ScientificScholar®
Knowledge is power
Publisher of Scientific Journals

www.surgicalneurologyint.com

Surgical Neurology International

Editor-in-Chief: Nancy E. Epstein, MD, Clinical Professor of Neurological Surgery, School of Medicine, State U. of NY at Stony Brook.

SNI: Epilepsy

Editor
Warren Boling, MD
Loma Linda University Medical Center, Loma Linda, CA, USA

SNI
Open Access

Original Article

Complete corpus callosotomy using a frameless navigation probe through a minicraniotomy in children with medically refractory epilepsy: A case series and technical note

Ahmed Belal[1,2], Gretchen Von Allmen[3], Indira Kommuru[3], Jeremy Lankford[3], John C. Mosher[4], Manish Shah[1], Michael Funke[3], Michael Watkins[3], Rajan Patel[5]

[1]Department of Pediatric Neurosurgery, McGovern Medical School, University of Texas, Houston and Children's Memorial Hermann Hospital, [2]Department of Neurosurgery, Indiana University, [3]Department of Pediatric Neurology, McGovern Medical School at UTHouston and Children's Memorial Hermann Hospital, [4]Department of Neurology, University of Texas Health Science Center at Houston, [5]Department of Radiology, McGovern Medical School at UTHouston and Children's Memorial Hermann Hospital, Houston, Texas, United States.

E-mail: *Ahmed Mostafa Belal - ahmedbelal2009@gmail.com; Gretchen Von Allmen - gretchen.vonallmen@uth.tmc.edu; Indira Kommuru - indira.m.kommuru@uth.tmc.edu; Jeremy Lankford - jeremy.e.lankford@uth.tmc.edu; John C. Mosher - john.c.mosher@uth.tmc.edu; Manish Shah - manish.n.shah@uth.tmc.edu; Michael Funke - michael.e.funke@uth.tmc.edu; Michael Watkins - michael.w.watkins@uth.tmc.edu; Rajan Patel - rajan.p.patel@uth.tmc.edu

***Corresponding author:**
Ahmed Belal,
Department of Pediatric Neurosurgery, McGovern Medical School, University of Texas, Houston and Children's Memorial Hermann Hospital, Houston, Texas, United States.
ahmedbelal2009@gmail.com

Received : 28 November 2021
Accepted : 13 September 2022
Published : 23 December 2022

DOI:
10.25259/SNI_1188_2021

Quick Response Code:

ABSTRACT

Background: Medically refractory epilepsy constitutes up to one-third of the epilepsy pediatric patients. Corpus callosotomy (CC) has been used for the treatment of medically refractory epilepsy in children with atonic seizures and generalized tonic–clonic (GTC) seizures. In this case series study, we are describing a novel technique for CC using the frameless navigation probe through a minicraniotomy.

Methods: Thirteen pediatric patients with the diagnosis of medically refractory epilepsy predominantly GTC with drop attack who underwent extensive Phase I. An L-shape was done, then through a 4 × 3 cm craniotomy, we were able to open the interhemispheric fissure until the corpus callosum is visualized. The Stealth probe is then used to go down to the midline raphe which is followed anteriorly then traced posteriorly to the anterior border of the vein of Galen. Finally, the Stealth probe is used to confirm the completeness of the callosotomy.

Results: The procedure was accomplished successfully with no intraoperative complications; mean surgical time is 3 h:07 m. The mean follow-up was 31.5 months. All patients achieved significant seizure control. No patients experienced worsening of their atonic seizures after surgery compared with their preoperative state; however, six patients achieved Engel Class I, four patients achieved Engel Class II, and three patients achieved Engel Class III.

Conclusion: Complete CC using a frameless navigation probe is a novel and effective technique for the treatment of medically refractory epilepsy with a very good surgical and seizure outcomes, minimal neurological morbidity, minimal blood loss, and short OR time.

Keywords: Case series, Corpus callosotomy, Epilepsy, Frameless navigator probe, Navigator

INTRODUCTION

Epilepsy is a neurological disorder affecting about 0.5–1% of the population. Most cases are controlled with medication; however, up to one-third of patients continue to seize despite the best medical management or have debilitating side effects of anticonvulsant medications and

may be defined as medically refractory.[10,17,21] Surgical options for treatment include hemispherotomy, corpus callosotomy (CC), focal cortical resection of the temporal lobe, focal cortical resection of extratemporal regions of the brain, and multiple subpial resections. A successful outcome of epilepsy surgery is defined as a seizure-free state with best neurological function.[15]

Disconnective procedures such as CC and hemispherotomy are keystones in the surgical treatment of medically refractory epilepsy in children. Children who have nonlocalizing or generalized epilepsy based on seizure semiology, ictal electroencephalography (EEG), and neuroimaging findings are not candidates for resective surgery, and therefore, palliative surgical options should be explored.[18]

CC is a commonly performed procedure, Dandy operated on a congenital cyst of a cavum septum pellucidum and cavum vergae in a 4.5-year-old boy in 1931 by sectioning the corpus callosum.[3] In addition to the original aim of the surgery, he unintentionally freed his patient from a seizure disorder and set the stage for a new treatment modality for epilepsy. Later in 1939, Van Wagenen and Herren in their series of patients with glioblastoma of the corpus callosum, in whom seizures were common, they noted that as the tumors progressed, destroying the corpus callosum, the frequency of seizures decreased.[20] This procedure is based on the hypothesis that the corpus callosum is the major pathway for the interhemispheric spread of ictal discharges and its disconnection disrupts synchronization of epileptiform discharges between bilateral cerebral hemispheres. Then, they started to surgically disconnect the corpus callosum to decrease the spread of seizures from one hemisphere to the other.[15]

Children who have been reported to respond favorably to CC are those with frequent atonic seizures, also known as "drop attacks," atypical absence, generalized tonic–clonic (GTC) seizures, and tonic seizures in particular, seizures with generalized inter-ictal and ictal EEG abnormalities with multifocal spike–slow wave activity, as do patients displaying generalized seizures with rapid secondary bisynchronous EEG activity.[5]

CC has been performed using microsurgery, complete callosotomy is carried through the splenium to the arachnoid of the quadrigeminal cistern, and the vein of Galen may usually be seen through this arachnoid. Spencer *et al*. showed a 68% seizure control rate after complete callosotomy for tonic–clonic seizures and a 57% seizure control rate for tonic seizures.[18]

Image-guided frameless stereotaxy has been demonstrated to be an important adjunct in the planning and performing of the procedure. The side of the approach and size of the craniotomy may be determined on the basis of favorability of the bridging veins with respect to the extent of the callosotomy.[8,14,19] This study presents a technical innovation in using the frameless stereotaxy probe itself to divide the callosum, minimizes interhemispheric dissection while achieving a complete posterior disconnection yet minimizing potential complications.

MATERIALS AND METHODS

The committee for the Protection of Human Subjects has approved the conduction of this research study in accordance with its guidelines and with the methods agreed on by the principal investigator and approved by the committee (HSC-MS-17-0092). Consent was not required for the study.

This was a prospective case series study, single-center experience, and nonconsecutive. We present a series of 13 children diagnosed with medically refractory epilepsy who underwent extensive Phase I workup including video EEG, magnetic resonance imaging (MRI), magnetoencephalogram, and positron emission tomography scan before being considered candidates for CC. The patient's population consisted of 13 children with a mean age of 6.1 years. Seizure disorder was predominantly GTC with drop attacks.

Technique description

Preoperative MRI is coregistered to the scalp and used for frameless stereotactic navigation [Figure 1] (Stealth AXIEM, Medtronic Inc.).

Position

The patient is positioned supine on the operating table with the head positioned laterally with the right side down, to allow for gravity-assisted retraction of the frontal lobe.

Exposure

A limited hair shave is performed around the planned incision, then an L-shape incision along the midline and then to the temporal line using the Stealth to get a good window to the anterior two-thirds of the corpus callosum. Once this was done, a myocutaneous flap is reflected anterolaterally. The Stealth navigation is again confirmed to be accurate. A 4 cm anteroposterior by 3 cm lateral craniotomy is made to include the sagittal sinus. The dura is then opened in an U-shaped fashion and reflected toward the superior sagittal sinus, until the interhemispheric fissure is exposed. Care is taken to preserve all cortical veins that are at or posterior to the coronal suture. Using a surgical microscope to open the interhemispheric fissure, the arachnoid is dissected down to the pericallosal arteries [Figure 2]. Once the glistening white corpus callosum is seen, the small blunt Stealth AXIEM probe and a Penfield 4 dissector are used to go down to the midline raphe [Figure 3]. The midline is followed anteriorly

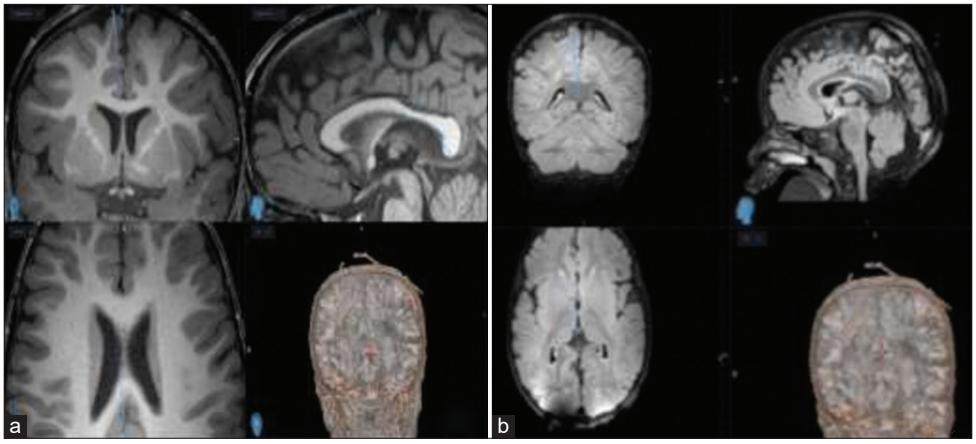

Figure 1: (a and b) Preoperative magnetic resonance imaging is coregistered to the frameless stereotactic navigation.

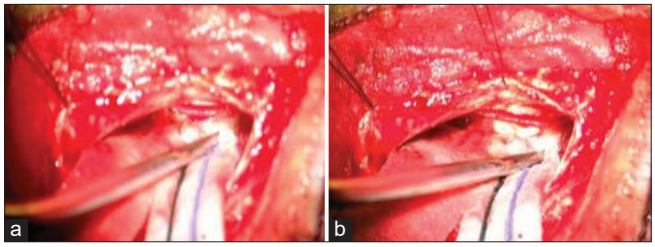

Figure 2: (a) Intraoperative exposure of the pericallosal arteries and (b) appearance of the glistening white corpus callosum.

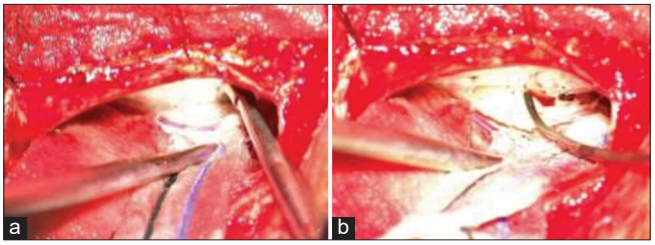

Figure 3: (a and b) Penfield 4 dissector alternatively used with the Stealth probe to go down to the midline raphe.

across the genu to the rostrum of the corpus callosum to the anterior cerebral artery (A2) and then down to the anterior communicating artery using the Stealth probe to prevent further cingulate dissection. The posterior aspect of the A2 segment is traced, the rostrum and the genu of the callosum are identified. Then, the microscope is reoriented and the Stealth dissector is carefully traced backward along the midline and traced posteriorly to the anterior border of the vein of Galen. Finally, the Stealth probe is used to confirm the posterior aspect of the callosotomy and then again traced forward and used to confirm the anterior aspect of the callosotomy [Figure 4]. After completion of the callosotomy, hemostasis is obtained. The dura is closed in a watertight fashion. The bone flap is repositioned with titanium or absorbable plates and screws. The galea is approximated; then, the skin is closed.

RESULTS

Patient characteristics and results

Between April 2016 and December 2020, 13 patients with a mean age of 6 years underwent complete CC using a frameless navigation probe at our institution [Table 1]. The operation was accomplished successfully in all patients. The average operating time of CC was 3 h and 7 min. The average estimated blood loss was 107.5 ml, only one patient required intraoperative blood transfusion as the starting hematocrit was 26%. The mean follow-up was 31.5 months. All patients were followed by the same epilepsy team at the same hospital and were assessed with respect to immediate postoperative complications, long-term complications, and seizure control. All patients achieved significant seizure control. Seizure outcome classification was based on the modified Engel classification scheme: Class I, seizure free from targeted seizure type; Class II, major reduction in targeted seizure type; Class III, worthwhile reduction in targeted seizure type; and Class IV, no worthwhile improvement. No patients experienced worsening of their atonic seizures after surgery compared with their preoperative state; however, six patients achieved Engel Class I, four patients achieved Engel Class II, and three patients achieved Engel Class III. Five patients required another surgical procedure. Of those five patients, three of them had the diagnosis of tuberous sclerosis and underwent seizure focus resection and two patients underwent vagal nerve stimulator placement, one of those two patients had the diagnosis of genetic epilepsy with a comprehensive mitochondrial DNA analysis demonstrating homoplasmic m.8308 A>G (tRNA Lys) variant, originally variant of uncertain significance. In our series, patient 12, in whom a watertight closure was difficult

due to small size and challenging hemostasis from long-term lacosamide administration, developed a pseudomeningocele and subsequent CSF leak. This was managed conservatively without any subsequent events [Figure 5]. Another patient developed postoperative pneumonia who recovered after a course of antibiotics.

DISCUSSION

This study presents our initial experience of 13 patients with completion of CC using the navigator probe through a minicraniotomy in children with medically refractory epilepsy. Overall, completion of CC was performed with a reasonable safety profile and minimal complications. We had one patient developed that pseudomeningocele was managed conservatively with aspiration of the fluid collection followed by head wrapping and prophylactic antibiotics. Another baseline disabled patient developed pneumonia during the hospital admission who recovered after a course of antibiotics. CC is traditionally offered as a palliative therapy for drug-resistant epilepsy aiming to prevent epileptic discharges from spreading between hemispheres and thereby preventing generalization of seizures, particularly drop attacks. Our institution has also found it helpful to lateralize epilepsy for further potentially curative surgery.

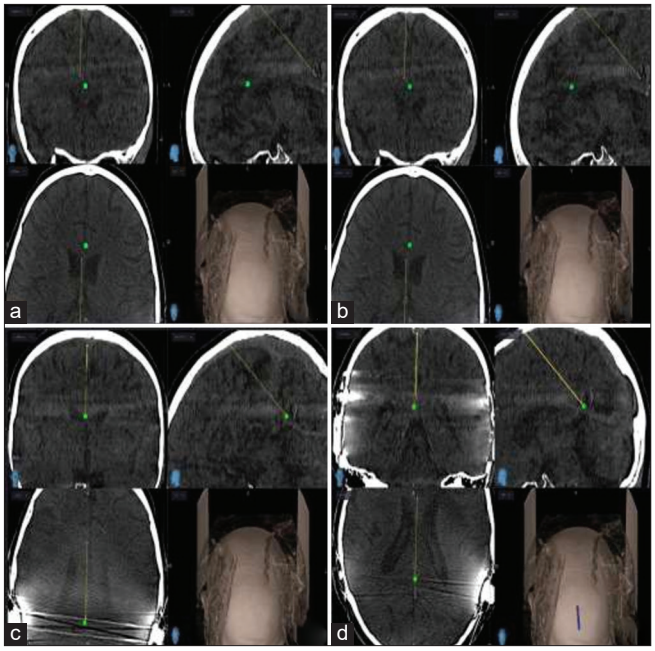

Figure 4: Green dots represent the actual intraoperative Stealth probe position. (a) Stealth probe after identification of the corpus callosum at the midline and (b-d) Stealth probe after completion of corpus callosotomy showing anterior and posterior extension of the callosotomy.

Our technical innovation involves using the electromagnetic navigation probe, in which registration accuracy is confirmed again after dissecting down to the midline raphe, allows for a very limited interhemispheric window. Careful study of the venous anatomy helps in meticulous planning of the skin incision, bone flap, and dural opening using the navigation probe to trace the bridging veins, hence minimizing the risk of venous injury and venous infarction. Complications associated with a large open craniotomy and vessel dissection include meningitis, venous or arterial infarctions, subgaleal fluid collection, and hydrocephalus. Hemiparesis and speech delay have also been reported after callosotomy with microsurgical dissection. The reported technique may potentially decrease the risk of large open craniotomy complications.[1,7]

Hemispheric edema and supplemental motor area syndromes are avoided by minimizing brain retraction using a minicraniotomy and minimal interhemispheric dissection using the navigation probe to perform the callosotomy using the navigation system. As only a small amount of the midline callosum needs exposure to find the raphe and confirm the Stealth accuracy, using the AXIEM probe critically avoids dissection injury to the bilateral, often adherent cingulate

Table 1: Demographics, operative data and seizure outcome in 13 patients following corpus callosotomy.

Pt. no	Age at time of surgery (years)	EBL (ml)	Operative time (H: M)	Post-op ENGEL	Pathology	Additional surgery	Follow up (months)	Complications
1	15	200	4:20	II	TS	Yes resection	54	Pneumonia
2	5	75	3:15	I		Yes VNS	47	None
3	2	100	3:16	III	TS	Yes resection	42	None
4	5	75	2:50	I		No	38	None
5	5	200	2:58	II		No	33	None
6	2	50	2:53	II		No	32	None
7	13	150	3:02	I		No	31	None
8	3	75	3:52	II		No	28	None
9	9	100	3:10	III	TS	Yes resection	25	None
10	2	100	2:25	I		No	12	None
11	10	75	2:18	I		No	12	None
12	3	100	3:05	I		No	4	Pseudomeningocele, CSF leak
13	5	100	2:50	III		Yes VNS	3	None

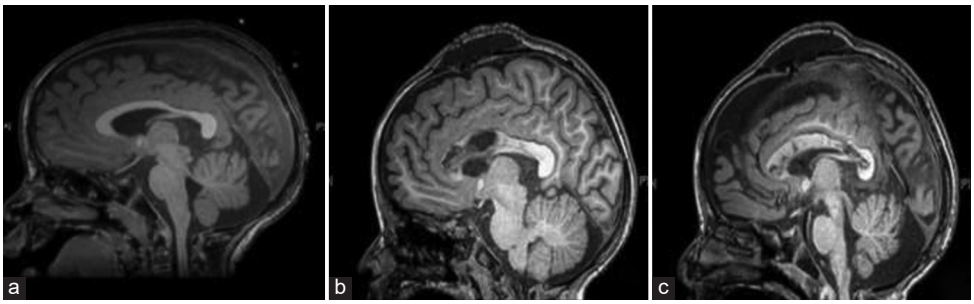

Figure 5: Sagittal magnetic resonance imaging (MRI) sequences (a) precallosotomy T1-weighted MRI and (b and c) postcallosotomy T1-weighted MRI showing the extent of corpus callosotomy from the genu to the splenium. Note the pseudomeningocele in one patient that resolved with conservative management.

gyri anteriorly and posteriorly in the setting of antiepileptic medications that induce platelet dysfunction, such as valproate and lacosamide. This was especially true for cases 1, 3, and 9 in whom substantial bilateral tuber burden made dissection challenging with nonexistent brain relaxation.

Maintaining the callosotomy to the midline raphe can be easily achieved under navigation, so avoiding lateral deviation and injury to the fornix or corona radiata thus avoiding possible memory disturbance or weakness, respectively. Avoiding violation of the ependyma and accidental entry into the ventricles is a great advantage of using the navigator probe, thus avoiding CSF leak, intraventricular bleed, or hydrocephalus.

Using an endoscope for CC has been described by many surgeons. The main disadvantage is that the ability to dissect is limited by the movement of the instrument only in the axial direction. Furthermore, bleeding may be difficult to control due to limitation of the endoscopic cautery instruments.[16]

MR-guided laser interstitial thermal therapy (LITT) is a treatment option that was first described by Curry *et al*. for medically refractory epilepsy in 2012.[2] The cost of the technology (laser fibers), the OR time, and the imaging studies should be considered. In a study conducted by Palma *et al*., the OR time average was 5 h and 10 min for LITT versus 3 h and 7 min for our technique due to the transport time and image acquisition time.[11] Our technique also avoids that other risks associated with LITT include catheter malposition, intracerebral hemorrhage, neurological impairment related to thermal injury, and equipment failure.[13]

Stereotactic radiosurgery (SRS) for CC was first reported in 1999.[12] Radiosurgery induces radionecrosis of the corpus callosum. Compared to SRS, our technique avoids the long-term postradiation complications such as radiation necrosis and brain edema which may lead to symptoms and signs of increased intracranial pressure or motor weakness. Radiosurgery-induced malignancy, especially in the pediatric population, is another concern of SRS which is avoided in our technique. However, it has been shown to be a rare event in the literature.[6] Given the late appearance of radiologic changes, it is advisable to wait at least 2 years to evaluate the radiologic and clinical results after SRS,[12] while our technique has immediate clinical and radiological results.

The efficacy of our technique is comparable to that demonstrated in other published series of completion CC. In an earlier study by Fuiks *et al*., open completion surgeries resulted in improvement in five out of 10 patients, with response to the initial partial CC being predictive of outcome following completion.[4] Jalilian *et al*. reported outcomes of seven patients who underwent completion surgeries (six microsurgical dissection and one SRS) where three patients achieved Engel Classes I-II, one patient achieved Engel Class III, and three patients achieved Engel Class IV.[7,9]

CONCLUSION

Complete CC using a frameless navigation probe through a minicraniotomy in children with medically refractory epilepsy is an alternative option to open, endoscopic, stereotactic laser, and stereotactic radio surgery for disconnection of the corpus callosum for the treatment of drop attacks in patients with epilepsy. In this study, we report good surgical outcomes (seizure outcome Classes I-III) in 100% of patients with minimal neurological morbidity, minimal blood loss, and short OR time. Future work should include more patients to better evaluate the efficacy of this novel technique.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Bower RS, Wirrell E, Nwojo M, Wetjen NM, Marsh WR, Meyer FB. Seizure outcomes after corpus callosotomy for drop attacks. Neurosurgery 2013;73:993-1000.
2. Curry DJ, Gowda A, McNichols RJ, Wilfong AA. MR-guided stereotactic laser ablation of epileptogenic foci in children. Epilepsy Behav 2012;24:408-14.
3. Dandy WE. Congenital cerebral cysts of the cavum septi pellucidi (fifth ventricle) and cavum vergae (sixth ventricle): Diagnosis and treatment. Arch Neurol Psychiatry 1931;25:44-66.
4. Fuiks KS, Wyler AR, Hermann BP, Somes G. Seizure outcome from anterior and complete corpus callosotomy. J Neurosurg 1991;74:573-8.
5. Graham D, Tisdall MM, Gill D. Corpus callosotomy outcomes in pediatric patients: A systematic review. Epilepsia 2016;57:1053-68.
6. Hong J, Desai A, Thadani VM, Roberts DW. Efficacy and safety of corpus callosotomy after vagal nerve stimulation in patients with drug-resistant epilepsy. J Neurosurg 2017;128:277-86.
7. Jalilian L, Limbrick DD, Steger-May K, Johnston J, Powers AK, Smyth MD. Complete versus anterior two-thirds corpus callosotomy in children: Analysis of outcome. J Neurosurg 2010;6:257-66.
8. Jea A, Vachhrajani S, Johnson KK, Rutka JT. Corpus callosotomy in children with intractable epilepsy using frameless stereotactic neuronavigation: 12-year experience at the Hospital for Sick Children in Toronto. Neurosurg Focus 2008;25:E7.
9. Kasasbeh AS, Smyth MD, Steger-May K, Jalilian L, Bertrand M, Limbrick DD. Outcomes after anterior or complete corpus callosotomy in children. Neurosurgery 2014;74:17-28.
10. Kwan P, Brodie MJ. Early identification of refractory epilepsy. N Engl J Med 2000;342:314-9.
11. Palma AE, Wicks RT, Popli G, Couture DE. Corpus callosotomy via laser interstitial thermal therapy: A case series. J Neurosurg 2018;23:303-7.
12. Pendl G, Eder HG, Schroettner O, Leber KA. Corpus callosotomy with radiosurgery. Neurosurgery 1999;45:303-7; discussion 307-8.
13. Pruitt R, Gamble A, Black K, Schulder M, Mehta AD. Complication avoidance in laser interstitial thermal therapy: Lessons learned. J Neurosurg 2017;126:1238-45.
14. Rich CW, Fasano RE, Isbaine F, Saindane AM, Qiu D, Curry DJ, *et al*. MRI-guided stereotactic laser corpus callosotomy for epilepsy: Distinct methods and outcomes. J Neurosurg 2022;135:770-82.
15. Roessler K, Hofmann A, Sommer B, Grummich P, Coras R, Kasper BS, *et al*. Resective surgery for medically refractory epilepsy using intraoperative MRI and functional neuronavigation: The Erlangen experience of 415 patients. Neurosurg Focus 2016;40:E15.
16. Sood S, Marupudi NI, Asano E, Haridas A, Ham SD. Endoscopic corpus callosotomy and hemispherotomy. J Neurosurg 2015;16:681-6.
17. Spencer S, Huh L. Outcomes of epilepsy surgery in adults and children. Lancet Neurol 2008;7:525-37.
18. Spencer SS, Spencer DD, Sass K, Westerveld M, Katz A, Mattson R. Anterior, total, and two-stage corpus callosum section: Differential and incremental seizure responses. Epilepsia 1993;34:561-7.
19. Valencia Calderón C, Cevallos AC, Valdiviezo AC, Dávila RE, Rosales FP, Alcocer JQ, *et al*. Neuronavigation in the surgical planning of callosotomy. Neurocirugia (Astur) 2016;27:186-93.
20. Van Wagenen WP, Herren RY. Surgical division of commissural pathways in the corpus callosum: Relation to spread of an epileptic attack. Arch Neurol Psychiatry 1940;44:740-59.
21. Wiebe S, Blume WT, Girvin JP, Eliasziw M. A randomized, controlled trial of surgery for temporal-lobe epilepsy. N Engl J Med 2001;345:311-8.

How to cite this article: Belal A, Von Allmen G, Kommuru I, Lankford J, Mosher JC, Shah M. Complete corpus callosotomy using a frameless navigation probe through a minicraniotomy in children with medically refractory epilepsy: A case series and technical note. Surg Neurol Int 2022;13:585.