Iraqi JMS

Published by Al-Nahrain College of Medicine
P-ISSN 1681-6579
E-ISSN 2224-4719
Email: iraqijms@colmed.nahrainuniv.edu.iq
http://www.colmed-alnahrain.edu.iq
http://www.iraqijms.net
Iraqi JMS 2024; Vol. 22(1)

Assessment the Planning by Using Gamma Knife Indices for the Patient with Vestibular Schwannoma

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Abstract

Background Stereotactic radiosurgery (SRS) is the use of a high dosage of radiation, usually to an intracranial target. Healthy brain tissue often surrounds the target when therapies are delivered inside the skull, and this is usually the main organ that is at risk (OAR). To reduce the possibility of normal tissue toxicity and its associated side effects, it is imperative to establish a steep dosage falloff from the target's periphery to normal tissue when using these kinds of treatments.

Objective To evaluate the plans of vestibular Schwannoma using the latest version of gamma knife "lightning by estimating the correlation between the overall sphericity degree and, most important the evaluation parameters such as coverage, selectivity, homogeneity index (HI), selectivity, gradient index (GI), and shot density.

Methods A cross-sectional study. The sphericity degree (ϕ) was determined by using planning for each target volume (TV) of the fifty patients who had stereotactic radiosurgery (SRS) performed on them in order to treat vestibular schwannoma, Calculating this parameter required developing a theoretical concept for operational sphericity, which was done and following are some of the measurements that are used in the analysis of the values that were found: coverage (*C*), selectivity (S), gradient index (GI), Paddick conformity index (*C*I Paddick), and dosage distribution (IV/TV).

Results The mean age of patients was 44.54±11.93 years ranging from (20-80) years and the prevalence of females in this study was 35 (70%) more than the males 15 (30%). The prescribed dose for vestibular Schwannoma patients was 12Gy. The mean target volume is 5.367±0.058 cm^3, ranging from (0.079-26.497) cm^3. This study showed that dividing the tumor into 2 spheres, the first sphere delineates the regular part of the tumor, and the second sphere is delineated irregular cancer components, since the reference plan is a spherical target, the degree of sphericity is an excellent parameter to use when evaluating the dose distribution of a plan for the treatment of vestibular Schwannoma.

Conclusion According to the findings of this study, dividing the tumor into two spheres provides valuable information regarding the dose distribution both inside and outside the desired volume.

Keywords Stereotactic radiosurgery, Acoustic neuromas, gradient index, selectivity, coverage

Citation Jasim MH, Abdullah SS, Faraj MK. Assessment the planning by using gamma knife indices for the patient with vestibular Schwannoma. Iraqi JMS. 2024; 22(1): 13-19. doi: 10.22578/IJMS.22.1.2

List of abbreviations: AN = Acoustic Neuromas, *C* = Coverage, CI = Conformity index, GI = Gradient index, GKRS = Gamma knife radiosurgery, HI = Homogeneity index, IV = Isodose volume, OAR = Organ at risk, PCI = Paddick conformity Index, S = Selectivity, SRS = Stereotactic radiosurgery, TV = Target volume, V = Volume, Φ = The sphericity degree

Introduction

In the treatment of vestibular Schwannoma, radiosurgery is frequently utilized. The radiosurgery treatment is a non-invasive treatment that provides the tumor with high-dose radiation while reducing the damage to the area around wholesome brain tissue. Beams of high-energy X-rays or gamma rays are used to deliver the radiation to the tumor. The goal of the radio surgical treatment for acoustic neuroma is to permanently stop the tumor from growing [1].

In order to better understand the segmented target volume, the sphericity (ϕ) notion was utilized. A measurement of how closely the form of an irregular volume (V) resembles that of a sphere was given the definition of sphericity. For the sake of this investigation, the "sphericity degree" is denoted by (ϕ), while the goal volume is denoted by (V) [2].

$\phi = Vp/Vcs$ …. [3].

Where Vcs is the volume of the lowest circumscribing sphere and Vp be the irregular target volume. You can roughly solve this equation [2].

Acoustic neuromas (AN), are benign intracranial tumors that develop from Schwann cells that produce myelin and are located in the area surrounding the vestibular branch of the vestibulocochlear nerve [3]. The symptoms of sporadic AN are typically a loss of hearing on one side of the body, vertigo, tinnitus, and headache. AN has an incidence of 1.1 cases per 100,000 people and the average age of patients when they are diagnosed is 53.1 years [4]. AN are considered to be benign lesions; however, the growth of these lesions can lead to neurologic deficits. In addition, without treatment, up to 50% of patients with AN will experience radiographic progression. Observation, radiosurgery, and microsurgical resection are the various approaches that can be taken to treat AN. Even though there have been many advancements in the surgical management of AN, there are still significant challenges in preserving patients' hearing and facial nerve function after surgery [5]. Gamma knife radiosurgery (GKRS) is a treatment that has been thoroughly researched and is proven to be both safe and effective. Its high overall efficacy, it carries some risks, including facial nerve paresis, hearing loss, and the progression or recurrence of the tumor [6,7].

It is possible to compare the target volumes (TV) of the various shapes to that of a sphere as shown in figure (1). This window in gamma Knife is used to distinguish tumor from normal tissue. Surface area, volume, plus the orthogonal axes' ratios are all taken into account. Operational sphericity is a theoretical concept. Physicians and physicists review proposals for radio surgical therapy with gamma knife equipment using previously stated quality indicators. Medical professionals do this review, and these measurements includes coverage (*C*), selectivity (S), gradient index (GI), and conformance index (CI). They are calculated using dose distributions that consider the target volume, the volume of the isodose that is half the prescribed isodose, the intersection of these volumes with the organ at risk, and the volume of the prescribed isodose [8,9].

This study aimed to investigate the worldwide dose distribution by making use of the Isodose Volume (IV)/ Target Volume (TV) ratio in the context of radiosurgery planning while also taking into account alternative IV of varying sizes besides the prescribed isodose.

It was attempted to find a correlation between the goal volume and the degree of sphericity of existing indicators. This is significant because utilizing this analysis, we will be able to investigate whether or not it is possible to enhance the evaluation of the plans by making use of the sphericity degree. Consequently, in order to construct this study using the dose distribution that was obtained for the planning of a two-sphere setup with equivalent volume, reference will be used from it.

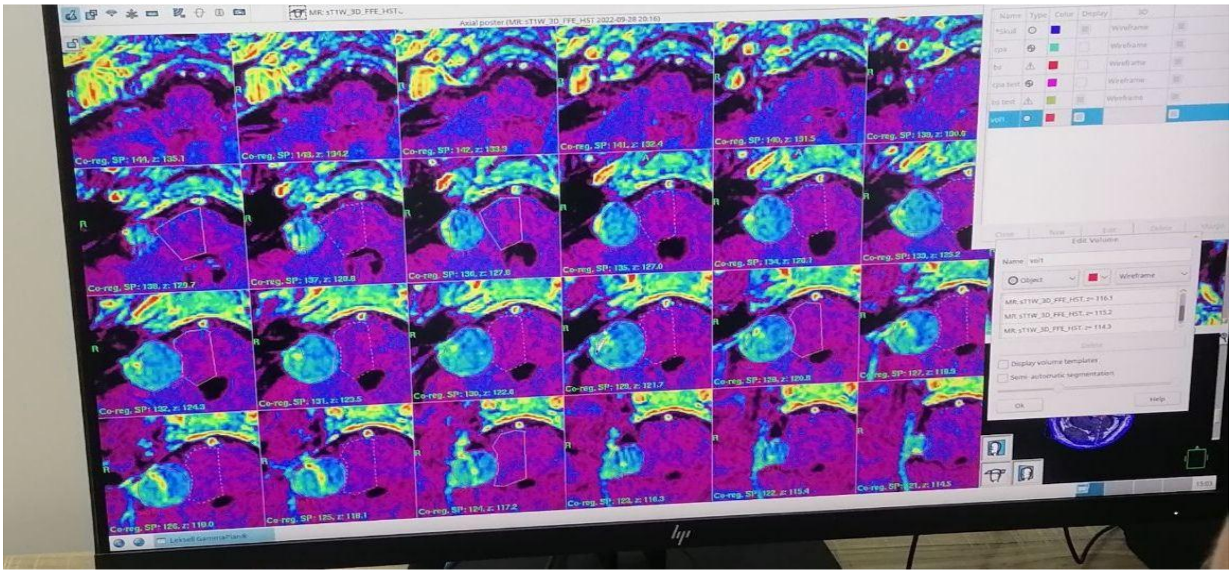

Figure 1. Explain target and organ at risk (Neuroscience Hospital Center, Baghdad, Iraq)

Methods

A cross-sectional study was carried out for a period of six months at both the Dr. Saad Al-Witry Hospital for Neurosciences and the Al-Altaj Hospital (from July 2022 to December 2022). Choosing fifty patients' data who had been diagnosed with vestibular Schwannoma by an oncologist or a neurosurgeon and then having them undergo gamma knife treatment at the Dr. Saad Alwitry Neuroscience Hospital and the Al-Altaj Hospital. After patients were diagnosed and referred to the gamma knife treatment, three-dimensional detailed anatomical images of the vestibular Schwannoma tumor were acquired using a magnetic resonance imaging (MRI) prototype manufactured by Philips called the Achieva 3 Tesla or 1.5 Tesla [10]. These models were used to acquire the images. The bone and other solid structures of the head are then acquired with the help of cone beam computed tomography (CBCT), which is mounted on the device known as the gamma knife. In general, the MRI using in gamma knife called MRI gamma knife protocol [11].

Inclusion criteria

1. Patients with vestibular Schwannoma tumor and underwent a surgery.
2. Patients who refuse the removal of the vestibular Schwannoma surgically.

Exclusion Criteria

All patients with other tumors such as meningioma, arteriovenous malformation (AVM), neuroma, acoustic neuroma, and pituitary tumors in gamma knife.

Statistical analysis

Analysis of data was carried out by using statistical packages for social sciences - version 25 (SPSS-25). Data were presented in simple measures of percentage, mean, standard deviation, and range (minimum-maximum values). The significance of the difference of different means (quantitative data) was tested using students t-test for the difference between two independent means or the Paired-test for a difference of paired observations (or two dependent means). Scattering distribution curve used for correlation. Statistical significance was considered whenever the p-value was equal to or less than 0.05.

Results

The mean age of the patients was 44.54±11.93 years with range (20-80) years. Gender composition of the patients was 15 (30%) Male and 35 (70 %) Female. The females in this study showed more prevalence than male patients. The prescribed dose for vestibular Schwannoma patients was 12 Gy, which was chosen by the neurologist depending on the tumor volume, location, and histopathology. The vestibular Schwannoma tumor is irregular in shape [12], for this reason, the tumor was divided into spheres; the first sphere delineates the regular part of the tumor, and the second sphere is delineated irregular cancer components. The irregular sphere was less than regular sphere in size, that difference in size give rise to increase the mean dose (Gy), minimum dose (Gy), maximum dose (Gy), and integral dose (mJ) for the regular sphere at value according to the readings taken in the table (1) shown in the results the regular and irregular spheres for vestibular Schwannoma dose parameters significant in maximum (Gy) and integral dose (mJ) when using P value ≤0.05 level.

Table 1. Regular and irregular spheres for vestibular Schwannoma dose parameters

Parameters	Regular Sphere	Irregular Sphere	*P* value
Mean (Gy)	22.26 ± 4.94	20.53 ± 6.01	0.1108
Minimum (Gy)	9.18 ± 1.64	7.95 ± 1.61	0.0881
Maximum (Gy)	33.47 ± 4.21	31.85 ± 5.24	0.007*
Integral dose (mJ)	72.66 ± 6.16	24.51 ± 2.68	<0.001

* Significant difference at *p*–value ≤0.05

Sphericity degree (ϕ) and evaluation parameters, regression curve was used to estimate the correlation between the overall sphericity degree and, most important the evaluation parameters such as coverage, selectivity, homogeneity index (HI), selectivity, GI, and shot density. The results showed that there was a direct link between ϕ and *C*, as shown in figure (2). While an inverse correlation appeared between the ϕ and HI as shown in figure (3).

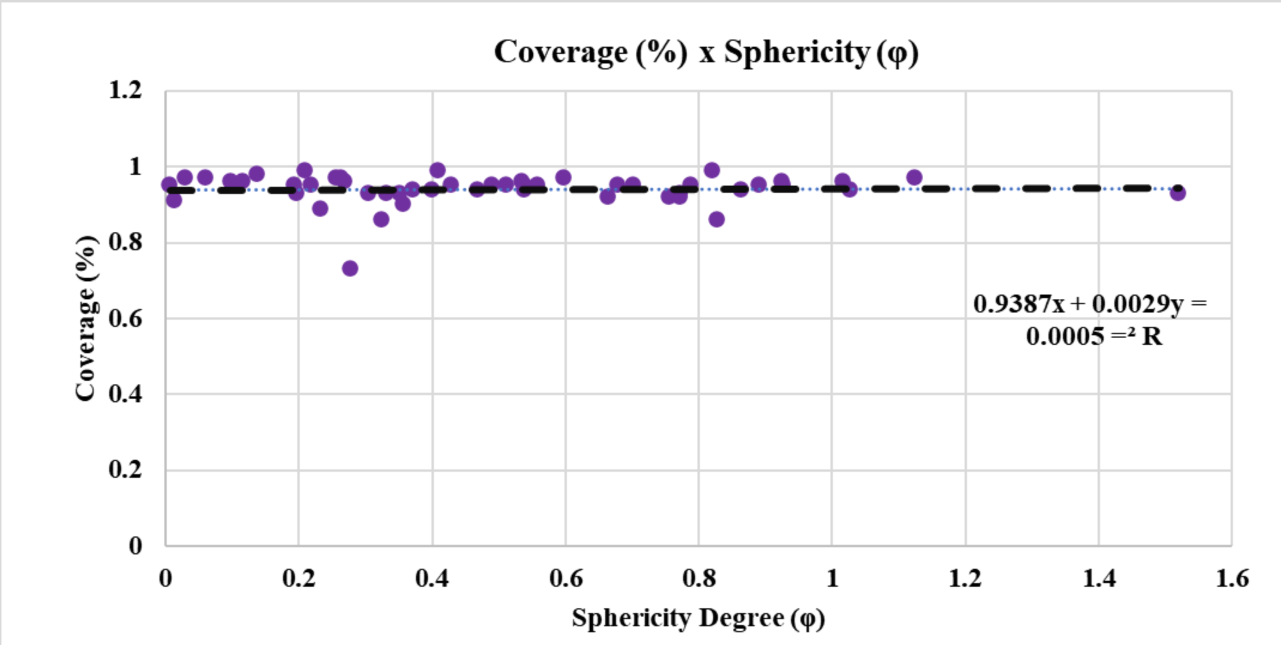

Figure 2. Correlation between the sphericity degree and coverage

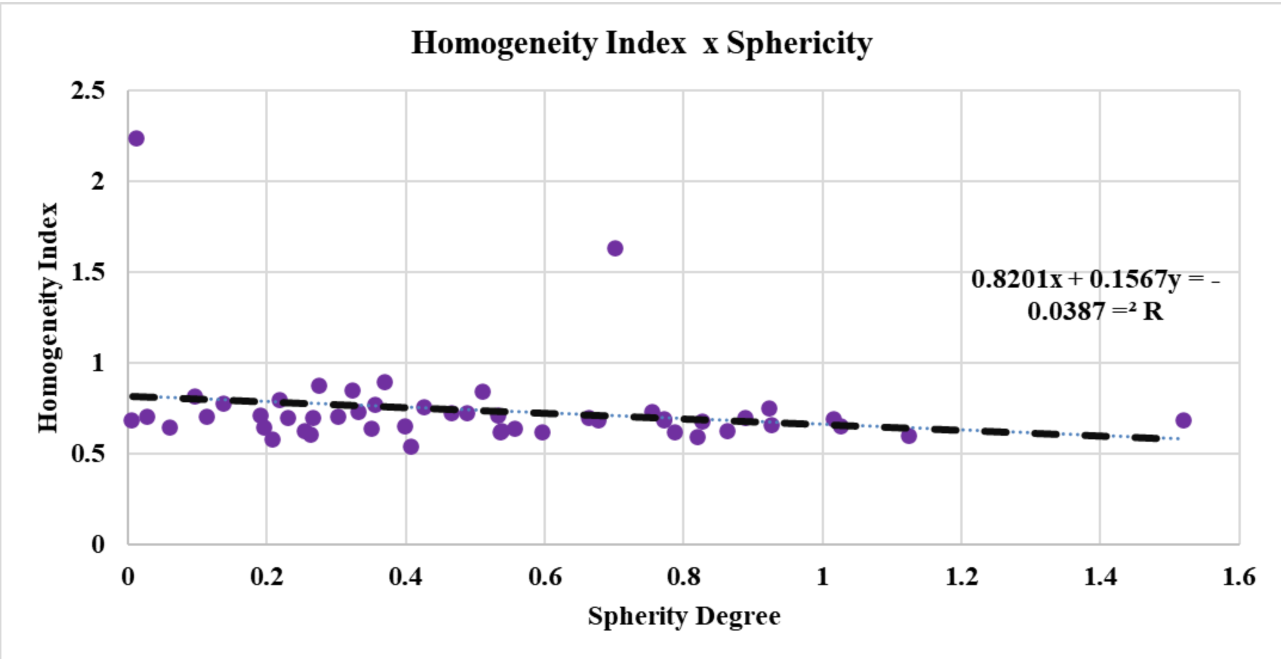

Figure 3. Correlation between the sphericity degree and homogeneity index

Discussion

The main dosimetric parameters used in this study for vestibular schwannoma are coverage, HI, Paddick conformity Index (PCI), Selectivity, GI, number of shots, shot density (number of shots/target volume), and time (minute) [13].

Sümer et al. [12] analyzed the effects of tumor shape irregularity on dose plan quality and identified significant parameters affecting treatment outcomes in vestibular Schwannoma. They used seven metrics to quantify tumor shape irregularity ranging from basic methods such as surface-to-volume ratio, flatness, elongation, spherical disproportion, compactness, and sphericity to newer methods. Their results indicated that the radionics-based shape irregularity features and treatment plan quality was significantly correlated. Additionally, irregularly shaped, and smaller tumors had lower selectivity index (SI), PCI and higher GI. In assessing the tumor's uneven contours, this study is comparable to the one we carried out.

Although it is universally accepted that the dose distribution is affected by the shape and size of the target, few authors have attempted to define the effect of tumor shape irregularity (TSI) on radiosurgery dose plan indices, Wu et al. [(14)] created mathematical simulations of targets with different degrees of irregularity and concluded that the TSI was inversely correlated with PCI and GI. This study shows a direct relationship between ϕ and *C*, S, and GI. At the same time, an inverse correlation appeared between the ϕ, HI, and shot density.

In the results (Figure 2), a straight line was used to adapt the received data in order to generate a trend line. When the sphericity value improves, the *C* value increases as well.

In figure (3), the received data were adjusted using a straight line to generate a trend line in the results. When the ϕ value grows, the HI decreases, and the correlation between them was (r = 0.0387).

In conclusion, the investigation's findings were provided, and they provide information that can characterize the behavior of the dosage distribution (IV/TV) based on the target volume's degree of sphericity. The ϕ is a useful tool when making an objective comparison between two or more treatment plans and determining whether or not it is possible to improve the plan taking low-dose spreading into consideration. As vestibular Schwannoma tumors grow larger, they become more spherical, which leads to improved plan quality.

Acknowledgement

Authors would like to thank the staff of Al-Taj Hospital and Saad Alwitry Hospital for their cooperation in completing the research.

Author contribution

Jasim: Contributing to the treatment plan for patients, collected the data and wrote the paper manuscript. Dr. Abdullah: checking the treatment plan, revising the manuscript. Dr. Faraj: Giving the specified radiation dose and supervising the treatment plan.

Conflict of interest

Authors declare there is no conflict of interest.

Funding

None.

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Received Apr. 30th 2023
Accepted Jun. 21st 2023