Prone Positioning in the Leksell G Frame for Posterior Fossa Stereotaxy in Young Children

Sabrina V. Kirchleitner[1]

■ BACKGROUND: **Stereotactic interventions in the posterior fossa of children are rarely performed due to anatomical constraints, technical limitations, and lack of dedicated studies. Traditional stereotactic methods, including upside-down frame placement or intraoperative repositioning, present challenges such as increased procedural complexity, risk of pin dislodgement, and the need for manual coordinate calculations. This study evaluates a novel technique using prone positioning in the Leksell G frame for posterior fossa stereotactic procedures in pediatric patients. By modifying standard intraoperative workflows, this method allows for safe, precise, and cost-effective stereotactic interventions without additional hardware.**

■ METHODS: **A retrospective analysis was conducted on 6 stereotactic procedures in 3 pediatric patients (ages 19 months—8.6 years, median 2.79 years) treated using the Leksell G frame in prone position. The approach involved adjusting computed tomography scan orientation to maintain compatibility with Brainlab iPlan software.**

■ RESULTS: **By positioning the patient in the final surgical alignment before computed tomography acquisition, unnecessary repositioning was avoided, reducing risks of frame instability and pin-related complications. Additional padding for stability and rotating the head within the frame secured optimal access. All procedures were technically successful, with accurate targeting confirmed postoperative.**

■ CONCLUSIONS: **Prone positioning in the Leksell G frame, with specific technical modifications, enables safe and accurate stereotactic posterior fossa procedures in pediatric patients. This approach eliminates the need for intraoperative repositioning and ensures seamless integration with widely available stereotactic planning software. By utilizing existing tools and refining workflow, this method provides a practical, cost-effective, and reproducible solution for extending stereotactic neurosurgery to the pediatric population.**

INTRODUCTION

Stereotactic neurosurgery is rarely performed on young children and infants due to significant anatomical and technical challenges.[1-6] Posterior fossa interventions, in particular, are technically demanding[7] due to the limited operative corridor, the small size of the posterior fossa, and the increased risk of complications such as skull perforation in developing bones. Furthermore, most stereotactic systems and studies are tailored for older children[8] and adults,[9] excluding infants from their scope.[10-19] In the few studies and case series that include children for stereotactic procedures for the brainstem or posterior fossa, alternative stereotactic frames are used.[8,20,21]

The sitting position, often preferred for posterior fossa surgery in adults,[22,23] is typically unsuitable for pediatric patients due to their anatomy and the elevated risks of venous air embolism and airway compromise. Consequently, prone positioning becomes a practical alternative, provided its inherent technical challenges can be addressed. To date, literature on the use of the Leksell G frame for posterior fossa surgery in adults describes an upside-down placement of the frame, requiring manual calculation of angles and coordinates.[24] A more widely

Key words
- Leksell G-frame
- Pediatric neurosurgery
- Posterior fossa
- Prone positioning
- Stereotactic surgery

Abbreviations and Acronyms:
cMRI: Cerebral magnetic resonance imaging
CT: Computed tomography
VP: Ventriculoperitoneal

Department of Neurosurgery, LMU University Hospital, LMU Munich, Munich, Germany

To whom correspondence should be addressed: Sabrina V. Kirchleitner, M.D.
[E-mail: SabrinaViktoria.Kirchleitner@uk-gm.de]

Present address: Department of Neurosurgery, University Hospital Marburg, Philipps University Marburg, Germany

Citation: World Neurosurg. (2026) 208:124870.
http://doi.org/10.1016/j.wneu.2026.124870

Journal homepage: ***www.journals.elsevier.com/world-neurosurgery***

Available online: ***www.sciencedirect.com***

used approach involves placing the frame as low as possible on the head, performing the computed tomography (CT) scan in the supine position, and subsequently repositioning the patient for surgery.[9] Repositioning poses a risk of pin dislodgement or skull perforation due to excessive force on the pin sites. However, when avoiding repositioning after CT scanning and combining the Leksell G frame with Brainlab iPlan software, users encounter a significant obstacle: The Brainlab iPlan software cannot process CT images acquired with the patient prone in the CT localizer box, as the software requires a standard supine reference orientation. Without a workaround, this would prevent the use of standard image registration and trajectory planning.

This report describes a practical technique for performing stereotactic posterior fossa procedures in small children using prone positioning in the Leksell G frame. By incorporating frame modifications, optimized patient positioning, and a CT scan processing adjustment, this method eliminates the need for intraoperative repositioning, reducing the risk of frame instability and pin-related complications. It also ensures accurate localization and seamless integration with Brainlab iPlan software, addressing software limitations.

To assess the feasibility and safety of this approach, a retrospective review was conducted on 6 stereotactic procedures in 3 pediatric patients, focusing on technical adaptations, surgical outcomes, and complications.

PATIENT SELECTION AND CLINICAL APPLICATIONS

Inclusion Criteria

Stereotactic procedures performed on pediatric patients between September 2021 and November 2024 were retrospectively analyzed. All patients underwent stereotactic interventions using the Leksell G frame system with prone positioning, as described later. No other stereotactic frame systems were included in this study.

Before 2021, a modified Riechert-Mundinger system was the primary tool used for stereotactic procedures. However, due to updated regulations and compatibility requirements, the Leksell G frame system was adopted as a replacement. This specific prone-positioning technique was exclusively applied to pediatric patients; therefore, only this population was included in the analysis.

Patient Characteristics

The study included 3 pediatric patients (2 males, 1 female) who underwent a total of 6 stereotactic procedures for various indications (**Table 1**). The patients ranged in age from 1.6 to 8.6 years.

The first patient, a female, initially underwent an internal cyst-to-fourth-ventricle shunt for an infratentorial arachnoid cyst at 1.6 years of age, followed by a fourth ventriculoperitoneal (VP) shunt placement at 2.3 years due to a trapped fourth ventricle. At 2.6 years, she required revision surgery with a cysto-VP shunt due to infection. The shunt function remained correct postoperatively, she had a follow-up period of 16 months after the initial surgery.

The second patient, a male with a complex syndromic malformation pattern, presented with a shunt infection after an abdominal surgery at 8.4 years and underwent external ventricular drain placement for both supra- and infratentorial compartments. Two months later, after successful antifungal treatment, he received VP shunts supra- and infratentorial.

The third patient, a 3-year-old male, underwent a stereotactic biopsy for a pontine tumor. Histological analysis confirmed an embryonal tumor with multilayered rosettes.

Procedural Workflow

All procedures were performed under general anesthesia. Patients were positioned prone in the Leksell G frame. Key steps are summarized in **Figure 1** and detailed below.

Table 1. Patient Characteristics, Indications, Performed Surgeries, and Outcome

ID	Gender	Age [years]	Indication	Surgery	Number of Catheters	Cyst/ Ventricle Volume	Shunt Placement	Pin Site	Histology	Follow-Up [month]
1	Female	1.6	Infratentorial arachnoid cyst	Internal shunt (cyst — fourth ventricle)	1	Reduced	Correct	Regular	-	16
		2.3	Trapped fourth ventricle	Fourth VP shunt	1	Reduced	Correct	Regular	-	7
		2.6	Infection	Cysto-VP shunt	2	Idem	Correct	Regular	-	4
2	Male	8.4	Abdominal shunt infection	EVD placement supra- and infratentorial	2	Reduced	Correct	Regular	-	6
		8.6	Abdominal shunt infection	VP shunt	2	Idem	Secondary migration	Regular	-	5
3	Male	3.0	Pons tumor	Biopsy				Perforation	Embryonal tumors with multilayered rosettes (ETMR)	13

EVD, external ventricular drain; VP, ventriculoperitoneal.

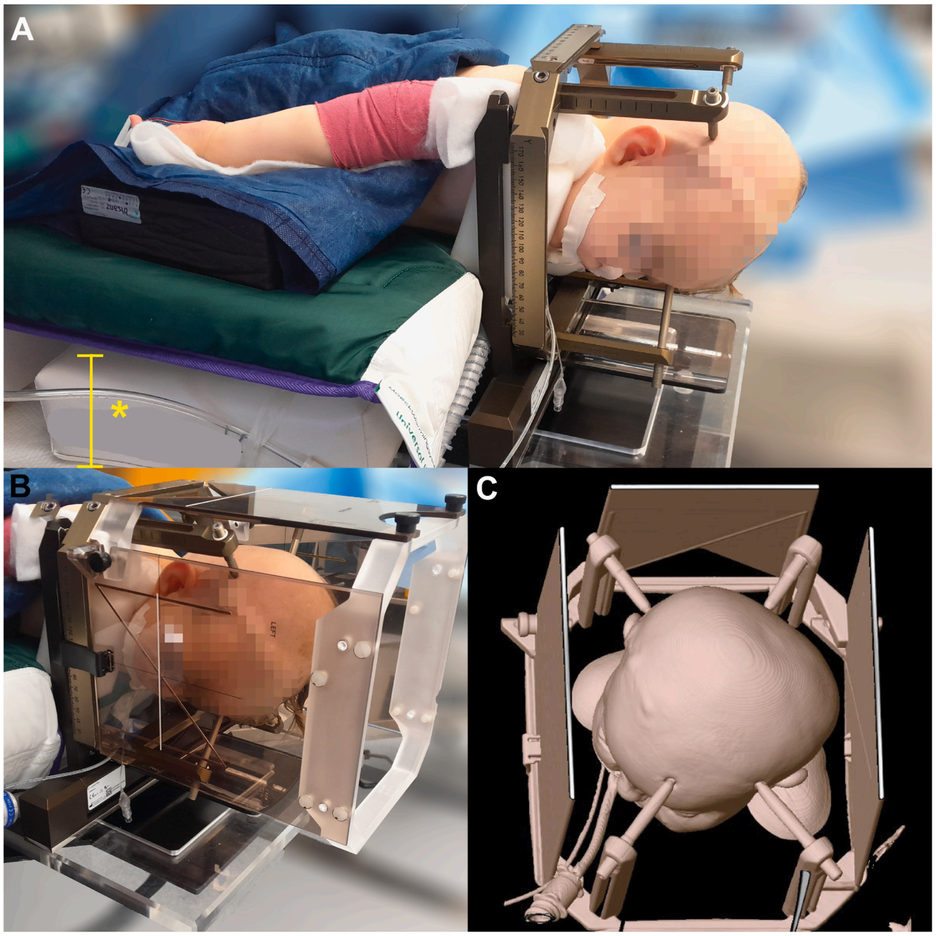

Figure 1. Intraoperative workflow: (**A**) prone positioning in the Leksell G frame with additional padding (*) used to elevate the body and head for optimal alignment. (**B**) The localizer box with N-shaped rods is mounted on the frame for intraoperative computed tomography scanning. (**C**) Three-dimensional trajectory planning in Brainlab iPlan. Notably, for airway management, the endotracheal tube can be positioned either over or under the frame, as demonstrated in (**A**) and (**C**).

Preoperative Preparation

The preoperative workup included cerebral magnetic resonance imaging (cMRI) performed on a 3.0-T scanner (Magnetom Symphony, Siemens, Erlangen). The imaging protocol consisted of axial T2-weighted sequences (2 mm slices), 3-dimensional T1-weighted sequences before and after intravenous administration of gadopentetate dimeglumine (0.1 mmol/kg body weight; Magnevist, Schering Corporation, Kenilworth, New Jersey, USA), and constructive interference in steady-state sequences (1 mm slices). Typically, the cMRI was performed one day before or at the day of the surgery, and potential trajectories were preliminarily evaluated based on this image set.

Positioning

The Leksell G frame (Elekta AB, Stockholm, Sweden) was used for all stereotactic procedures in this study. Patients were positioned prone, and frame fixation was performed under general anesthesia (Figure 1A). For better accessibility and to avoid piercing through prior craniotomy sites or foreign material (e.g., shunts) in pretreated patients, the patient's head was rotated within the frame prior to fixation (Figure 1A and Figure 2). Pin placement and tightening were performed manually to finger tightness, with pressure adjusted on a case-by-case basis by a senior stereotactic neurosurgeon.[1] No fixed pressure values were used due to pediatric skull variability. The open CT indicator with N-bar fiducials was attached to the headframe (Figure 1B).

Intraoperative CT

Intraoperative cranial CT with angiography was performed for surgical planning (Figure 1C). Because the Brainlab iPlan software (Elements Stereotaxy, Brainlab, Munich, Germany) requires the scan orientation to match a standard supine configuration, the patient's prone orientation in the frame was ignored during scan processing. Instead, the CT acquisition settings were adjusted to match the required supine orientation of the frame and localizer plates, ensuring compatibility with the software input. The orientation of the G frame and the attached localizer plates was used as the reference for alignment. This adjustment allowed the software to interpret the scan correctly and align it with the required reference rods.

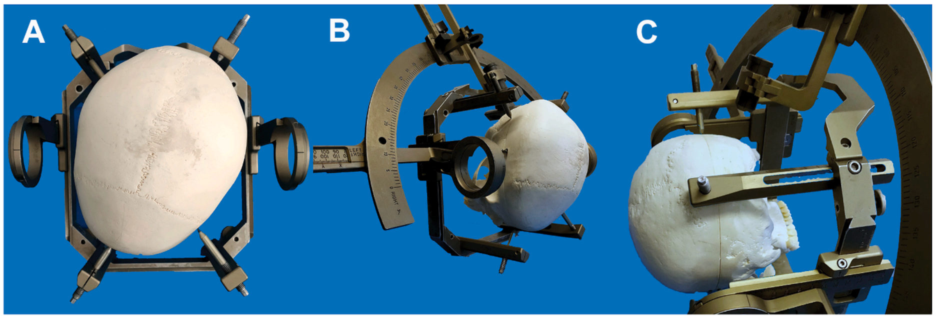

Figure 2. Head positioning in the Leksell G frame demonstrated on a skull model. (**A**) The head is secured in a prone position within the frame. A slight rotation shifts the trajectory through the right pedunculi cerebelli toward the midline, optimizing access and preventing obstruction by the fixation post. (**B**) The arc is mounted in the "lateral left" position, referencing the left side of the frame rather than the patient's anatomy. (**C**) Utilizing the nose front piece expands the operative corridor, allowing for a deeper entry point when necessary.

Trajectory Planning

The preoperative cMRI was fused with the intraoperative contrast-enhanced CT angiography images. Due to the unconventional head orientation in the prone CT image set, particular care was taken during the image fusion process. Manual adjustments were made whenever automatic fusion failed to achieve accurate alignment. Once the scans were fused, frame localization and trajectory planning proceeded as usual.

Preplanned trajectories were meticulously evaluated and adjusted to avoid vascular structures or sulcal contact. The frame setting was defined as "lateral left," with the left side of the frame, rather than the patient's head, used as the reference point (**Figure 2B, C**). Coordinates based on this configuration were then utilized for the procedure.

Surgical Technique

Biopsy or catheter placement was performed according to previously described standard protocols.[1,11,12,15,16,18,19] After sterile attachment of the stereotactic arc, a small skin incision (4–6 mm) was performed, followed by frame-guided burr hole trepanation with a diameter of 3 mm. After dural opening, a guiding tube with blunt trocar was advanced stereotactically to the predefined target. For biopsy procedures, multiple tissue samples were obtained using biopsy forceps passed through the guide tube.

For cerebrospinal fluid diversion or cyst drainage, a stereotactic catheter with pediatric burr hole reservoir was implanted according to the planned trajectory, connecting the cyst or ventricular system as indicated. Additional catheter perforations were created manually when required to optimize drainage. If no reservoir was used, the catheter was secured extracranially using a titanium hemoclip to ensure stable positioning.[1,11,12,15,16]

In cases where subcutaneous tunneling to the abdomen could not be completed safely within the same sterile field due to frame positioning, a staged approach was used. The proximal catheter was temporarily placed in a subcutaneous pocket and secured, followed by skin closure. After removal of the stereotactic frame, the patient was repositioned, reprepped, and redraped under sterile conditions. The abdominal catheter was then tunneled and connected to the proximal system, allowing completion of the shunt procedure without compromising stereotactic accuracy or sterility.

Postoperative Care

After skin closure, the pins and G frame were carefully removed, and the patient was repositioned into the regular supine position. Patients were closely monitored for immediate complications. Follow-up imaging, either cMRI or cranial CT, was performed on the first postoperative day to confirm the precise placement of catheters.

Outcome and Complications

In all 6 surgeries, an appropriate trajectory to the target region was successfully identified, and the procedures were completed as planned. The median duration of surgery including intraoperative CT scan was 2 hours and 33 minutes, ranging from 1 hour and 3 minutes to 4 hours and 35 minutes.

The biopsy provided sufficient material for a conclusive histological diagnosis. Catheter placements were successful in all cases, with postoperative MRI confirming the reduction of cysts or ventricles as intended. One catheter showed secondary migration and needed surgical repositioning.

One case revealed a pin perforation on the intraoperative CT scan (**Figure 3**). However, no pin-related complications commonly reported in other cohorts—such as skull fractures, infections, air embolisms, hematomas, or cerebrospinal fluid leaks[6,25,26] were observed in this patient group. Furthermore, no neurological deficits or bone irregularities were detected during follow-up physical examinations. Minor skin irritation at the pin fixation sites was noted in a few cases; however, these resolved spontaneously without requiring medical intervention.

DISCUSSION

Positioning Considerations and Surgical Accessibility

This study demonstrates that prone positioning in the Leksell G frame is a feasible and safe technique for stereotactic posterior fossa procedures in young children. The use of long posterior fixation posts and curved frame pieces enabled deeper frame positioning and widened the operative corridor, effectively

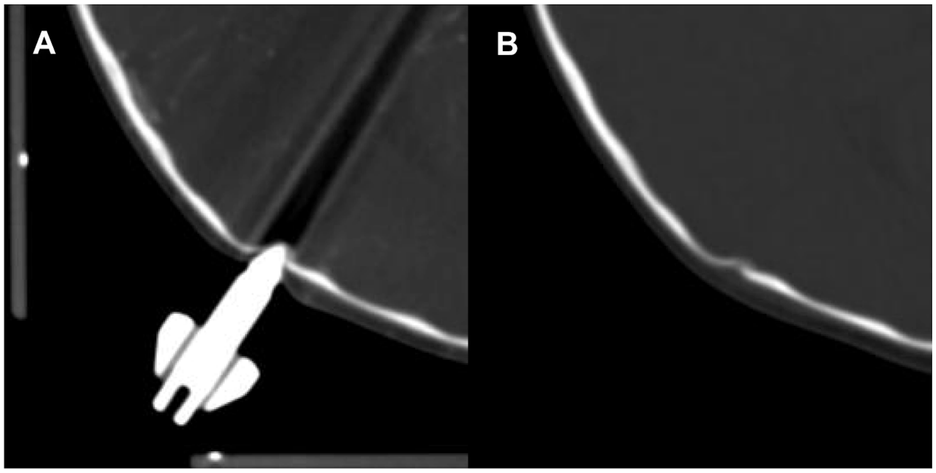

Figure 3. Pin site findings in the intraoperative cCT scan: (**A**) visible impressions on the calvaria caused by the right posterior pin in a 3-year-old male patient due to excessive pressure during fixation. (**B**) The postoperative cCT of the affected area of the former pin perforation shows no severe complications such as skull fracture, hematoma, CSF leak, or damage to the underlying brain. CSF, cerebrospinal fluid; cCT, cranial CT.

addressing the anatomical constraints inherent to the pediatric posterior fossa.

Advantages of the prone positioning method over the upside-down placement of the frame[24] include better localization and workflow accuracy. By placing the localization rods around the head and the region of interest, the surgical target is included within the CT slices used for localization. In contrast the upside-down approach positions the rods above the head, away from the pathology.[24] Additionally, the prone positioning method eliminates the need to manually calculate target coordinates,[22,24] as the Brainlab iPlan software automatically generates the coordinates, reducing the risk of human error.

Compared to both the upside-down approach and the commonly used method of placing the frame as low as possible, performing the CT scan in the supine position, and then repositioning the patient for surgery, our approach has a significant advantage: it eliminates any repositioning step that could loosen the frame pins. Such loosening risks inaccuracy or, in extreme cases, detachment of the frame from the head, necessitating reattachment and restarting the entire procedure. By positioning the patient in their final surgical orientation before the CT scan, this method maintains pin stability and ensures consistent accuracy throughout the procedure.

Lateral positioning may theoretically facilitate access to posterior fossa targets; however, in the context of frame-based stereotaxy, this position introduces significant challenges. In particular, mounting the open CT indicator with N-bar fiducials is not feasible when the frame is placed laterally, necessitating CT acquisition in the supine position followed by repositioning—thereby negating the benefits of avoiding repositioning. Shunt placement under a stereotactic frame can be technically demanding, especially during catheter tunneling beneath the frame. These challenges were mitigated by optimizing frame height, applying additional padding, and planning tunneling trajectories prior to frame fixation. In selected cases, completion of the abdominal component required temporary subcutaneous placement of the proximal catheter, followed by frame removal, patient repositioning, resterilization, and final catheter connection. This staged approach allowed safe completion of the procedure without compromising stereotactic accuracy.

Finally, removing one fixation post to improve accessibility, as previously described,[27] carries a higher risk of loosening the remaining 3 pins or causing skull perforation due to excessive force applied during fixation to compensate for the missing post. Instead, the head should be rotated within the frame prior to fixation, ensuring that the entry point is aligned closer to the center of the x-axis, thereby maintaining stability, and minimizing the risk of complications.

Pin Fixation Technique and Safety Considerations

Pin fixation in pediatric patients remains a critical concern due to thinner cranial bones.[1] In this series, pins were tightened manually to finger tightness by an experienced stereotactic neurosurgeon, with pressure adjusted individually based on skull thickness and patient age. No fixed torque values were applied, as pediatric skull compliance varies significantly and overtightening may increase the risk of perforation.[1] A modified rubber stopper technique can additionally be used to prevent the pins from plunging through the thin pediatric skull[28] but restricts visibility of the pin site. Positioning the patient in their final surgical orientation prior to CT scanning significantly reduces the need for subsequent adjustments, thereby avoiding excessive force on the fixation pins and potentially lowering the risk of skull perforation.[1,26,29]

Alternative Fixation and Navigation Methods

Several alternatives to frame-based stereotaxy have been described, each with specific advantages and limitations for posterior fossa procedures in pediatric patients, depending on the clinical context. Frameless neuronavigation systems offer the benefit of avoiding rigid head fixation and may be suitable for selected cases.[30-33] However, frameless stereotaxy generally does not achieve the same level of spatial accuracy as frame-based systems, particularly in approaches that rely on surface registration or lack rigid fixation.[30] This limitation becomes especially relevant in posterior fossa procedures, where millimeter-scale precision is critical. Frameless, pinless methods may represent a reasonable alternative when the target region is relatively large and anatomical constraints are limited[32,34]

Intraoperative ultrasound guidance using burr hole probes has also been reported as a minimally invasive option.[35] While this technique provides real-time visualization and may be advantageous in infants with an open fontanel, in older children, it typically requires larger burr holes than frame-based stereotactic approaches.[35,36] Furthermore, ultrasound guidance is less suitable for procedures demanding precise trajectory planning and high reproducibility, particularly for deep or small posterior fossa targets.[36]

In contrast, frame-based stereotaxy using the Leksell G frame enables highly accurate localization through small-caliber burr holes, minimizing surgical invasiveness while maintaining geometric precision. This level of accuracy is particularly important in posterior fossa interventions, where narrow operative corridors and proximity to critical neurovascular structures leave little margin for error. The flexibility and compatibility of the Leksell G frame with modern planning software further support its role as a reliable tool for high-precision stereotactic procedures in pediatric patients.

Software Integration and Resource Considerations

The use of intraoperative CT imaging in this workflow did not require additional hardware beyond infrastructure already available in many neurosurgical centers. By avoiding patient repositioning after imaging, this approach optimizes operating room efficiency while maintaining stereotactic accuracy. Compared with alternative navigation systems or workflows requiring supine imaging followed by repositioning, the described method represents a time and cost-effective solution that maximizes the utility of existing frame-based stereotactic equipment and planning software.

Integration of intraoperative CT imaging with Brainlab iPlan software required a technical adaptation, as scans acquired with the patient in prone position cannot be directly processed by the software using standard settings. This limitation was addressed by defining scan orientation based on the Leksell G frame head ring and CT localizer rather than the patient's anatomical orientation, allowing accurate frame localization and trajectory planning. Depending on the software version used, manual correction of scan orientation after acquisition may also be possible to achieve compatibility. Future software updates enabling localizer detection on the posterior aspect of the head, in addition to the currently supported anterior and lateral positions, would further facilitate prone positioning workflows.

Importantly, this technique is not intended to lower the threshold for performing complex posterior fossa stereotactic procedures in inexperienced settings. It is specifically designed for centers with established expertise in pediatric neurosurgery and routine stereotactic procedures in children, seeking to extend these capabilities to the posterior fossa. Institutions without sufficient experience in pediatric stereotaxy or without the necessary technical infrastructure should continue to refer such patients to specialized centers to ensure optimal safety and outcomes. Despite the small sample size, this study represents a valuable technical advancement in extending the application of stereotactic surgery to young children. It expands the possibilities for using the Leksell G frame in combination with Brainlab iPlan software, demonstrating a practical method to adapt existing tools that are already widely available. By optimizing the utility of these established systems, this report aims to provide neurosurgeons with a broader range of options and ultimately improve outcomes for young patients in need of complex neurosurgical interventions.

CONCLUSION

This study introduces a novel approach for prone positioning in the Leksell G frame, allowing for safe, accurate, and efficient stereotactic posterior fossa procedures in young children. By eliminating the need for intraoperative repositioning and overcoming software processing limitations, this method expands the feasibility of pediatric stereotactic surgery while maintaining high precision and patient safety.

Unlike alternative methods requiring manual coordinate adjustments or additional hardware, this approach leverages existing tools and refines standard workflows, making it a cost-effective and widely applicable solution. Given the success of this technique in this series, we propose that prone positioning with appropriate technical modifications be considered a viable standard for pediatric posterior fossa stereotaxy, enabling broader access to these critical neurosurgical interventions.

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this work the author used ResearchGPT was utilized for language editing. After using this tool, the author reviewed and edited the content as needed and takes full responsibility for the content of the publication.

ACKNOWLEDGMENTS

The author sincerely thanks the scrub nurses, Eldin Operta and Boris Grabovac, for their meticulous preparation and unwavering support during the procedures. Their expertise and professionalism were essential to the success of this study.

The author also extends her gratitude to the technical assistants from the Neuroradiology Department for their critical role in developing the workaround for intraoperative CT scanning, ensuring accurate imaging and seamless integration into the stereotactic workflow.

Finally, the author appreciates the operating room nursing team for their dedicated efforts in patient positioning and padding, which were crucial for both safety and surgical precision. Their contributions were invaluable to this work.

REFERENCES

1. Kirchleitner SV, Zimmermann H, Quach S, et al. Leksell G frame in pediatric neurosurgery: experiences from 73 stereotactic procedures. *J Neurosurg Pediatr*. 2025;36:601-608.

2. Kondziolka D, Adelson PD. Technique of stereotactic biopsy in a 5-month-old child. *Childs Nerv Syst*. 1996;12:615-618.

3. Ruge MI, Simon T, Suchorska B, et al. Stereotactic brachytherapy with iodine-125 seeds for the treatment of inoperable low-grade gliomas in children: long-term outcome. *J Clin Oncol*. 2011;29:4151-4159.

4. Meshkini A, Shahzadi S, Zali A, et al. Computed tomography-guided stereotactic biopsy of intracranial lesions in pediatric patients. *Childs Nerv Syst*. 2011;27:2145-2148.

5. Del Rio RJ, Gonzalez RO, Jaimovich R. Method to perform safety stereotactic procedures in children under 2 years of age. *Childs Nerv Syst*. 2018;34:555-558.

6. Furlanetti LL, Monaco BA, Cordeiro JG, Lopez WO, Trippel M. Frame-based stereotactic neurosurgery in children under the age of seven: Freiburg University's experience from 99 consecutive cases. *Clin Neurol Neurosurg*. 2015;130:42-47.

7. Godano U, Frank F, Fabrizi AP, Ricci RF. Stereotactic surgery in the management of deep intracranial lesions in infants and adolescents. *Childs Nerv Syst*. 1987;3:85-88.

8. Rajshekhar V, Moorthy RK. Status of stereotactic biopsy in children with brain stem masses: insights from a series of 106 patients. *Stereotact Funct Neurosurg*. 2010;88:360-366.

9. Parker P, Levesque MF, Bittoun J, Doyon D, Tadie M. Stereotactic transcerebellar approach to pontine lesions through the middle cerebellar peduncle. *Interv Neuroradiol*. 1999;5:19-25.

10. Thorsteinsdottir J, Vollmar C, Tonn JC, et al. Outcome after individualized stereo-electroencephalography (sEEG) implantation and navigated resection in patients with lesional and non-lesional focal epilepsy. *J Neurol*. 2019;266:910-920.

11. Schmutzer-Sondergeld M, Quach S, Niedermeyer S, et al. Risk-benefit analysis of surgical treatment strategies for cystic craniopharyngioma in children and adolescents. *Front Oncol*. 2024;14:1274705.

12. Schmutzer-Sondergeld M, Gencer A, Niedermeyer S, et al. Evaluation of surgical treatment strategies and outcome for cerebral arachnoid cysts in children and adults. *Acta Neurochir (Wien)*. 2024;166:39.

13. Rachinger W, Oehlschlaegel F, Kunz M, et al. Cystic craniopharyngiomas: microsurgical or stereotactic treatment? *Neurosurgery*. 2017;80:733-743.

14. Rachinger W, Grau S, Holtmannspotter M, et al. Serial stereotactic biopsy of brainstem lesions in adults improves diagnostic accuracy compared with MRI only. *J Neurol Neurosurg Psychiatry*. 2009;80:1134-1139.

15. Niedermeyer S, Terpolilli NA, Nerlinger P, et al. Minimally invasive third ventriculostomy with stereotactic internal shunt placement for the treatment of tumor-associated noncommunicating hydrocephalus. *Acta Neurochir (Wien)*. 2023;165:4071-4079.

16. Lenski M, Biczok A, Tonn JC, Kreth FW. Stereotactic internal shunt placement in congenital intracranial cysts. *World Neurosurg*. 2019;123:e670-e677.

17. Kunz M, Nachbichler SB, Ertl L, et al. Early treatment of complex located pediatric low-grade gliomas using iodine-125 brachytherapy alone or in combination with microsurgery. *Cancer Med*. 2016;5:442-453.

18. Katzendobler S, Do A, Weller J, et al. The value of stereotactic biopsy of primary and recurrent brain metastases in the era of precision medicine. *Front Oncol*. 2022;12:1014711.

19. Katzendobler S, Do A, Weller J, et al. Diagnostic yield and complication rate of stereotactic biopsies in precision medicine of gliomas. *Front Neurol*. 2022;13:822362.

20. Pincus DW, Richter EO, Yachnis AT, et al. Brainstem stereotactic biopsy sampling in children. *J Neurosurg*. 2006;104(2 Suppl):108-114.

21. Roujeau T, Machado G, Garnett MR, et al. Stereotactic biopsy of diffuse pontine lesions in children. *J Neurosurg*. 2007;107(1 Suppl):1-4.

22. Horisawa S, Nakano H, Kawamata T, Taira T. Novel use of the leksell gamma frame for stereotactic biopsy of posterior fossa lesions. *World Neurosurg*. 2017;107:1-5.

23. Neal JH, Van Norman AS. Transcerebellar biopsy of posterior fossa lesions using the leksell gamma model stereotactic frame. *Neurosurgery*. 1993;32:473-474. ; discussion 474-5.

24. Lee TK, Lim SH, Jeong J, et al. Leksell frame-based stereotactic biopsy for infratentorial tumor : practical tips and considerations. *J Korean Neurosurg Soc*. 2024;67:249-256.

25. Lee M, Rezai AR, Chou J. Depressed skull fractures in children secondary to skull clamp fixation devices. *Pediatr Neurosurg*. 1994;21:174-177. ; discussion 178.

26. Pang D. Air embolism associated with wounds from a pin-type head-holder. Case report. *J Neurosurg*. 1982;57:710-713.

27. Phi JH, Chung HT, Wang KC, Ryu SK, Kim SK. Transcerebellar biopsy of diffuse pontine gliomas in children: a technical note. *Childs Nerv Syst*. 2013;29:489-493.

28. LoPresti MA, Nguyen J, Lam SK. Pinning in pediatric neurosurgery: the modified rubber stopper technique. *J Neurosurg Pediatr*. 2020;26:98-103.

29. Berry C, Sandberg DI, Hoh DJ, Krieger MD, McComb JG. Use of cranial fixation pins in pediatric neurosurgery. *Neurosurgery*. 2008;62:913-918. ; discussion 918-9.

30. Girgis F, Royz E, Kennedy J, et al. Superior accuracy and precision of SEEG electrode insertion with frame-based vs. frameless stereotaxy methods. *Acta Neurochir (Wien)*. 2020;162:2527-2532.

31. Grote A, Gjorgjevski M, Carl B, et al. Frameless stereotaxy in stereoelectroencephalography using intraoperative computed tomography. *Brain Sci*. 2025;15:184.

32. Ozek E, Abdallah A, Kitis S, Hatiboglu MA. Surgical outcomes of third ventriculostomy using neuronavigation-guided new modified endoscopic approach: a series of 11 patients. *Childs Nerv Syst*. 2025;41:232.

33. Natt MA, Khizar A, Qadri HM, et al. Free-hand frameless pinless electromagnetic-navigation (AXIEM)-guided brain lesion biopsies: an institution based experience from a low-middle-income country. *Pak J Med Sci*. 2024;40(Suppl):S6-S14.

34. Reavey-Cantwell JF, Bova FJ, Pincus DW. Frameless, pinless stereotactic neurosurgery in children. *J Neurosurg*. 2006;104(6 Suppl):392-395.

35. Li QX, Li ZF, Yu YQ, Xu PK. The application of intraoperative ultrasound with burr hole probe in minimally invasive diagnosis and treatment in neurosurgery. *World Neurosurg*. 2024;188:e506-e512.

36. Strowitzki M, Moringlane JR, Steudel W. Ultrasound-based navigation during intracranial burr hole procedures: experience in a series of 100 cases. *Surg Neurol*. 2000;54:134-144.

Conflict of interest statement: The author declares that the article content was composed in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Statement of ethics: Ethics approval for this study was not required in accordance with the regulations of the ethics committee of the Ludwig-Maximilians-University Munich, which determined that formal approval was unnecessary for this retrospective technical note. Written informed consent was obtained from the legal guardian of the individual(s) for publication of the details of their medical case and any accompanying images.

Data availability statement: All data generated or analyzed during this study are included in this article and its material files. Further inquiries can be directed at the corresponding author.

Received 31 December 2025; accepted 10 February 2026

Citation: World Neurosurg. (2026) 208:124870.
http://doi.org/10.1016/j.wneu.2026.124870

Journal homepage: ***www.journals.elsevier.com/world-neurosurgery***

Available online: ***www.sciencedirect.com***