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Letter to Editor

Safety Checklist for Gamma Knife Radiosurgery

Sir,

Stereotactic radiosurgery (SRS) is defined as the delivery of a single, high dose of ionizing radiation to a small and critically located intracranial volume through the intact skull,[1] and it was developed by a neurosurgeon Lars Leksell in the mid-20th century. The word SRS refers to irradiate an intracranial target with narrow beams of radiation from multiple directions using accurate correlation of a virtual target, seen in the patient's radiological images using a three-dimensional coordinate system. Later, Leksell created the gamma knife (GK), a using multiple focusing cobalt-60 sources frame-based stereotactic procedure, combining image guidance with high-precision convergence of multiple gamma rays, emitted by 192 sources of cobalt-60.[2] The clinical applications of GK radiosurgery (GKRS) include both benign and malignant tumors of the brain and skull base, vascular malformations, and functional and psychiatric disorders.[3] Overtime, successive GK models have been introduced such as B, C, 4C, Perfexion, and the latest being ICON. Each successive generation has been tested to decrease treatment time, combined with an increase in conformity. Compared to C/4C, the latter models have changes in radiation unit, collimator configuration, and patient positioning system (PPS). The latest model ICON allows both frame-based and thermoplastic mask-based treatment allowing single as well as hypofractionated treatment. The inbuilt cone-beam computed tomography (CT) is integrated into the patient positioning and source unit as one rigid entity, making this imaging in true Leksell coordinate space.[4]

GKRS treatment involves a multidisciplinary coordination, under the supervision of a neurosurgeon. Safety checklists ensure complete and effective communication between disciplines. They avoid preventable errors and increase safety and efficacy. This further reduces complications, as well as ambiguities in the workflow. Using a safety checklist has the major advantage of double-checking verification with further decrease of human errors, and therefore avoiding unnecessary and preventable toxicity.[3]

In one of the recently published articles by Tuleasca *et al.*,[3] they introduced their checklist in their institute in 2010 and customized it to subsequent issues as well as technical advances. The checklist is very simple and the medical physicist is in-charge for verification of particulars by reconfirming with the neurosurgeon for its completion. Only when the checklist is verified, the treatment planning is approved in the Leksell gamma plan (LGP) and is exported to the LGK console. With this article, we want to highlight some of the additions which we intend to make to their checklist so that it can be used universally.

Safety considerations in GKRS start with appropriate patient selection. The most important decision is to ascertain the radiological diagnosis before embarking the treatment in primary GKRS. A wrong diagnosis carries a high chance of failure and morbidity. Literature is flooded with reports of clinicoradiological mimickers, leading to suboptimal and infrequent disastrous outcomes. Fungal lesions could be mistaken as meningioma, cavernous sinus meningiomas may be mistaken as hemangiomas, mesenchymal chondrosarcoma can be mistaken as glomus jugulare[5] or lower cranial nerve schwannomas, pituitary adenoma can be mistaken as a meningioma, and so forth.

Before the frame fixation, the radiosurgery team should review the preoperative images and discuss optimal frame placement strategy. It is noteworthy to precheck the chances of noncooperative children, hyperhidrotic patients, and patients with difficult body figures. All efforts should be made to keep the lesion as close to the center of the frame as possible, especially for lesions at the periphery (especially needed for 4C and prior models). The possibility of collision by the frame base ring, the posts/pins assembly, or the patient's head with the collimator helmet during the treatment should also be considered.[3,6,7] At a busy center, the frame is usually assembled by the nursing staff. The most important points to remember in frame preparation are correct orientation of the base frame and the anterior pillars [Figure 1a-f]. In a few instances, we have found that the staff prepared the frame in wrong orientation (superior-inferior or anterior-posterior) and was subsequently fixed. This error was noticed when the magnetic resonance (MR) indicator frame could not be fixed on the frame G. A simple trick to remember is that the upper surface of the frame has grooves for fixing the MR indicator frame and the left anterior hole is the largest among all the holes on the upper surface [Figure 1f]. If the anterior/posterior orientation is misplaced, the fiducials will not be properly oriented [Figure 1g-j]. Similarly, the anterior pillars are always curved and long, while the posterior pillars can be short or long but always straight [Figure 1d-i]. Tightening the frame brings the pillar away from the skull; hence, a proportionate length of the pillars should be above or below the base frame to prevent outward splaying of the posts to minimize chances of collision in patients with large head such as acromegaly [Figure 2]. Even if the images are acquired, the LGP fails to define the fiducials in the wrong orientation, and the series gets discarded. Frame fixation demands special attention in patients with prior surgical defects or implantation of any intracranial foreign body such as ventriculoperitoneal shunt or electrode leads. Frame should be fixed in a manner to avoid any contact with these to minimize chances of malfunction.

Figure 1: (a-c) Correct orientation of the frame and pillars; (d) wrong placement of straight long pillar anteriorly; (e) the view of the lower part of the base frame; (f) largest whole on the left anterior corner of the upper surface of the base frame; (g-j) different possible combinations of the wrong frame preparation

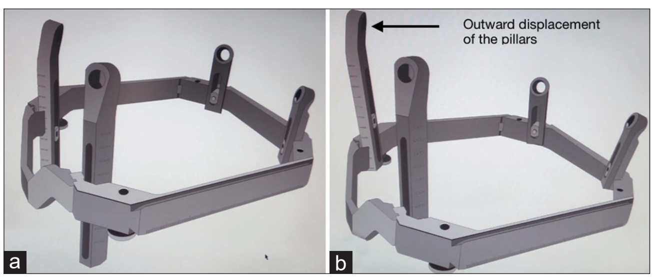

Figure 2: (a) Relatively straight orientation of the pillars when the full length of the pillars are not utilized; (b) outward displacement of the pillars after tightening of the screws utilizing the full length of the pillars increasing the chances of collision error with frame

Authors recently reported their experience with a weeping child, whose tears caused collision errors during treatment. The gamma gantry is very sensitive, and tear/sweat droplets are sufficient to cause untimely stoppage of treatment due to collision errors.[8] With the current ICON model, authors have also noticed difficult IR registration in obese female patients with large breasts as it obstructs the way to the infrared signals. In such a patient, it is advisable to use frame-based technique. Special indicator boxes with fiducial markers are attached for different imaging modalities. Thus, there are different indicator boxes for magnetic resonance imaging, computed tomography, and angiography, which should not be confused. An additional point to remember is the correct orientation of the fiducials in digital subtraction angiogram (DSA) frame. A wrong orientation of the DSA tube places the crosses outside the checks and the images cannot be defined in that situation.

We wish to point out that Perfexion and ICON models for GK, which have been used by the authors are fully automated with respect to set up of the stereotactic coordinates, set up of different sector positions, defining collimator sizes or blocked beams, and set up of exposure times. It not only increases the ease but also maintains the confidence in radiation delivery. Still, there are more than hundred centers in the world that use Leksell 4C model.[9,10] In our opinion, strict safety guidelines and checklists are more important in 4C model and the earlier models as they have multiple steps in planning and treatment that need physical verification rather than automation. The 4C model comes with trunnion mode (manual patient positioning) or automated positioning system (APS)/robotic positioning mode, or a combination of the two (mixed treatment). Once the plan is exported, we select a run with a collimator size (either 4, 8, 14, or 18 mm) after fixing the specific-sized collimator helmet. Once the dose is delivered, the helmet is removed and the next-sized collimator helmet is attached for the delivery of the rest of the treatment. Before starting the treatment, the system prompts the user to perform clearance checks first for all the planned isocenters in which the pins, posts, frame, or patient's head would be <12 mm away from the inner surface of the collimator helmet. The clearance check is performed by moving the patient to those positions under APS manual control and by visual check of collision with the collimator helmet.[8] After the clearance check, the system prompts the surgeon to carry out position checks. In the position checks, all the isocenters using the same helmet are checked, one by one, by moving the patient's head to these positions using APS manual control to make sure that the patient handles all head position changes with sufficient comfort. All personnel then leave the room, and the radiosurgical dose is delivered. Hence, in a case where four different collimators are used, we need to change the helmets four times.

Table 1: The modified checklist compared to "Lausanne checklist" the additional points are marked with asterisk

Patient identity		
	Patient's name	
	Personal identification number (as provided by the global identification system of the institution)	
	Date of birth (as per patient's hospital file)	
	Gamma knife ID	
	Treatment date	
	Confirm diagnostic radiology and localization*	
	Check consent form in file*	
Frame fixation*		
	Review the preoperative images	
	Check the chances of noncooperative children, hyperhidrotic patients, patients with difficult body figures	
	Check optimum frame fixation and keep lesion at center of frame as much as possible	
Imaging*		
	Check different indicator box for MRI, CT, and angiography	
	Check correct orientation of the fiducials in DSA frame	
Prescription		
	Number of fractions	
	Dose per fraction (Gy)	
	Stereotactic frame of thermoplastic mask	
Image registration		
	MRI for each sequence	
	CT	
Geometry and collision		
	Collisions check	
	Head contour on imaging	
	Matrix (extrafine)	
Target		
	Dose prescription	
	Prescription isodose	
	Maximum dose	
	TV, in cc	
	TV coverage (%)	
	TVpiv (volume covered by PIV, in cc)	
	Dmin TV (dose to TV, which gives 99% coverage, in Gy)	
	Dmin TV (dose to TV, which gives 100% coverage, in Gy)	
	PIV, in cc	
	PIV 50 (volume of the matrix receiving half of the prescription isodose)	
Index		
	Coverage (TVpiv/TV)	
	Conformity (PIV/TV)	
	Selectivity (TVpiv/PIV)	
	Paddick index	
	Gradient index (if >3.0, provide explanation)	
Dose to organs at risk		
	Right lens, left lens, chiasm	
	Cochlea (eventually, maximal dose and dose received by the 1 mm^3)	
	Optic pathways (eventually, maximal dose and dose received by the mm^3)	
	Brainstem (maximal dose, dose received by the 10 and 100 mm^3)	
	Integral dose to the trigeminal nerve, as defined on imaging (for trigeminal neuralgia)	
	Distance from the brainstem to the target (for trigeminal neuralgia)	
Plan		
	Number of shots	
	Number of runs	
	Irradiation time	
	Treatment time	
Dose rate		
	Clearance checks with patient on table*	
		Check mode of patient positioning (automated/trunnion/mixed)
		Perform clearance checks. Pins, posts, frame or patient's head would be <12 mm away from the inner surface of the collimator helmet
		Perform position checks in all the isocenters helmet sizes. Specially in cases which need gamma angles of 110° and 125°
		Check patients comfort in all positions

We should note that a single checklist is proposed compared to two separate ones for tumors and functional radiosurgery. MRI – Magnetic resonance imaging; CT – Computed tomography; TV – Target volume; PIV – Prescription isodose volume; DSA – Digital subtraction angiogram

Compared to PPS in newer models in which the whole couch moves to the desired stereotactic coordinates, the 4C has APS where only the head with the frame moves. It becomes very important to check patient's comfort in each coordinate, especially when with gamma angles of 110° and 125° (there is no gamma angle of 125° in the Perfexion and ICON model) before starting the treatment.[9]

Overall, we would like to add that the following points should be included in centers using 4C model of LGK along with the "Lausanne checklist for safe SRS" [Table 1]. It needs to be reiterated that these points, especially the coordinates during clearance and position checks, have to be crosschecked by both physicist and neurosurgeons.

1. Check optimum frame fixation to keep lesion at center of frame as much as possible
2. Check usage of different fiducial markers in different imaging modalities
3. Choose appropriate helmet sizes
4. Note the collisions, gamma angle, and different coordinate positions for different collimator helmets
5. Do clearance tests for pins, posts, frame, and patients head
6. Do position checks for plans with different collimator size helmets
7. Check patients comfort at clearance tests and position checks
8. Check patients comfort at different gamma angles.

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Conflicts of interest

There are no conflicts of interest.

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