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The evaluation of the novel efficiency index in relative to the conformity indices in stereotactic radiosurgery for patients with arteriovenous malformation

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ABSTRACT

Background: Stereotactic radiosurgery (SRS) is distinguished by high levels of conformity and high radiation gradients from the target's periphery to surrounding normal tissues. treatment regimens for radiosurgery should be adjusted by reducing the amount of dosage delivered to the surrounding tissue while increasing the amount of radiation delivered to the target volume. There have been many different indexes suggested to assess the quality of a radio surgical plan, but they all have some drawbacks. To overcome the limitations of the currently used metrics, a novel metric is proposed by Ian Paddick and his team called the efficiency index (η50%).

Method: Calculate the efficiency index (50%), which is based on the idea of integral dosage calculation:

$$\eta_{50\%} = \text{integral dose TV/ integral dosePIV50\%}$$

the integral dosage (volume times mean dose). The TV and PIV50% differential Dose Volume Histograms (DVHs) are an alternative. The amount of energy inside the PIV50% that falls into the target is effectively represented by the resultant 50% value. The potential range of this value is between 0 and 1, with 1 denoting perfection. The index yields a single number that incorporates conformance, gradient, and mean dosage to the target. 50 clinical SRS designs were used to get the value of 50%.

Results: The evaluation of η50% for the 50 plan treatments used in SRS ranged between the lower percentage of 43% and the upper percentage of 84%, with a mean value recorded of 64% in this study. The result was shown a strong relationship between the efficiency index and essential parameters in treatment plan evaluation of the arteriovenous malformations.

Conclusion: The efficiency index that had been introduced is considered an innovative method for assessing the quality of the plan since it has the ability to combine the conformity, gradient, and mean dosage into a single indicator. It provides a numerical value for the proportion of the dosage presented by "does good" to the amount that "does harm."

Key words: conformity, efficiency index, plan quality, radiotherapy, stereotactic radiosurgery

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INTRODUCTION

Around 50 years ago, a team of neurosurgeons and physicists in Sweden developed stereotactic radiosurgery (SRS) to administer radiation to specific brain targets with limiting harm to neighboring areas. It employs advanced 3-D imaging technology to precisely direct the photon beams to deliver a highly concentrated dosage of radiation to a specific target in a single session. Stereotactic radiation therapy is not surgical in the traditional sense because no incisions are made and no general anesthesia is required for adults [1]. SRS, like other kinds of radiation, operates by altering and destroying the DNA of tumor cells. As a result, these cells are unable to proliferate and perish. [2]. An AVM is a tangle of aberrant and poorly formed blood vessels (arteries and veins) with a greater incidence of bleeding than normal vessels [3, 4]. AVMs can develop everywhere in the body, but brain AVMs pose significant concerns when they bleed. Dural AVMs arise in the brain's covering and are an acquired condition that can be initiated by an injury. Although the effects of SRS on tumor tissue can be detected a few weeks after the treatment, the effects of SRS on an AVM may take up to two years. When SRS is used to treat an AVM, an angiography is obtained to increase the precision of targeting the essential areas of the lesion [5, 6].

The nidus, or the most concentrated area of the AVM, is the essential target in AVMs. The target should be no larger than 3.5 cm in size. If the AVM nidus is big, SRS may be split into many sessions to minimize difficulties. Another contrast with AVMs is that, in certain cases, before SRS, embolization of the AVM may be done to limit blood flow inside it [7, 8].

METHODOLOGY

The Dr. Saad Al-Witry Hospital for Neurosciences in Baghdad City was the venue for this cross-sectional investigation. The data gathering was completed in three months, from October 2022 to December 2023.

Inclusion Criteria

- This study included 50 individuals who had previously been identified with various single target volumes of cerebral (AVM).
- The age of patients was over 12 years old.
- Patients were interviewed to acquire information on their clinical symptoms of illness and willingness to participate in this study.

Exclusion Criteria

1. Pregnant patients.
2. The patients with a target volume great than 3 cm.

To solve the drawbacks of previously used indexes, the efficiency index (50%) is presented. by Divide the entire integral (int) dosage of TV by the total integral (int) dosage of PIV50% to get the index:

Paddick Conformity Index (PCI) and new Conformity Index (CN) will be calculated manually by using this equation:

TV_{PIV} target volume is occupied by 50% of the prescribed dose, TV is the target volume, and PIV is the volume occupied by the prescribed dose.

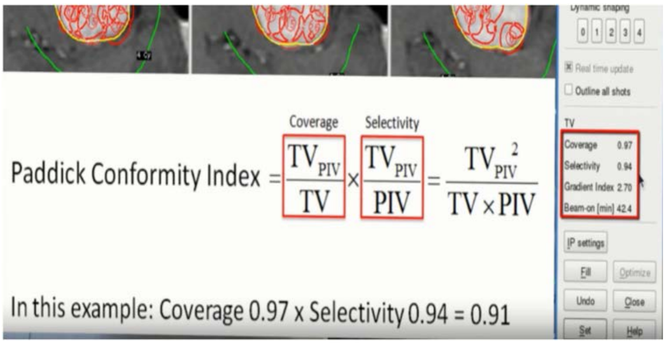

Fig 1. Shows calculate Paddick conformity

Lomax and Scheib [9] offered an alternative conformity index to the RTOG conformance index. Their index is a refinement of the stereotactic plan accuracy criterion first developed for arteriovenous malformations by the SaintAnne, Lariboisiere, Tenon (SALT) group. CILomax, Lomax, and Scheib's modified index are provided by:

The Radiation Therapy Oncology Group (RTOG) defined three commonly used criteria for describing the quality of stereotactic radiosurgery (SRS) plans [10].
The first statistic is the conformance index, abbreviated as CI_{RTOG}.

where PIV is the volume encompassed by the prescription isodose and *TV* is the target volume [9].

Statistical Evaluation

The available statistical program for Social Sciences (version 25 (SPSS-25)) was used to analyze the data. For the 30 single-target plans, data were provided as mean, standard deviation, and ranges of values (minimum and maximum). The Pearson correlation coefficient was used to assess the importance of the difference between the two types of data. When the P-value was equal to or less than 0.05, the statistical analysis was judged significant.

RESULTS AND DISCUSSION

In Table (1), The four conformity treatment parameters including the $CI_{paddick}$, CILomax, CN, CI_{RTOG}, and calculation of efficiency index are expressed as mean value± SD which are a result of the optimization process involving each patient.

Tab 1. conformity treatment plan parameters

Parameter	Mean	Min	Max	
η50%	0.63±0.1	43	83	
$CI_{paddick}$	0.64±0.25	0.42	0.84	0
CI_{Lomax}	0.93±0.04	0.83	0.98	0.126
CN	1.68±0.07	1.22	2.34	0.00001
CI_{RTOG}	1.44±0.11	1	1.99	0

There is sufficient evidence that was identified by a significant positive correlation between the efficiency index and the $CI_{paddick}$ index of treatment plans, the correlation results were defined by (r = 0.7035, R^2 = 0.4956, and *p*-value = 0.0000000), as shown in Figure 1. While in Figure 2, the efficiency index showed a low nonsignificant negative relationship with the CI_{Lomax} index of a treatment plan (r= -0.221, R 2=0.0491 and *P*-value=0.126).

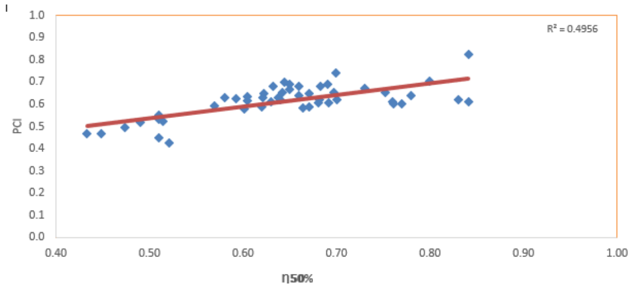

Fig 2. Efficiency index values(η50%) for the 50 single-target plans in relation to the $CI_{paddick}$.

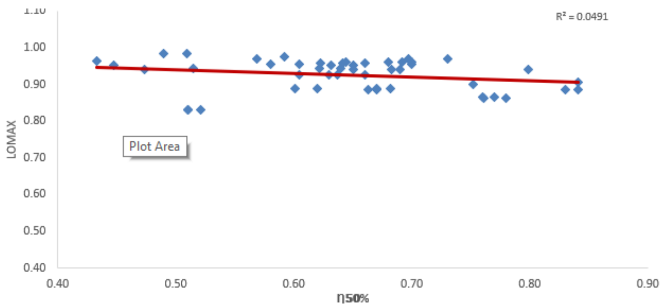

Fig 3. Efficiency index values(η50%) for the 50 single-target plans in relation to the CI_{Lomax}.

Meanwhile, in (Figure 3), the efficiency index reveals a high inverse significant relationship with the CIRTOG index of a treatment plan, (r = - 0.831, R^2 = 0.692, and P-value =0.0001).

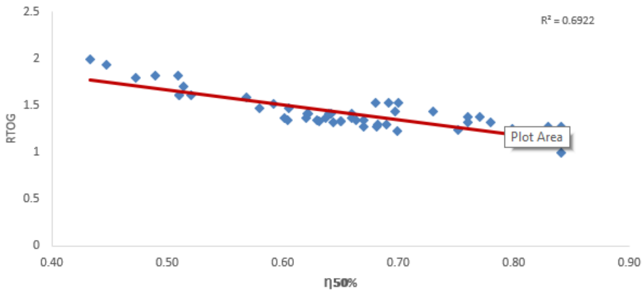

Fig 4. Efficiency index values(η50%) for the 50 single-target plans in relation to the CI_{RTOG}.

(Figure 4), the efficiency index reveals a high inverse significant relationship with the CI_{RTOG} index of a treatment plan (r = - 0.630, R^2 = 0.397, and P-value =0.0000). The trend line is not zero intercepts.

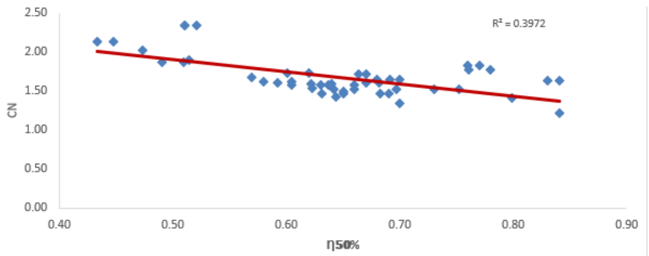

Fig. 5. Efficiency index values(η50%) for the 50 single-target plans in relation to the CN.

DISCUSSION

The results showed that the relationship between efficiency and the Paddick Matching Index (PCI) leads to a moderate positive relationship. The conformance index is a measure of the extent of dose radiation distribution corresponding to the size and shape of the target volume, so the efficiency is affected by the degree of conformity and the gradient achieved, which are changing with the size and complexity of the target. Where the high conformance index (0.82) corresponds to the high value of the efficiency index (0.84). The results of this study were consistent with the research demonstrated by Dimitriadis and Padek (11), who stated that clinically appropriate gamma-knife radiotherapy regimens often obtained values between 50% and 40% and 56% with 12GY prescription doses. According to the research of

Nakamura et al. Nakamura [12], there is a strong relationship between compatibility and toxicity. Matching targets smaller than (1cm-3cm) was poor, but there were no major difficulties. According to Paddick [13], a matching scheme may be generated faster for large-sized lesions, but toxicity increases with irradiated volume.

The ratio between the volume in the Target Region (TV) with at least the Prescribed Dose (PIV) and the volume of the Target Volume (TV) is the best indicator of Coverage, it was shown greater than 0.90 in this study. Where the high value of the Coverage parameter can reduce the formation of cold spots, that thought to reduce the tumor control probability, as every tumor cell needs to receive the prescription dose, indicated by Andratschke N and his team (14), and Guckenberger M and his team (15). One may prevent the under-dosing of cells in the radiosurgical target by assuring good target coverage by the prescribed dosage. Regarding radiosurgical targets, they stated that the presence of hotter regions is good since it increases the tumor control probability (TCP) and They have the potential to enhance positive results and maybe shorten the time to obliteration for vascular targets [16].

The mean overall RTOG Match Index for the 50 targets was found to be 1.44. the comparative value of the efficiency index was 0.63, as the efficiency index achieved the matching value with high percentages compared to the results found with Lomax and Scheib 0.93. where forty-three of the targets achieved conformity index values to be classified as "per protocol" by the RTOG. The majority of targets that were classified as having significant deviations from Protocol, seven targets had volumes smaller than 1 cm3.

Lomax and Scheib suggested that, while for larger target volumes the RTOG conformance index is independent of the target volume, for target volumes smaller than 1cm-3cm, the conformity index is affected by the target volume. This assertion is supported by our data set. On the other point of view, Knoss et al. suggested that the target size effect is because when the PTV is small, a small change in the absolute size will translate into a large relative change [17].

CONCLUSIONS

In this study, it was found that the efficiency index can express the information for both values including conformity and gradient indexes in a single value; the results showed a good correlation between the efficiency index and the conformity indicators with an exception for Lomax conformity, according to the that, the conformity index can be used as an evaluation coefficient for the parameters in the plan conformity during the treatment plan and it is not considered an alternative to it.

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