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The Journey of SRS: An Initial Experience of Starting Sterotactic Radiosurgery Facility at Purbanchal Cancer Hospital—First in Nepal

Birendra Kumar Yadav[1], Karthik Nagamuthu[1*], Alok Thakur[1], Kushal Rizal[1], Umesh Kumar Sharma[2], Ujwal Rai[3], Dinesh Thapa[4], Shishir Thapa[1], Kumar Chinnappan[1], Amit Kumar Dubey[1], Suraj Gurung[1], Aman Yadav[1], Utpalkant Kumar[1], Ranjay Kumar[1]

[1]Department of Radiation Oncology, Purbanchal Cancer Hospital, Jhapa, Nepal
[2]Department of Radiology, Purbanchal Cancer Hospital, Jhapa, Nepal
[3]Deapartment of Pathology, Purbanchal Cancer Hospital Jhapa, Nepal
[4]Department of Neurosurgery, Purbanchal Cancer Hospital Jhapa, Nepal
Email: *karthikphysicist@gmail.com

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Abstract

Introduction: Radiotherapy (RT) is a vital cancer treatment modality for both curative and palliative purposes. Nepal is a developing country with a population of around 30 million people. Cancer affects 100 - 120 people out of every 100,000, and the figure is increasing. The number of radiation facility machines in the country is still countable in fingers. Purbanchal Cancer Hospital, Nepal is the first comprehensive cancer facility capable of performing stereotactic radiosurgery (SRS). Our facility has cutting-edge Varian Truebeam Linear Accelerators with millennium MLC, which makes SRS and SRT'S for intracranial lesions such as small benign and malignant tumors much easier. In addition to SRS, we are the pioneers of SBRT for lung using 4DCT, interstitial & intraluminal brachytherapy, RPM Gated & DIBH modalities in Nepal. **Methods & Materials**: The purpose of this study is to share our experience in establishing an SRS facility in the country, which includes training the RT team on the importance of process accuracy, patient selection, patient assessment, mould preparation, and describing image data acquisition, target, and organ at risk delineation on CT and MRI images, treatment planning process, and quality assurance. **Results & Discussion**: The plans for all SRS and SRT cases are based on target coverage, OAR sparing, hotspot inside the target, conformity index, heterogeneity index, and dose fall off. To select the final plan, we used strict passing criteria such as a conformity index Paddick (CIPaddick) more than 0.85, a falloff between 100% and 50% of less than 5.5 mm (maximum 6 mm in irregular targets), and a hotspot

*Corresponding author.

inside the target between 115 to 140 percent, as per clinical standards. In addition, we determined the CILomax and CIRTOG for each case. Passing criteria for verification plans are set as minimum of 95% for a 2% percentage dose difference (% DD) and a 2-mm distance to an agreement (DTA). We also gathered demographic data from patients treated in the first year, such as diagnosis, lesion size, dose fraction, heterogeneity index (HI), conformity index (CI) and gamma index. SRS/SRT treatment was successfully implemented, and over 40 patients were treated with positive clinical outcomes. **Conclusion**: SRS now has a wider range of alternatives, thanks to technology advancements in recent years. SRS's dosimetric advantages have steadily been extended to extracranial locations. Purbanchal Cancer Hospital, Birtamode, Nepal established a comprehensive cancer facility with qualified workforce with the goal of providing high-quality treatment to the people of Nepal.

Keywords

Conformity Index, Double Shell Positioning System, Electronic Portal Imaging Device, Linear Accelerator, Millennium MLC, Octavius Detector 1500, Setup Field

1. Introduction

Radiotherapy (RT) is one of the most important cancer treatment modalities for both curative and palliative purposes, and more than 60% of new cancer patients should undergo radiotherapy at least once, with up to 25% receiving a second course as part of their cancer management program. Nepal is a developing country with a population of around 30 million people. Cancer affects 100 - 120 people out of every 100,000 people, and the number is rising. According to GLOBOCAN 2018, the age-standardized cancer incidence and death rates in Nepal are 103.7 and 77.8 per 100,000, respectively [1] [2] [3]. The number of radiation facility machines available in Nepal is still in the single digits. In total, there are 6 linear accelerators, 4 telecobalt units, and 6 HDR brachytherapy machines. We are the first centre capable of doing stereotactic radiosurgery out of all the radiation facilities (SRS) in Nepal. Patients previously had to travel outside of the nation to receive such advanced therapies. Our facility has state-of-the-art Varian Truebeam Linear Accelerator with millenium MLC, making sterotactic radiosurgery (SRS) and stereotactic radiation therapy (SRT) for intracranial lesions like small benign and malignant tumors much easier.

SRS is a non-surgical radiation therapy that is used to treat functional impairments and tiny malignancies in the brain. It can deliver precisely-targeted radiation in fewer high-dose doses than standard therapy, allowing healthy tissue to be preserved. The principles of cranial SRS, notably high precision radiation with delivery accuracy of one to two millimetres, are currently being used to treat body malignancies via a process called stereotactic body radiotherapy (SBRT).

SRS and SRT are fundamentally two-step processes that include: 1) identifying the shape and location of the lesion and neuroanatomy in the reference frame of a stereotactic frame system with CT, MRI, or angiography; and 2) developing and providing the planned therapy. The treatment methods deliver a concentrated dosage to the lesion, with steep dose gradients externally and greater conformance to the treatment volume. The quick dose falloff at the treatment volume's edge results in significant normal brain tissue sparing.

Purbanchal Cancer Hospital in Birtamode, Jhapa, Nepal plans to build a state-of-the-art radiotherapy facility in Nepal that meets international standards, and it has been operating complete cancer care with treatment planning techniques such as 3D conformal radiotherapy (3DCRT), intensity modulated radiation (IMRT), and volumetric-modulated arc therapy (VMAT). In the same year, we began our first SRS patient in Nepal for an intracranial lesion. Meningioma was the first instance of SRS at our Hospital.

This study intends to share our experience in establishing an SRS facility in the country, which involves training the RT team on the importance of process accuracy, patient selection, patient assessment, mould preparation, and more.

2. Methods & Materials

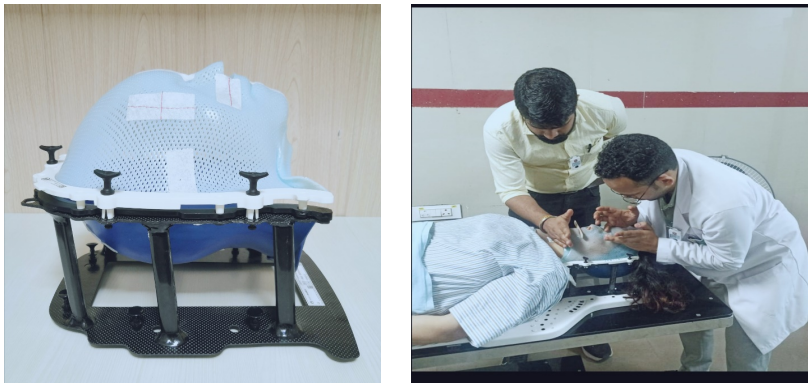
2.1. Selection of Patients

SRS and SRT are commonly used to treat intracranial and high spinal (cervical) lesions such as small benign and malignant tumors (meningiomas, trigeminal schwannomas, vestibular schwannomas, craniopharyngiomas, gliomas, chordomas), selected brain metastatic lesions, cranial nerve arteriovenous malformation (AVM), and trigeminal neuralgia, among others.

2.2. Preparation of the Mould and CT Simulation

RTTs (radiation therapy technologists) detailed the operations from simulation to treatment delivery to the patient before starting the mould preparation. After that, we transported the patient to the moulding room and instructed him/her to lie down comfortably in a supine posture on the couch, where he/she was properly aligned with the sagittal laser. To prevent the patient from moving during treatment, an immobilization device tailored to the anatomical spot to be treated is constructed. To immobilize the patient and preserve precision, we used a customized non-invasive DSPS (Double Shell Positioning System) SRS frame mask [4] [5] [6]. The RTT prepares this mould in the mould room using the CT simulation instruction sheet provided by the radiation oncologist (RO) (**Figure 1(a)** and **Figure 1(b)**).

The patient is then transferred to the CT (Computed Tomography) room to get CT pictures. We next reposition the patient on the CT couch and secure the SRS frame that was made in the mould room (**Figure 2**). The scan was performed in the Siemens 4DCT scanner with 1 mm slice thickness for the intended area as indicated by RO after we captured the topogram image to select the FOV



(a) (b)

Figure 1. (a) Double Shell Positioning System (DSPS), (b) DSPS mould preparation by RTTs.

Figure 2. Position the patient on CT couch to acquire the CT Images.

(field of view). For all our cranial lesion patients, we performed three separate scans: a regular CT, a CT with contrast, and a delayed scan. We can visualize the tumor more clearly with the use of three separate scans. Female patients undergoing simulation shall be always accompanied by a female assistant. The obtained data set is delivered to the Eclipse Treatment Planning system (TPS), which is already connected to the CT machine via network, after the scan is completed. Following the CT scan, the patient had planning-MRI (Magnetic Resonance Imaging) scanning for the intended area with a slice thickness of 1 mm. Patients are sometimes accompanied by MRI images that are taken outside. We will accept scans that were taken more than two weeks prior to the CT simulation date. Otherwise, we recommend that the patient get a new MRI scan. The time between the planning-MRI and the actual SRS treatment should be maintained as short as feasible, according to agreement. To avoid a geographic miss of the tumor, a maximum of two weeks (ideally one week) is reasonable [6] [7] [8].

2.3. Contouring and Image Fusion

The planning CT and planning MRI images are fused in the image registration window once all of the collected data is input into the TPS. The position of the tumor on both the MRI and the CT (if visible) can be used to assess the registration quality (Figure 3). An independent assessment of the registration by a medical physicist (MP) and/or radiation oncologist by matching the anatomical landmarks is required to reduce the likelihood of registration errors. Once the images were fused, the RO began contouring with radiologist assistance, using the radiation therapy oncology group (RTOG) atlas to delineate the target and OAR's (Organ at Risk) to generate a 3D data set of the patient anatomy, which was then handed over to the medical physicist to generate the treatment plan, including dose prescription and constraints.

2.4. Treatment Planning

In this investigation, the Eclipse Treatment Planning System (version 15.6) (Varian Medical Systems, USA) was used to generate SRS and SRT plans utilizing the Dynamic SRS Arc approach with a 6MVFFF (Flattening Filter Free) dose rate of 1400 MU/min [9]. AcurosXB algorithm was computed using this approach. Varian Truebeam Linear Accelerator with Millenium MLC was used to carry out SRS designs (central 40 pairs of leaves of 0.5 cm width at isocenter and outer 20 pairs of leaves 1 cm width). In the TPS, the Medical Physicist adjusts various parameters of the radiation beam to construct several plans with rapid dose falloff and a higher conformity index (CI). The non-coplanar SRS arc can be utilized to increase efficiency while keeping treatment plan quality good. This is a highly conformal dynamic intensity modulated approach that delivers large doses of radiation to the target while sparing the OAR to the greatest extent possible. In all instances, one to two full arcs in 0 deg couch and two to three partial arcs in non-coplanar couch angles are used, depending on the position and size of the target (Figure 4).

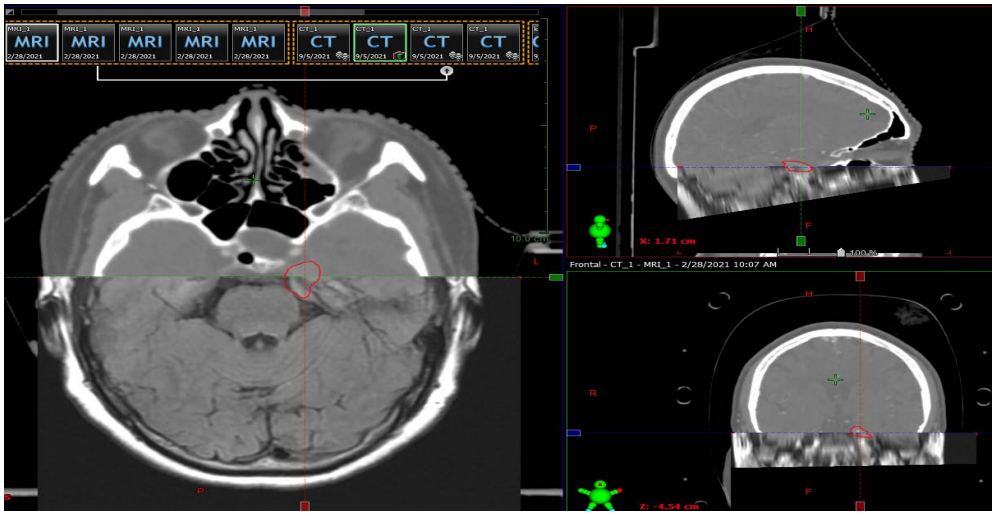


Figure 3. Fusion of computed tomography—magnetic resonance image.

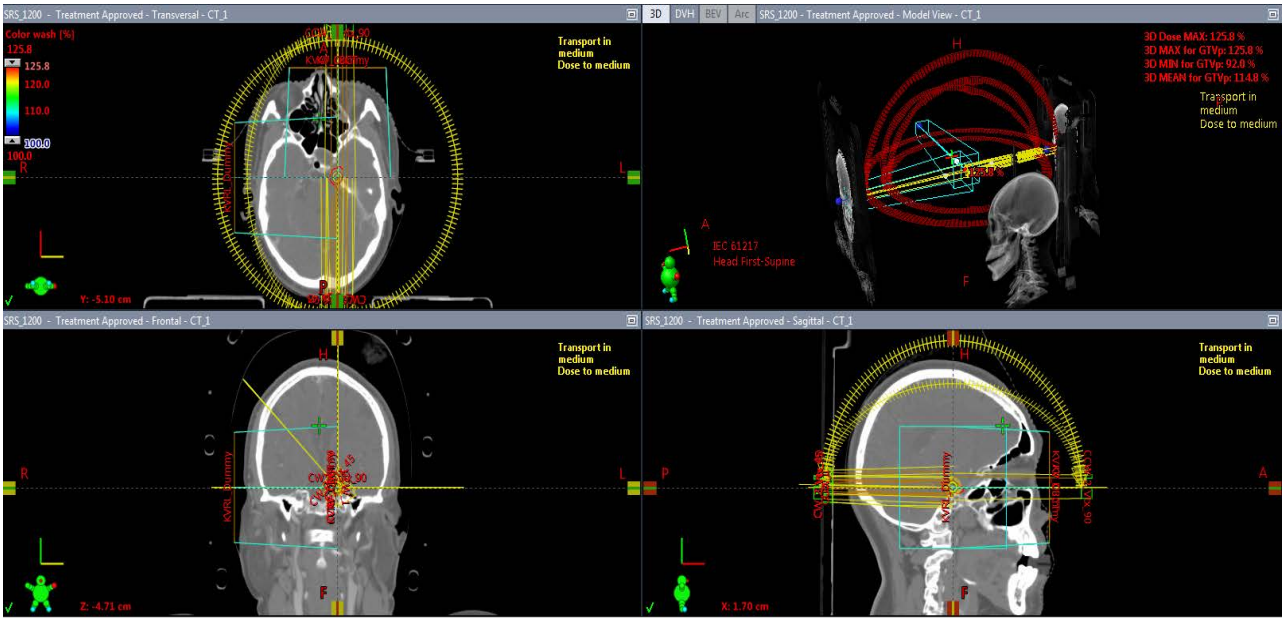
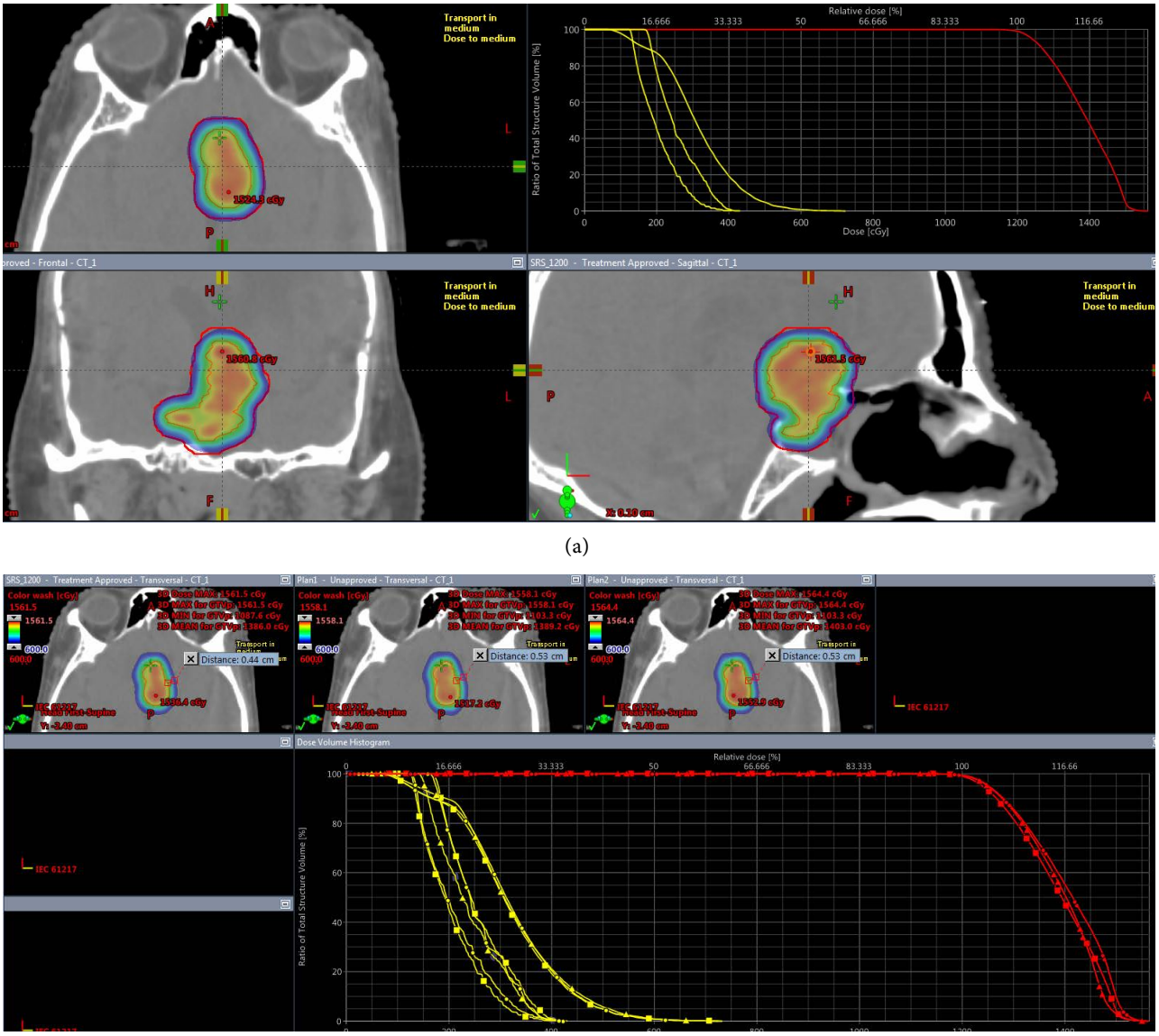


Figure 4. Treatment plan with non-coplanar SRS Arcs.

3. Results & Discussion

3.1. Plan Evaluation

Inverse treatment planning optimization is employed in the plans, and it is a sort of planning in which objectives such target volumes and organs at risk (OAR) are automatically allowed for according to a pre-selected methodology. The algorithm is used to calculate beam parameters in order to create a better dose distribution that matches the initially set objectives as closely as feasible, and it is utilized to achieve the required dose distribution. Dose constraints were utilized to reduce the dose to Organs at Risk (OARs), and they were applied according to the guidelines of the radiation therapy oncology group (RTOG) protocol. Medical physicists finalize three superior plans for all SRS and SRT cases based on target coverage, OAR sparing, hotspot inside the target, conformity index, heterogeneity index, and dose fall off. To select the final plan, we used strict passing criteria such as a conformity index paddick (CIPaddick) more than 0.85, a falloff between 100% and 50% of less than 5.5 mm (maximum 6 mm in irregular targets), and a hotspot inside the target between 115 to 140 percent, as per clinical standards. In addition, we determined the CILomax and CIRTOG for each case [10]. Further, RO reviewed all three plans in a plan evaluation window (fig) in a clinical view with a medical physicist, seeing the dose distribution slice by slice and visual inspection of hotspots, target coverage, and OAR doses in the dose volume histogram (DVH), and chose the best plan out of three better plans based on the above-mentioned parameters and the dose received by the whole brain for the treatment. Once the RO has approved the plan, we have recorded all the dosimetric parameters, target, and OAR doses on the SRS plan assessment sheet, which has been signed by the RO and medical physicist in accordance with department practice (**Figure 5(a)** and **Figure 5(b)**).



(a)

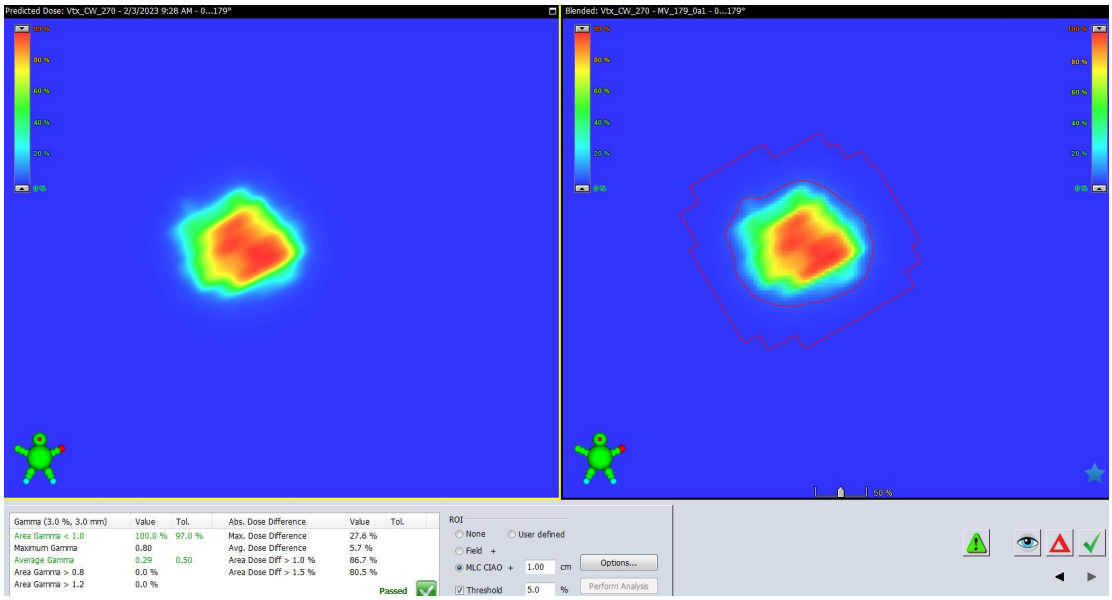
(b)

Figure 5. (a) Dose colour wash & DVH, (b) Comparison of plans in plan evaluation window.

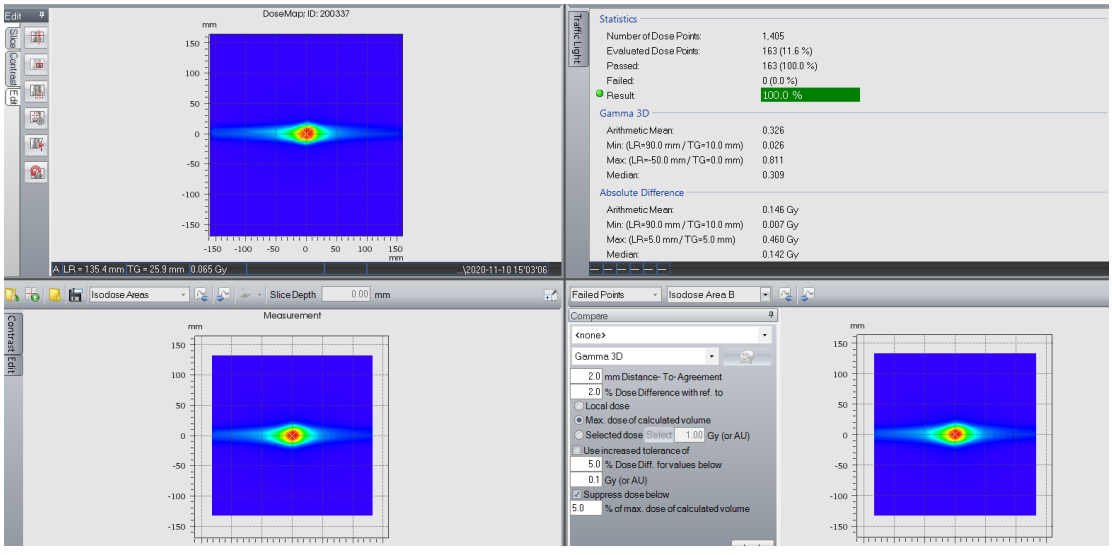
3.2. Assurance of Quality

According to the World Health Organization's Radiotherapy Risk Profile, adequate QA measures are essential for reducing the possibility of accidents and errors, as well as increasing the likelihood that errors will be discovered and corrected if they do occur. As a result, patient-specific QA is required for all high-precision treatments such as IMRT, VMAT, SBRT, SRS, and SRT, and it must also meet the established requirements as outlined in the standard recommendations. Before giving the treatment plan to the patient, the medical physicist performs patient-specific QA. To validate the computed and delivered fluence, a verification plan was built in TPS and sent to the phantom [11] [12]. We use the PTW OCTAVIUS array detector 1500 in our centre for verification, as well as the electronic portal imaging device (EPID) detector (Varian aS 1200 flat panel

detector) that is installed in the machine. Whenever we treat SRS patients, we assess our isocenter using the Winston-Lutz test tool and machine performance check (MPC) isocal phantom on the same day. The gamma index values are computed by comparing the calculated dose from TPS with the measured dose from the QA phantom using the PTW mephystho program for array detector and portal dosimetry verification in Eclipse TPS. According to our department's procedure, all verification plans must pass a minimum of 95% for a 2% percentage dose difference (% DD) and a 2-mm distance to an agreement (DTA) value in order to be accepted for delivery to the patient. All our patients passed with a score of >95 percent in our situation (Figure 6(a) and Figure 6(b)).



(a)



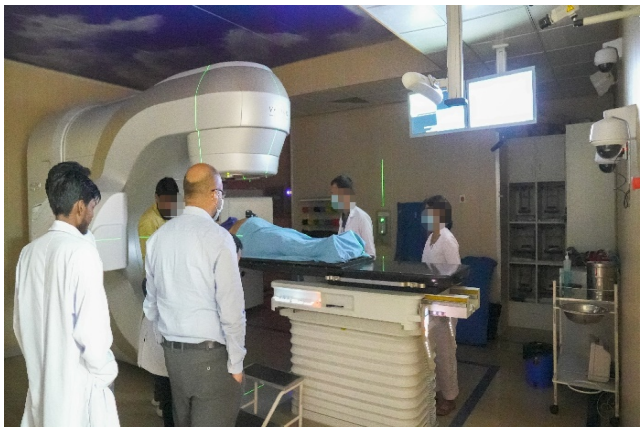
(b)

Figure 6. (a) Fluence Verification using Portal Dosimetry (Varian as1200 flat panel detector), (b) Fluence Verification using PTW Octavius array detector 1500.

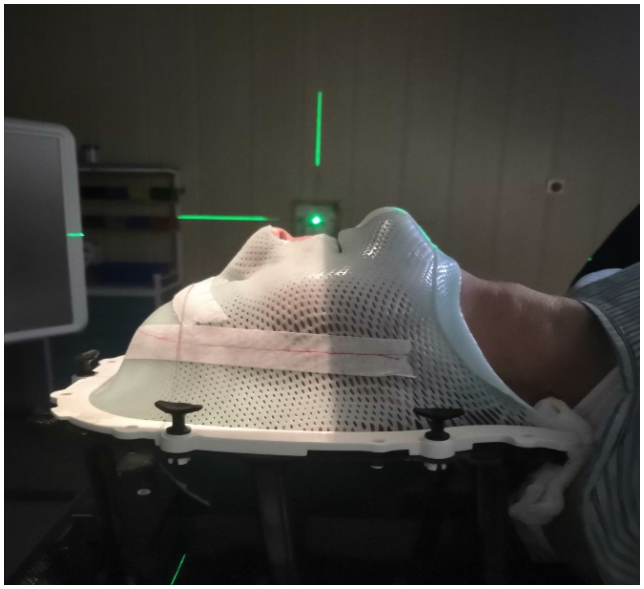
3.3. Verification of Patient Position (IGRT) and Treatment Delivery

Before starting treatment, our RTT staff double-checks the patient's identity, immobilization devices, treatment plan parameters, dose prescription, and consent form signed by the patient's relatives. Following all these pre-checks, the patient is placed on the couch according to the treatment plan report, under the observation of the RO and medical physicists. A dry run was conducted to ensure that the collision-free treatment was effective (**Figure 7(a)** and **Figure 7(b)**).

Image guided radiotherapy (IGRT) verification is performed on the patient, in which the treatment position advised by the planning system is achieved on the treatment table. All image guidance activities—picture acquisition, image registration/interpretation, and patient correction—can be done remotely with the



(a)



(b)

Figure 7. (a) and (b) positioning the patient on the treatment couch as per the treatment plan sheet.

onboard Imager (OBI) system. Using the findings given by the OBI system, all axes of the couch (x, y, z translations, and couch rotation) can be modified remotely. The OBI system employs the concept of a "setup" field to allow for the preparation of the image-guidance session before the patient arrives at the treatment equipment. The setup field is part of the patient plan and contains all data needed for image collection (e.g., gantry angle, reference images, imager positions, kind of image to acquire radiograph or cone beam computed tomography (CBCT), etc.). Before going to kvCBCT, RTTs will first take kv-kv paired images and match the bony landmarks to decrease the maximum setup error while also preventing excessive exposure from kvCBCT. With a precision of less than 1 mm, we are comparing our current CBCT with a reference CT (**Figure 8**). If non-coplanar beams are utilized in the treatment plan, RTTs take a MV image for each couch angle and verify the patient position. The RTT, RO, and physicist are all involved in the procedure. After the image has been validated, we will begin the final treatment. RTT goes inside and manually rotates the couch for each couch angle to limit the jerk. Throughout the therapy process, the patient is monitored by CCTV and spo2 meters are used to continuously monitor his or her vitals.

3.4. Follow-Up Schema

Patient are followed up for a duration of 5 years, in the first two years patient is advised to follow-up 3 monthly, and from third year to fifth year patient is advised six monthly follow-up. After 5 years patient is advised annual follow-up.

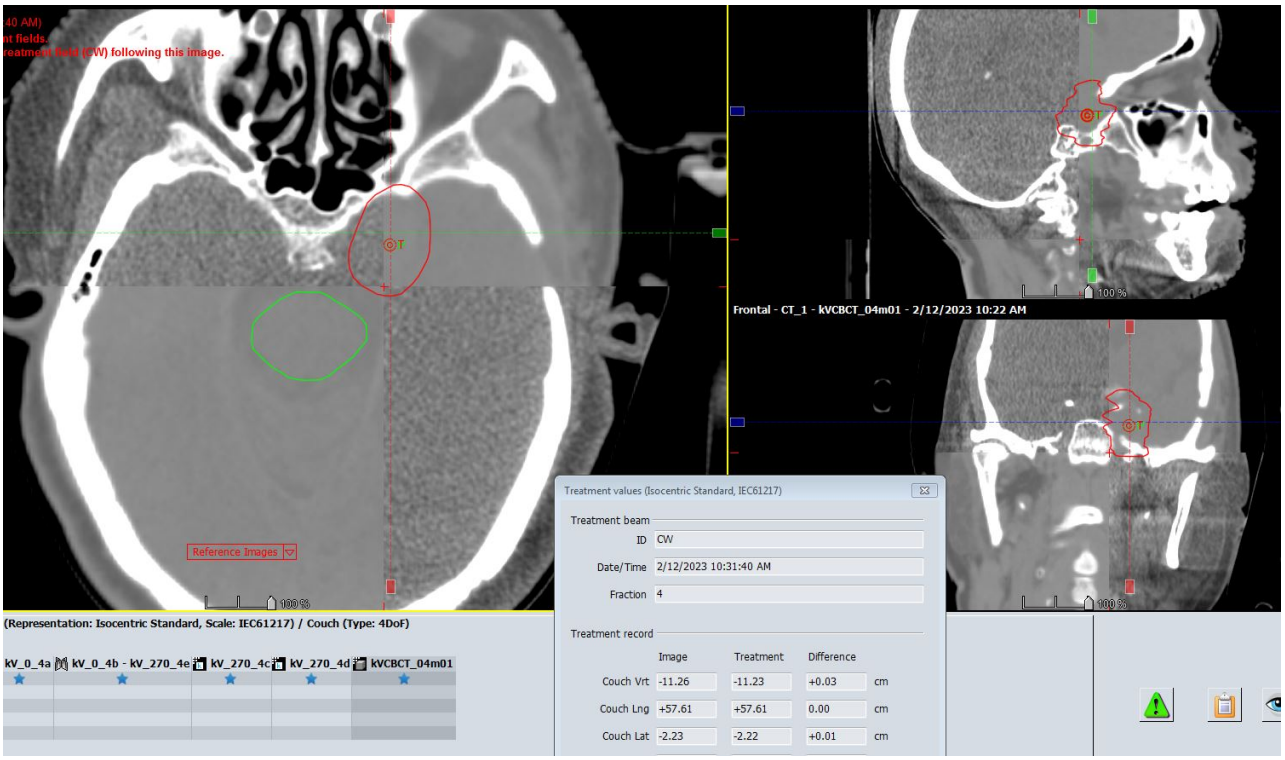


Figure 8. CBCT fused with Planned CT with submillimetre precision.

Key assessment for follow-up includes clinical examination for neurological deficit and patients progression is assessed based on questionnaire from EORTC QOL Questionnaire from BN-20, QLQ-C30 Questionnaire, and MMSE (mini-mental state examination) Questionnaire [13] [14].

Table 1. Patient characteristics and dosimetric parameters.

S. No	Patient Characteristics				Dosimetric Parameters				
	Age/Sex	Diagnosis	Volume in cc	Dose in Gy	CI (Paddick)	CI (Lomax)	CI (RTOG)	HI	Gamma Index (2 mm, 2%)
1	28/F	Breast with brainmets	20.52	15/#	0.889	0.998	1.121	1.11	99.2
2	40/M	Meningioma	15.0	24/3#	0.905	0.985	1.073	1.14	99.0
3	41/F	Meningioma	10.46	12.5/#	0.854	0.973	1.109	1.13	99.5
4	45/F	Suprasellar Meningioma	12.64	25/5#	0.924	0.996	1.076	1.11	100.0
5	37/M	Craniopharngyoma Recurrence	2.74	14/#	0.851	0.959	1.19	1.14	98.9
6	60/F	Clival Meningioma	5.17	14/#	0.939	0.980	1.024	1.14	99.3
7	38/F	Meningioma	4.28	21/3#	0.898	0.995	1.14	1.23	99.2
8	55/F	Ca Left Breast with brainmets	9.36	21/#	0.880	0.989	1.11	1.26	99.7
9	52/F	Pituitary Macro Adenoma	1.06	14/#	0.851	0.99	1.27	1.25	100.0
10	29/M	Meningioma	8.75	14/#	0.870	0.997	1.14	1.33	99.6
11	51/F	Meningioma	4.01	16/#	0.880	0.997	1.14	1.21	99.7
12	25/M	Vestibular Schwannoma	14.02	21/3#	0.935	0.984	1.036	1.21	100.0
13	30/M	AVM	10.52	18/#	0.855	0.998	1.18	1.13	99.8
14	63/M	GBM	28.67	30/5#	0.866	0.998	1.15	1.14	99.9
15	28/M	Pituitary Macro Adenoma	10.77	12	0.881	0.989	1.11	1.3	99.2
16	52/F	Trigeminal Schwannoma	0.83	12/#	0.900	0.955	1.013	1.28	99.8
17	37/M	Craniopharngyoma	8.61	21/3#	0.900	0.979	1.07	1.22	97.8
18	56/F	Trigeminal Schwannoma	1.22	12#	0.872	0.966	1.071	1.26	98.7
19	68/M	Meningioma Recurrence	4.99	12/#	0.852	0.997	1.2	1.17	99.8
20	45/F	GBM	39.99	25/5#	0.924	0.988	1.058	1.25	99.6
21	41/M	Meningioma Grade 1	1.4	14/#	0.907	0.992	1.085	1.20	99.8
22	43/F	Ca Right Breast with brainmets	14.76	18/#	0.952	0.988	1.026	1.17	99.1
23	34/M	Unknown primary with brainmets	2.62	20/#	0.945	0.978	1.017	1.10	98.9
24	50/M	Vestibular Schwannoma	3.02	12/#	0.866	0.993	1.139	1.22	99.1
25	50/F	Meningioma Recurrence	3.91	14/#	0.914	0.978	1.038	1.20	98.2
26	69/M	Meningioma	6.68	12.5/#	0.920	0.974	1.030	1.24	98.9

Utilizing MRI/MRS, the patient is radiologically examined. The maximal increase in the size of the lesion is noted up to 13 months after stereotactic radiotherapy, and pseudo-progression is a known factor seen on follow-up after SRS/SRT. Within one year of radiotherapy, patients with asymptomatic enlargement are encouraged to undergo surveillance [15]. During followup audiologic examinations are performed, and these include pure tone audiometry, speech discrimination, and Gardner-Robertson grading. A six-monthly follow-up includes a visual acuity and visual field examination as well. The pituitary hormones are also evaluated during follow-up based on the patient's symptoms and disease. The Common Terminology Criteria for Adverse Events (CTCAE) grading scale is used to evaluate and document acute toxicities such as headache, nausea, vomiting, fatigue, local alopecia, and local skin responses [15]. CTCAE grading scale is frequently used to assess late toxicities, such as headache, seizure, exhaustion, and dizziness.

3.5. Patient Statistics

Table 1 lists the patients who were seen within the first one year after the addition of this contemporary facility in our department. Over 45 patients have received treatment from us so far. From 25 to 69 years old, the patient's age ranged. The 6-MV FFF mode was used for most of the patients' treatments, delivered via Dynamic SRS VMAT modality and the radiation dose ranged from 12 Gy to 30 Gy [6]. All verification plans are passed between 97% to 100%. Most of our patients were monitored for six to nine months. Clinical results are encouraging, and most of our patients may continue living their normal lives without experiencing any major issues Table 1.

4. Conclusion

SRS now has a wider range of alternatives, thanks to technology advancements in recent years. SRS's dosimetric advantages have steadily been extended to extracranial locations. Patients with modest malignant, non-malignant, and functional intracranial anomalies may benefit from SRS. The non-coplanar flattening filter free dynamic SRS arc is an efficient and thus appealing delivery technology for delivering high dosages to the target while protecting the organs at risk. SRS-SBRT services should be delivered in a systematic manner, with roles, responsibilities, procedures, and action levels well specified. Recent improvements in radiation treatment delivery technology, as well as advanced dosimetric equipment for precision treatment, have given clinicians and medical physicists more leeway to provide treatment in a much faster and more exact manner. Purbanchal Cancer Hospital, Birtamode, Nepal established a comprehensive cancer facility with qualified workforce with the goal of providing high-quality treatment to the people of Nepal and to date, we have treated over 40 patients, with encouraging clinical outcomes. People in this country no longer need to travel abroad to receive such precise treatment because it is available right in their own backyard.

Conflicts of Interest

No conflict of interest from any authors.

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