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Case Report

A Novel Approach in Cerebellar Cystic Pilocytic Astrocytoma Surgery: Spherical Coordinate System

Serebellar Kistik Pilositik Astrositom Cerrahisinde Yeni Bir Yaklaşım: Küresel Koordinat Sistemi

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ABSTRACT

Achieving gross total resection is the primary prognostic factor in pilocytic astrocytomas. The spherical coordinate system (SCS) is an alternative to the Cartesian system for defining a point's location in space. While the Cartesian system uses X, Y, and Z axes, the SCS utilizes ρ (distance from the origin), θ (the angle with the positive X-axis, 0 to 360 degrees), and ϕ (the angle with the positive Z-axis, 0 to 180 degrees). A 73-year-old female patient presented with headaches, dizziness, and gait disturbance over the past month, along with nausea and vomiting. She had previously undergone cerebellar tumor surgery in February 2020, and two years later, similar solid and cystic structures reappeared, suggesting a residual tumor. In such cases, using the SCS may help reduce remnant tumor rates and minimize the need for secondary operations.

Keywords: Cystic pilocytic astrocytoma, spherical coordinate system

ÖZ

Küresel koordinat sistemi (KKS), uzayda bir noktanın yerini tanımlamak için kullanılan alternatif bir yöntemdir. Kartezyen koordinat sisteminde X, Y ve Z yönleri kullanılırken, KKS'de kullanılan bileşenler ρ (orijinden olan uzaklık, her zaman sıfırdan büyük), θ (ρ'nin pozitif X ekseni ile yaptığı açı, 0 ile 360 derece arasında değişebilir) ve ϕ (ρ'nin pozitif Z ekseni ile yaptığı açı, 0 ile 180 derece arasında değişebilir) olarak tanımlanır. Yetmiş üç yaşındaki kadın hasta, son bir aydır baş ağrısı, baş dönmesi ve yürüme bozukluğu şikayetleriyle başvurdu. Başvuru sırasında ayrıca mide bulantısı ve kusma şikayetleri de mevcuttu. Hasta, Şubat 2020'de serebellar tümör ameliyatı geçirmişti. İki yıl sonra, aynı solid kitle ve kistik yapılar tekrar gözlemlendi. Bu durumda, başlangıçta tümör kalıntısı olabileceği düşünüldü. KKS, Kartezyen koordinat sistemi gibi vaka yönetiminde potansiyel bir alternatif olarak kullanılabilir. Bu yaklaşım, tümör kalıntısı oranlarını ve ikinci operasyon gereksinimini azaltabilir.

Anahtar Kelimeler: Kistik pilositik astrositom, küresel koordinat sistemi

INTRODUCTION

Thomas Stromer, quote "measure what can be measured, and make measurable what cannot be measured" attributed to Galileo; He simplifies it by saying "measure what needs to be measured" (1). (In the same article, it is stated that this statement attributed to Galileo is not precise) Advanced mathematical calculations have been used in medicine for over a hundred years. Horsley and Clarke introduced the stereotaxy apparatus, which is a device that combined coordinate systems and anatomy, in 1908 (2). Since many revolutionary advances such as stereotactic functional surgery, stereotactic radiosurgery, and associated biopsy have developed to the present day, these technologies have significantly improved patient outcomes. It has provided significant contributions to human life (2-4).

The dominant prognostic factor in pilocytic astrocytomas is the performance of gross total resection (5). Mair et al. (6) showed that the localization of the lesion is critical for effective tumor resectability.

The spherical coordinate system (SCS) is one of the alternative methods used to define the location of a point in space (7). The X, Y, Z directions are used in the Cartesian coordinate system. In the SCS, ρ, θ, and ϕ are defined as follows: ρ (radial distance) the from the origin , to be calculated, always greater than zero; θ (azimuth angle), the angle of ρ with the positive X-axis, which can take a value between 0 and 360 degrees; ϕ (elevation angle or polar angle), the angle that ρ makes with the positive Z-axis, which can take a value between 0 and 180 degrees 7. Our aim in presenting the case is to calculate the location of the preoperative solid mass with mathematical accuracy using a SCS. Our other aim is to present an alternative coordinate system to the Cartesian system used in stereotaxy.

CASE REPORT

A 73 year-old female patient with headache, dizziness, and gait disturbance in the last month. At the time of presentation, there was nausea and vomiting. On physical examination, she had dysmetria, dysdiadochokinesia and ataxia. The examination showed an arterial blood pressure of 120/75 mmHg, a pulse rate of 80/minute, a respiratory rate of 20 breaths/min, and an axillary temperature of 36.2 °C. She had a Glasgow Coma Scale (GCS) of 15. The patient was cooperative, with clear consciousness and oriented to time, place, and person. She did not have any weakness or neurological deficits. Also, coronary artery disease and diabetes mellitus were detected in anamnesis. The patient was comprehensively informed about the surgical procedure and its associated risks, and informed consent was obtained from the patient.

Surgical History

The patient had surgery for a cerebellar tumor in the second month of 2020 (Figure 1A,B). The previous pathology report indicated that there was no tumor tissue. The same solid mass and cystic structures were observed after two years. In this case, firstly, the total impression of the remnant tumor was considered (Figure 1C,D).

Preoperative Calculations with Imaging and Spherical Coordinate System

The patient's cerebellar cystic space-occupying lesion resembles a sphere. The cerebellar cystic lesion was considered to be spherical, and an attempt was made to reach the solid lesion. With the help of the SCS, the coordinates of the solid lesion were calculated according to the point designated as the center of the sphere. The distance of the solid lesion to the center of the cyst; That is, the "ρ" value, was approximately 12 mm (Figure 2A). The angle of the solid lesion with the x-axis of the cyst, that is, the θ value, was calculated between 300° and 346° (Figure 2B). The angle of the solid lesion with the z-axis of the cyst, that is, the ϕ value was calculated between 97° and 144° (Figure 2C). The coordinates of the patient's solid lesion were calculated as r, θ_1- θ_2, ϕ_1- ϕ_2 values according to the accepted center of the cyst: 12 mm, 300°-346°, 97°-144°.

Surgical Technique

The surgery was started with precise calculations in the pre-operative stage. The tumor was completely resected in approximately 70 minutes. The patient was taken to the intensive care unit in the early post-operative stage. However, the patient's GCS decreased to 12 after 2 hours. Control brain tomography shows cerebellar edema and mild brainstem compression. The patient was started on 600 mg mannitol. After medical treatment, the patient's GCS rose again to 15 on the postoperative second day. Mannitol treatment was terminated after gradually reducing the dose. The patient was taken to the service on the 5th postoperative day. On the 15th postoperative day, the patient was discharged with full recovery. The reason the patient is monitored for such a long time is the imbalance in blood pressure and glucose levels. In this process, necessary branch consultations were conducted.

Postoperative control brain magnetic resonance imaging (MRI) examinations of the patient showed that the total tumor resection was successful and the cyst had disappeared (Figure 3A). Pilocytic astrocytoma, WHO grade 1 was detected in histopathological examination (Figure 3B).

A neoplastic proliferation with a rich capillary vascular network within the cerebellum was remarkable in hematoxylin-eosin sections. This lesion had no distinctive capsule structure but was well demarcated. Neoplastic cells were clear, polygonal or rounded, with abundant cytoplasm and revealed no prominent nucleoli (Figure 3 B1,B2). These neoplastic cells were positive for glial fibrillary acidic protein (Figure 3 B3), S100, and ATRX and negative for OLIG-2 and Neu-N. The proliferation index was about 1-2% as determined with the marker Ki67 (not shown). When clinical, radiological, and histopathological findings were evaluated together, the case was diagnosed as pilocytic astrocytoma/ WHO grade 1.
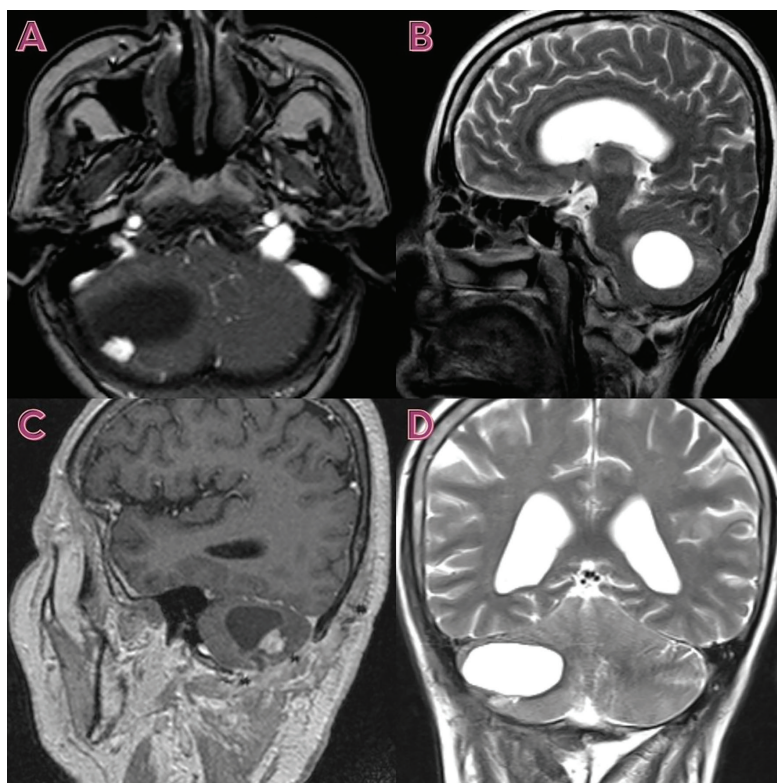
Figure 1. (A) Preoperative magnetic resonance imaging (MRI) images of the case are viewed in the 2nd month of 2020. (B) two months post operative MRI images showed the solid mass and cyst of the lesion after the first surgery
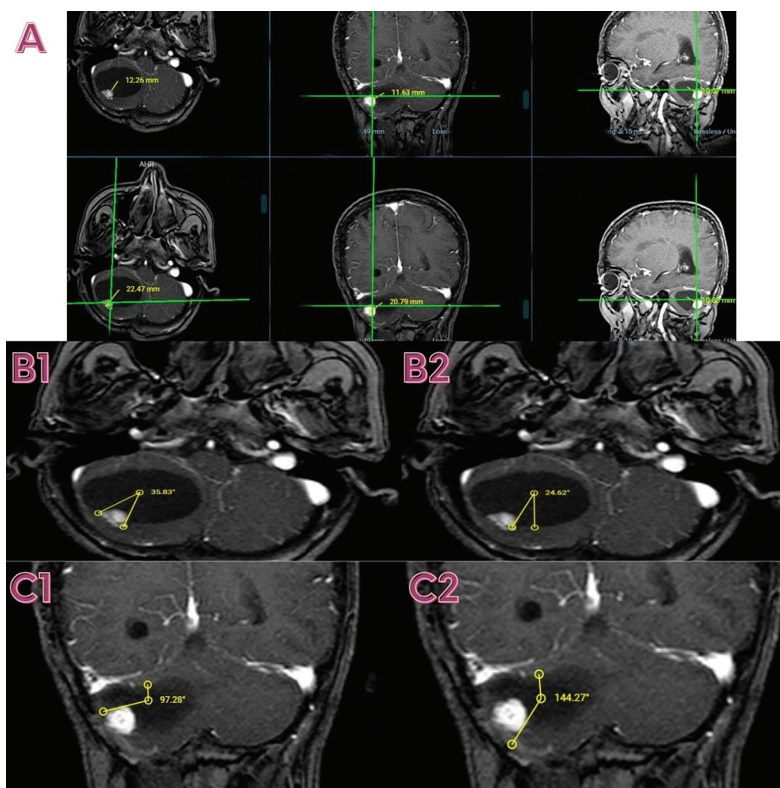
Figure 2. A: The distance of the solid lesion to the tumor center was calculated in contrast-enhanced MRI. B2: in contrast-enhanced axial sections, "θ" values of solid tumor were calculated according to the accepted center of the cyst. C2: in contrast-enhanced coronal sections, ϕ values of solid tumor were calculated relative to the accepted center of the cyst
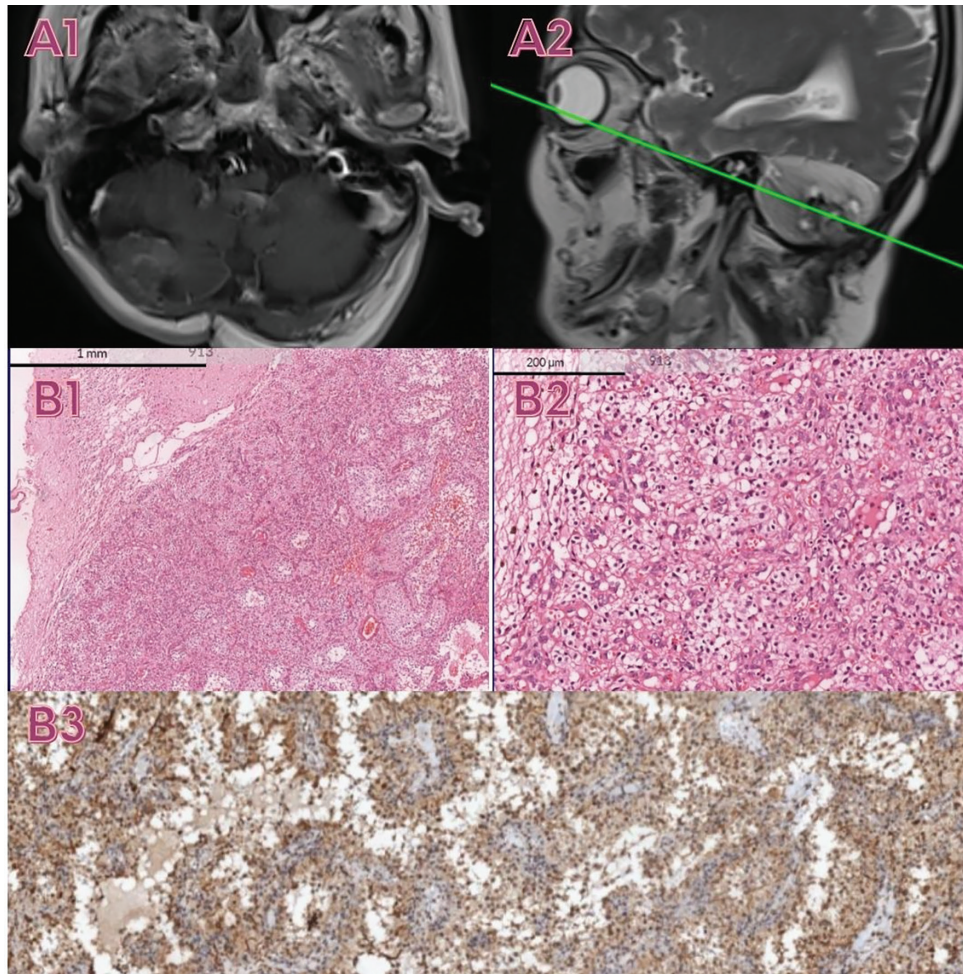
Figure 3. (A1-A2) In contrast-enhanced (A1) and sagittal sections (A2) taken postoperatively, it is observed that the tumor and cyst have completely disappeared. (B1-B2) well circumscribed neoplastic lesion with polygonal-rounded cells with abundant cytoplasm and a rich capillary vascular network (H&E, digitally scanned) (B3) neoplastic cells were positive for GFAP (digitally scanned)
GFAP; Glial fibrillary acidic protein

DISCUSSION

As far as we could detect, the finding of tumor localization using the SCS was reported in the literature for the first time. The SCS can also be used as an alternative in case management, just like the Cartesian coordinate system. This may reduce the rates of remnant tumors and secondary operations. This case report provides a foundation for a more in-depth study of SCS and its clinical outcomes.

However, a study in the engineering literature shows Cheng joint rotations with an SCS (8).

Techniques such as intraoperative MRI are available to guide surgeons during surgery (9). Several techniques are beneficial during surgery, depending on the pathology of the tumor, such as intraoperative ultrasound navigation, 5-aminolevulinic acid, and Fluorescein Na,

and intraoperative computed tomography (10). The mathematical calculations that we used to find the tumor's address can potentially be used alone or in combination with the techniques we mentioned above (Figure 2).

After reaching the cyst, we were able to immediately locate the solid tumor, whose spherical coordinates we calculated. We completely removed the solid lesion by circumferential excision. It can be simplified in an illustration to make the mathematical calculations easier (Figure 4). A cystic sphere can be divided into 8 chambers. The locations of these chambers can be evaluated with MRI. Sphere-like cyst: 8 chambers as superior-lateral-posterior, superior-lateral-anterior, inferior-lateral-posterior, inferior-lateral-anterior, superior-medial-posterior, superior-medial-anterior, inferior-medial-posterior, inferior-medial-anterior are separable. Solid mass was calculated in the inferior, lateral, and posterior chambers of the cyst (Figures 2A, 4A). Cystic cerebellar hemangioblastomas that may
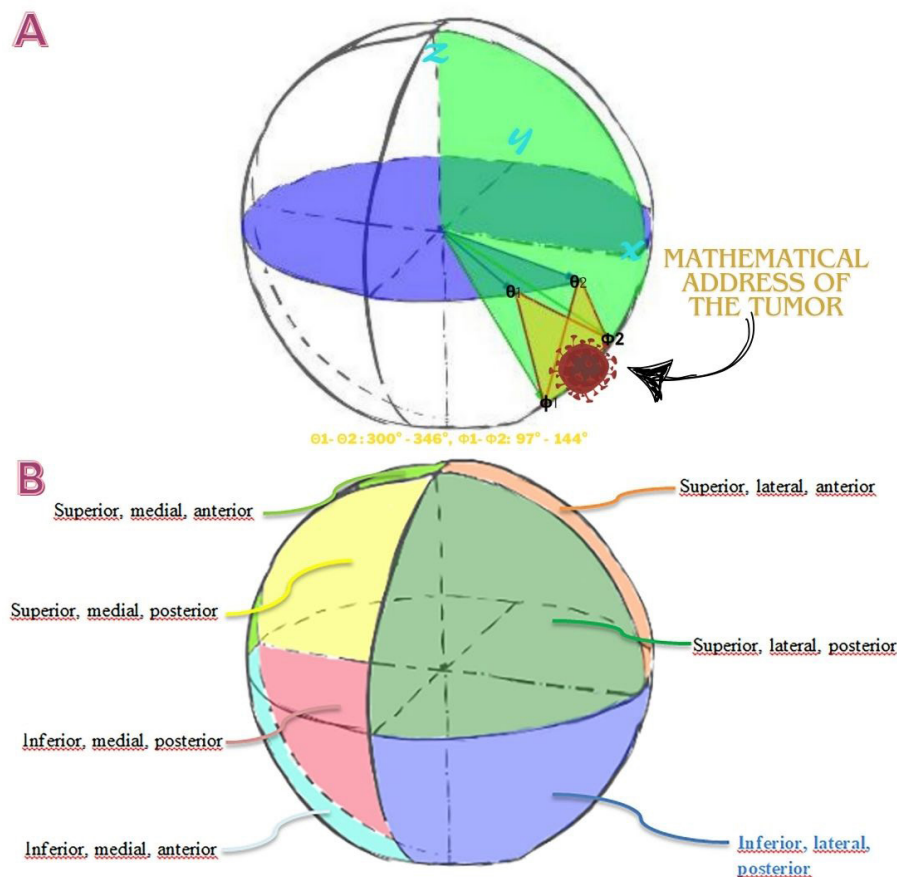
Figure 4. (A) Posterior view of the spherical coordinate system. (B) The division of a sphere into 8 chambers is shown to simplify the spherical coordinate system. In our opinion, the solid mass was inferior, lateral and posterior to the globe. (Figure 2A) (Since the mass is in the right cerebellum, the drawing was drawn in the prone position with posterior view, and in the natural anatomical position for the right side cerebellum)

have similar radiological characteristics due to remnant tumors have been reported in literature (11). The mathematical system we used could be useful in locating tumors. It can reduce the amount of residual and remnant tissue.

Study Limitations

Our study has some limitations, and it progresses by initially accepting the cyst as a sphere. We are aware that the cyst is not a complete sphere. Since the cyst was not a complete sphere, the coordinates of the solid mass were calculated approximately. However, even this calculation was sufficient to locate the tumor. The presented study is based on a single case, limiting the generalizability of findings. A broader patient cohort would be necessary to validate the consistency and efficacy of the SCS approach across different anatomical variations.

CONCLUSION

The article lacks a comparative analysis with traditional stereotactic methods. A comparative study would provide a

clearer understanding of the advantages and disadvantages of the SCS in contrast to existing techniques.

ETHICS

Informed Consent: The patient was comprehensively informed about the surgical procedure and its associated risks, and informed consent was obtained from the patient.

FOOTNOTES

Authorship Contributions

Surgical and Medical Practices: A.E.T., Ö.E.S., Concept: A.E.T., Design: A.E.T., Data Collection or Processing: R.B.G., Analysis or Interpretation: A.E.T., Ö.E.S., Literature Search: A.E.T., Writing: A.E.T., R.B.G.

Conflict of Interest: No conflict of interest was declared by the authors.

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