mind, here, we want to introduce RadiAnt DICOM Viewer as a powerful 3D-rendering tool, which its capabilities as a preoperative planning tool are yet to be studied for neurosurgery in Viet Nam.

Using nothing rather than data from MR imaging, RadiAnt DICOM processes and supplies us better images to study, we can operate on the reconstructed 3D simulation as well, such as to measure, cut, and rotate to view the tumor shape, change the plane of view, specify related vessels, locate the tumor on skin.

In figure 4, we view the meningioma on 3 different planes: coronal, sagittal and axial, simultaneously. In which, we are able to know the shape and size (area and perimeter) of that tumor on each plane, then have pictures of the mass in our head three-dimension. Nevertheless, this function is not the best of what RadiAnt can do. On figure 5, we see the space-occupying mass in relation to its adjacent vessels. There are many vessels coursing in and through the tumor from different directions that we need to be attentive to and avoid during surgery. Especially the one that closely attaches to the medial surface of the meningioma, and densely matrix of arteries coursing inferiorly. Figure 6 shows us the meningioma in a solitary state. Thus, it clarifies the tumor shape as a near wedge with multi arches that may make resection a little more difficult. The images once again emphasize the risk of damaging that pipe in the close medial position, and those that coil in the dorsal surface of the mass. Illustrated in figure 7 are simulations of our patient's meningioma position projected on the skin. With the help of RadiAnt DICOM Viewer, we can fairly calculate the distance from the projected mass to the patient's outer canthus, to her middle sagittal line on lateral view; or the gap between her tumor and her inner and outer canthus on the anterior surface; or the length to middle sagittal line looked from superior. Hence, surgeons have the ability to decide the best incision line and cranial opening location. With the capability to provide us with those functions, we can say that the use of 3D reconstruction using RadiAnt markedly improved the ability to visualize the tumor and its relation to the vascular structures and to the sagittal and other sinuses, enabling better identification of tumor feeders and its proximity to major arteries, and increased the possibility of establishing tumor location and relation to the cortex.

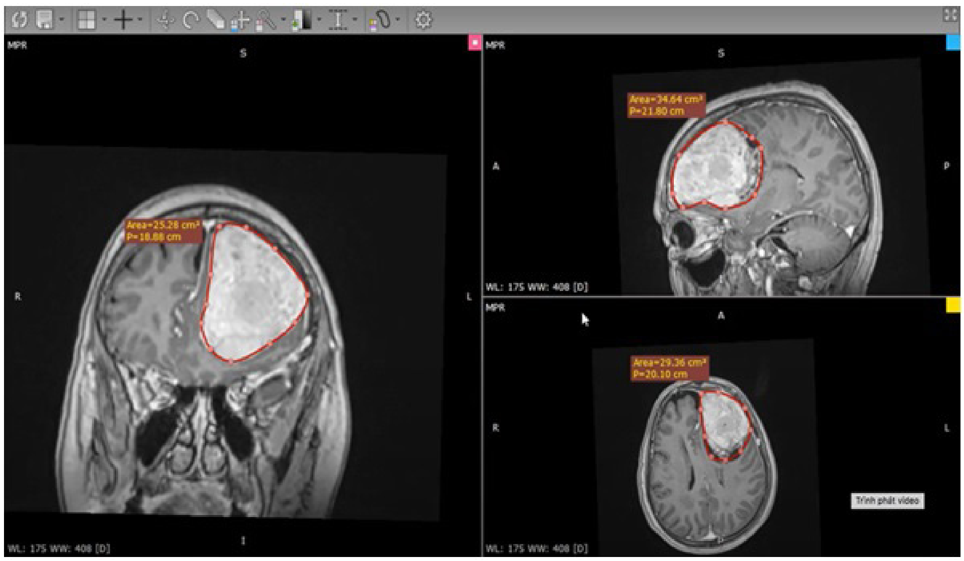

Figure 4: The meningioma on 3 plane view with area and perimeter size

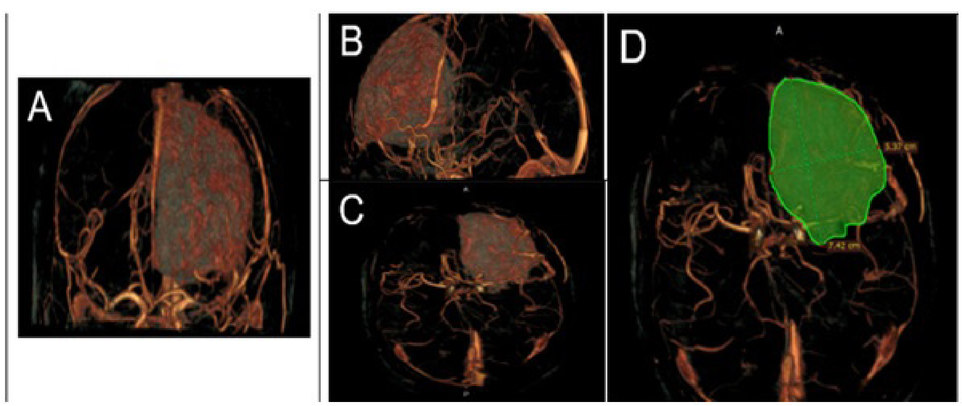

Figure 5: 3D TOF images: (A) front view of the meningioma in correlation with related blood vessels (stained gold); (B) lateral view of the meningioma in correlation with vessels; (C) parietal view of the tumor; (D) shape and size of the tumor in relation to surrounding vessels

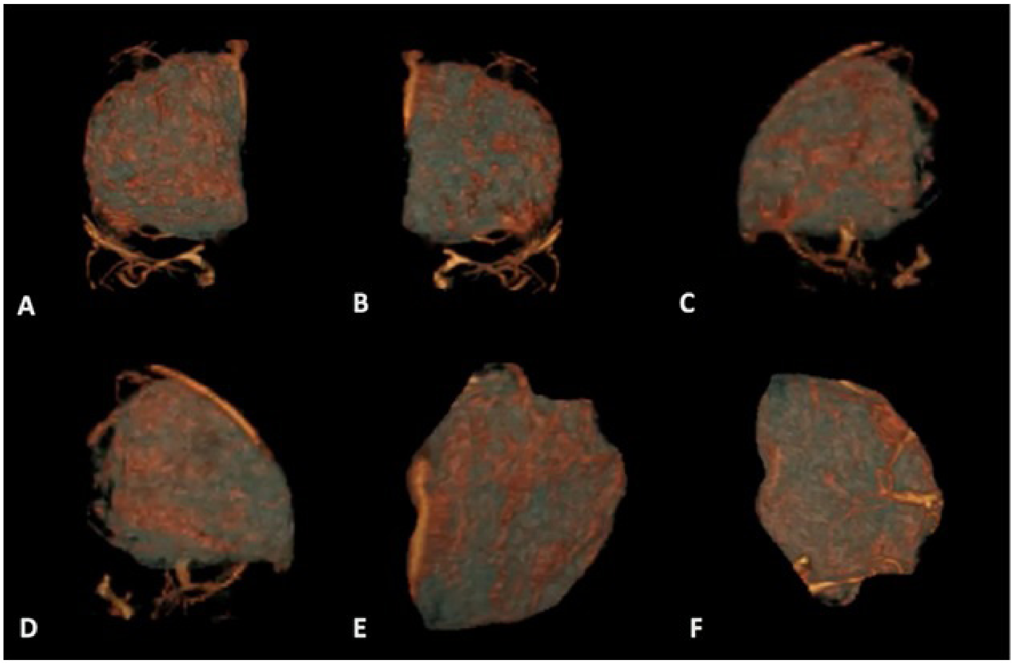

Figure 6: 3D TOF images show Solitary meningioma in different points of view: (A) and (B) anterior and posterior view of the tumor, respectively; (C) and (D) left and right view of the tumor, respectively; (E) and (F) superior view of the tumor

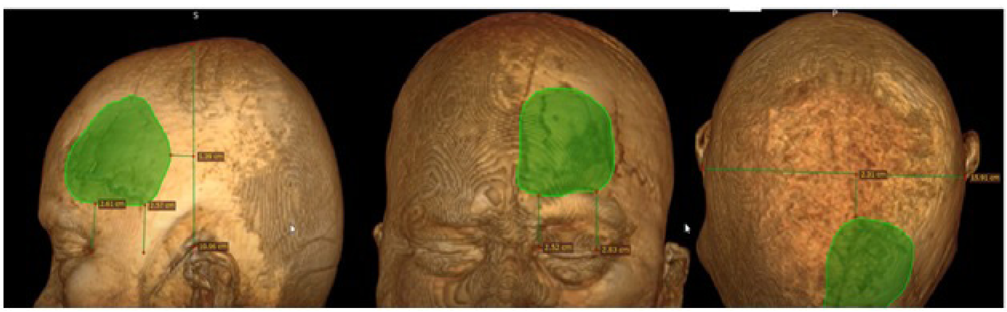

Figure 7: The meningioma position projected on the skin: Left panel – lateral view; Middle panel – anterior view; Right panel – Superior view

4.10. Outcome and Prognosis

For WHO grade I convexity meningiomas as in our case, the prognosis is excellent after surgical resection alone due to their superficial location, no need to indicate radiation therapy. The recurrent rate depends mostly on the extent of resection, in this case of total removal, the recurrent rate is hence fairly low. Studies have shown that rates of recurrence for WHO grade I and II resection range from 3 to 10 percent only [11]. Meanwhile, the survival rate is up to 91.3% [1, 3].

Brain MRI with contrast is the best modality for evidence of recurrence of progression of residual disease. The recommended approach is to repeat the imaging procedure in three to six months, annually for three to five years, and every two to three years thereafter if there is no evidence of progression.

5. Conclusion

Management of giant frontal intracranial WHO grade I meningioma as in our case is a fairly common practice in the neurosurgical center in developing countries like Viet Nam, with the aim of extensive removal of the tumor. However, such giant meningiomas raise challenges for surgeons, due to the risk of damaging adjacent critical structures. In this context, the role of the preoperative assistant tool is significant, especially for residents in their first years of career. RadiAnt DICOM Viewer shows up as a free, simple, and accessible tool with great potential for 3D rendering. The resulting detailed preoperative understanding of the nature of the lesion, as well as the surgical view obtained from simulation of the perspective of intraoperative positioning, will enable the surgeon to achieve better outcomes from the surgery itself.

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