Clinical case / Клинический случай
https://doi.org/10.47093/2218-7332.2022.13.2.12-19

Optimization of intraoperative ultrasound navigation during focal cortical dysplasia surgery: a case report

Keith Simfukwe[1], Albert A. Sufianov[1,2,3,✉]
[1]Sechenov First Moscow State Medical University (Sechenov University)
8/2, Trubetskaya str., Moscow, 119991, Russia
[2]Federal Centre of Neurosurgery, Tyumen
5, 4th km of Chervishevsky tract, Tyumen, 625032, Russia
[3]Peoples' Friendship University of Russia (RUDN University)
6, Miklukho-Maklay str., Moscow, 117198, Russia

Abstract

Intraoperative ultrasound (IUS) is known to be an effective method for neuronavigation during surgical treatment of intractable seizures caused by focal cortical dysplasia (FCD). However, the 2-dimensional (2D) IUS has poor image quality and low spatial resolution. We describe via a case report how Ultrasound integrated Brainlab (BL) – Navigation software was used to optimize 2D IUS and thereby reduce these challenges.

Case report: We present a case report of a 22-year-old female patient with a long-standing history of seizures. The patient was treated with more than two anti-epileptic drugs without any clinical efficacy. In 2022 she was diagnosed with temporal lobe FCD. We performed a temporal lobe lesionectomy using optimized IUS BL-Navigation that provided enhanced 3-dimensional (3D) images.

Discussion: The extent of resection of the underlying FCD lesion is a key factor in determining whether a patient achieves meaningful seizure freedom after surgery. While the 2D IUS offers admirable characteristics that have been used as an aid during surgery, it is our view that IUS enhanced 3D BL-Navigation offers better appreciation of FCD lesions and therefore improves the extent of resection.

Keywords: drug-resistant epilepsy; neuronavigation; 2D ultrasound navigation; 3D ultrasound navigation; microsurgical technology

MeSH terms:
EPILEPSIES, PARTIAL – DIAGNOSTIC IMAGING
EPILEPSIES, PARTIAL – SURGERY
INTRAOPERATIVE NEUROPHYSIOLOGICAL MONITORING
ULTRASONOGRAPHY

For citation: Simfukwe K., Sufianov A.A. Optimization of intraoperative ultrasound navigation during focal cortical dysplasia surgery: a case report. Sechenov Medical Journal. 2022; 13(2): 12–19. https://doi.org/10.47093/2218-7332.2022.13.2.12-19

CONTACT INFORMATION:
Albert A. Sufianov, Dr. of Sci. (Medicine), Professor, Corresponding Member of RAS, Head of Federal Centre of Neurosurgery; Head of the Department of Neurosurgery, Sechenov First Moscow State Medical University (Sechenov University); Professor, Peoples' Friendship University of Russia (RUDN University).
Address: 5, 4th km of Chervishevsky tract, Tyumen, 625032, Russia
Tel.: +7 (909) 190-24-65
E-mail: sufianov@gmail.com

Conflict of interests. The authors declare that there is no conflict of interests.
Financial support. The study was not sponsored (own resources).

Received: 15.08.2022
Accepted: 14.09.2022
Date of publication: 23.09.2022

УДК 616.853-089.166-07:615.073.431

Оптимизация интраоперационной ультразвуковой навигации при оперативном лечении очаговой кортикальной дисплазии: клинический случай

К. Симфукве[1], А.А. Суфианов[1,2,3,✉]

[1]ФГАОУ ВО «Первый Московский государственный медицинский университет им. И.М. Сеченова» Минздрава России (Сеченовский Университет)
ул. Трубецкая, д. 8, стр. 2, г. Москва, 119991, Россия
[2]ФГБУ «Федеральный центр нейрохирургии» Минздрава России
4-й км Червишевского тракта, д. 5, Тюмень, 625032, Россия
[3]ФГАОУ ВО «Российский университет дружбы народов»
ул. Миклухо-Маклая, д. 6, г. Москва, 117198, Россия

Аннотация

Интраоперационное ультразвуковое исследование является эффективным методом нейронавигации при хирургическом лечении резистентных к терапии судорог у пациентов с фокальной кортикальной дисплазией (ФКД). Однако двумерное УЗИ имеет низкое качество изображения и пространственное разрешение. Представлен клинический случай оперативного лечения ФКД с применением программного обеспечения Brainlab (BL)-Navigation, интегрированного с ультразвуком.

Описание случая. Представлен клинический случай 22-летней пациентки с длительным анамнезом судорог. Лечение более чем двумя противоэпилептическими препаратами было неэффективным. В 2022 году установлен диагноз ФКД височной доли. Мы выполнили удаление пораженного участка височной доли с использованием оптимизированного УЗИ с BL, позволяющего получить улучшенные трехмерные (3D) изображения.

Обсуждение. Объем резекции при оперативном лечении ФКД – ключевой фактор эффективности лечения приступов эпилепсии. Несмотря на то что двумерное УЗИ широко используется в практике и обладает приемлемыми характеристиками, на наш взгляд, УЗИ с BL позволяет лучше оценить объем ФКД и, следовательно, точнее определить объем резекции.

Ключевые слова: фармакорезистентная эпилепсия; нейронавигация; 2D ультразвуковая навигация; 3D ультразвуковая навигация; микрохирургическая технология

Рубрики MeSH:
ЭПИЛЕПСИИ ФОКАЛЬНЫЕ – ДИАГНОСТИЧЕСКОЕ ИЗОБРАЖЕНИЕ
ЭПИЛЕПСИИ ФОКАЛЬНЫЕ – ХИРУРГИЯ
ИНТРАОПЕРАЦИОННЫЙ НЕЙРОФИЗИОЛОГИЧЕСКИЙ МОНИТОРИНГ
УЛЬТРАСОНОГРАФИЯ

Для цитирования: Симфукве К., Суфианов А.А. Оптимизация интраоперационной ультразвуковой навигации при оперативном лечении очаговой кортикальной дисплазии: клинический случай. Сеченовский вестник. 2022; 13(2): 12–19. https://doi.org/10.47093/2218-7332.2022.13.2.12-19

КОНТАКТНАЯ ИНФОРМАЦИЯ:
Суфианов Альберт Акрамович, д-р мед. наук, профессор, член-корреспондент РАН, главный врач ФГБУ «Федеральный центр нейрохирургии» Минздрава России; зав. кафедрой нейрохирургии ФГАОУ ВО «Первый МГМУ им. И.М. Сеченова» Минздрава России (Сеченовский Университет); профессор ФГАОУ ВО «Российский университет дружбы народов».
Адрес: 4-й км Червишевского тракта, д. 5, Тюмень, 625032, Россия
Тел.: +7 (909) 190-24-65
E-mail: sufianov@gmail.com

Конфликт интересов. Авторы заявляют об отсутствии конфликта интересов.
Финансирование. Исследование не имело спонсорской поддержки (собственные ресурсы).

Поступила: 15.08.2021
Принята: 14.09.2021
Дата печати: 23.09.2022

List of abbreviations
FCD – focal cortical dysplasia
IUS – intraoperative ultrasound
BL – Brainlab
MRI – magnetic resonance imaging
EEG – electroencephalogram

Focal cortical dysplasia (FCD) is a common cause of seizures in adults and is known to be the main cause of focal intractable epilepsy in children, accounting for up to 50% of cases in paediatric epilepsy surgery. Attaining adequate seizure control with consequent chance for normal cognitive development are the goals of surgical intervention in the management of refractory epilepsy with underlying histological evidence of cortical dysplasia [1–3]. However, one the necessities required during the surgical resection of the offending lesion is the ability to distinguish clearly between the atypical tissue and normal brain. These tissues are hardly differentiated from one another. Intraoperative neuronavigation is therefore essential not only to discriminate between abnormal and normal tissue but also ascertain lesion dimensions and identify vital neurovascular structures.

Intraoperative ultrasound (IUS) is an imaging modality that has been purported to efficiently circumvent these challenges. The ability to acquire real-time images at any stage of the procedure while counteracting the element of brain shift are palpable benefits of using IUS [4–8]. It is also quicker to perform than other imaging navigation modalities. Institutions are also spared from huge budgetary constraints as it is considerably economically cost effective [9, 10].

Despite the overwhelming advantages of using IUS, it is not without flaws. The two-dimensional (2D) IUS systems have poor image quality, lack of spatial resolution and dynamic range. Additionally, due to the steep learning curve, many neurosurgeons are usually unable to confidently read 2D IUS views. IUS artifacts at the bottom of the resection cavity make it difficult in visualizing lesion bounders which in turn results in insufficient visualization of lesion residue.

Here-in, we discuss the technical nuances via a case of intractable epilepsy secondary to FCD type II of enhancing 2D IUS navigation by integrating (co-registering) it with pre-operative magnetic resonance imaging (MRI) in Brainlab (BL) navigation (Brainlab Digital O.R. Brainlab AG, Germany) to archive 3D IUS views. BL a form of frameless stereotactic surgery provides intraoperative guidance in real-time. This greatly improves precision needed to archive safe but adequate resection of intra axial lesions.

CASE REPORT

A 22-year-old female presented early 2022 to our institution (Federal Centre of Neurosurgery, Tyumen, Russia) with a long-standing history of bilateral tonic-clonic focal onset epileptic seizures twice a week. Over the course of her condition, she was placed on more than two anti-epileptic drugs: Lamotrigine (200 mg BD PO), Carbamazepine (400 mg BD PO) Topiramate (100 mg BD PO), Levetiracetam (750 mg BD PO), Oxcarbazepine (600 mg BD PO) without meaningful seizure relief. Her neonatal, developmental, past medical, and surgical histories were unremarkable.

The patient underwent a full range of pre-surgical examination by a team of epilepsy specialists: neurosurgeons, neuro-epileptologists, neuropsychiatrists, neurologists, speech therapists and neuro-radiologists according to current clinical guidelines.

Preoperative evaluation

Electroencephalogram

Long-term video electroencephalogram (EEG) monitoring (8 days) using 64 scalp electrodes (10-10) was used to record epileptiform activity. Epileptiform activity during the interictal phase, were detected in the form of periodic single and grouped series of spike-wave discharges localized in the right posterior temporal region emanating from leads T6 and TP8. During the ictal phase (left sided head tilt, a deviation of the mouth to the left, with subsequent generalized tonic-clonic convulsions) the epileptiform activity emanated from TP8 origin. Ultimately, the right posterior temporal area TP8 was identified as the seizure onset zone (I.1).

Magnetic resonance imaging

Pre-operative 1.5Tesla MRI (Epilepsy Protocol) was used. On FLAIR, an intra-axial lesion (2.9 ×1.9 cm) was depicted in the posterior sections of the right temporal lobe, on the border of the middle and inferior temporal gyri, typical of cortical dysplasia (characteristic thickening of the cortex, blurring of the contours of the gray-white mater junction, as well as with the presence of a typical trans mantle dysplasia. These findings provided correlation between the lesion defined in the MRI examination, seizure semiology and EEG monitorization to demonstrate the association between the epileptic focus and the lesion.

Diagnosis

The diagnosis was made by a panel of neurosurgeons, neuroepileptologists, neuropsychiatrists, neurologists, speech therapists, and neuroradiologists: Structural focal epilepsy. Bilateral tonic-clonic focal onset epileptic seizures. Drug-resistant form. FCD of the right frontal lobe (ICD-10 G40.2).

The decision was made to perform right temporal lobe lesionectomy using optimized IUS with BL as neuronavigaton.

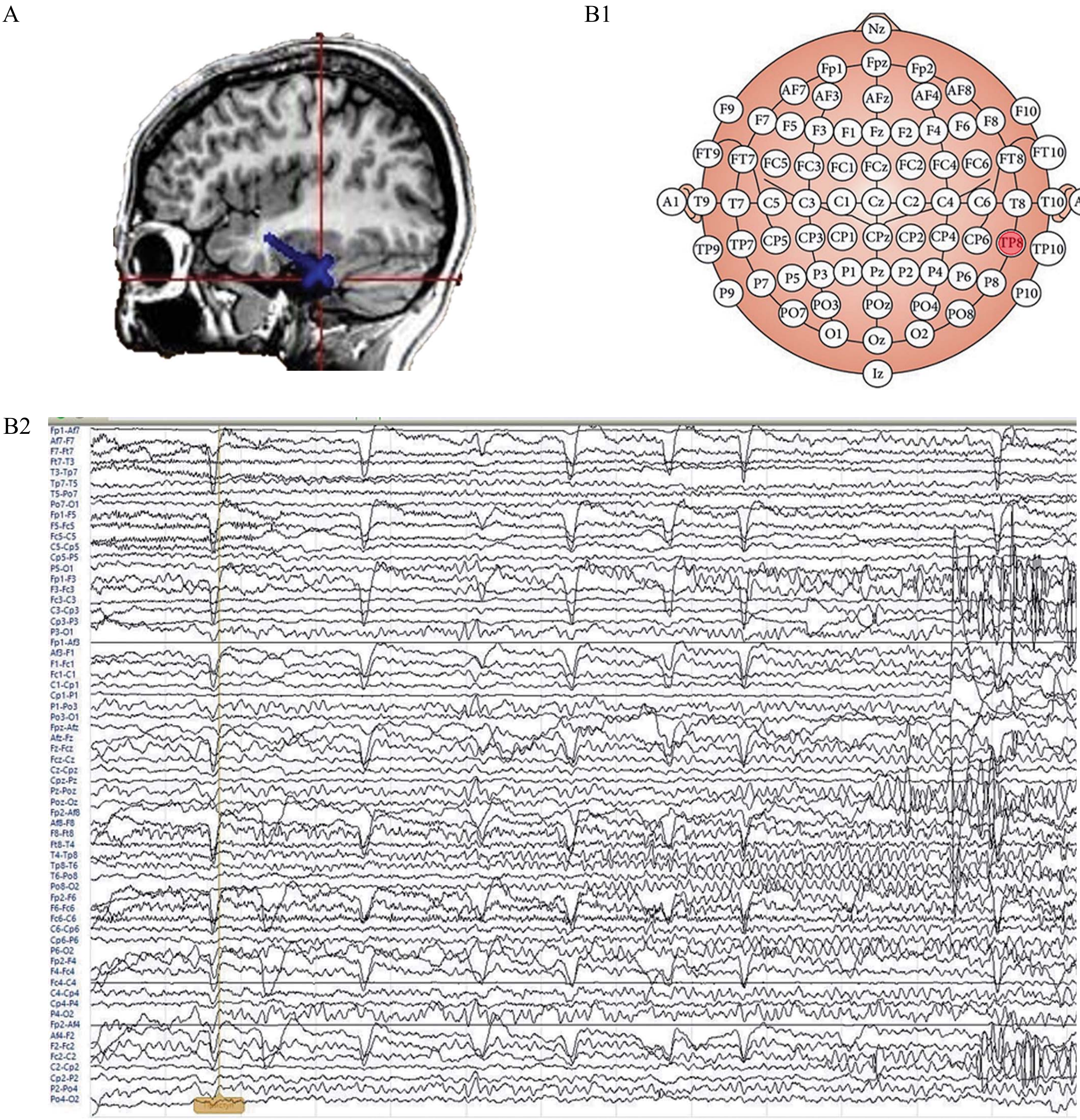

FIG. 1. Location of the epileptogenic zone on the electroencephalogram. A – location of the epileptogenic zone in the right temporal lobe (the blue arrow). B1, B2 – the zone during the ictal period was represented on the electroencephalogram by periodic single and grouped spike-wave discharges, localized in the right posterior temporal region – in lead TP8.

РИС. 1. Локализация эпилептогенной зоны на электроэнцефалограмме. А – локализация эпилептогенной зоны в правой височной области (синяя стрелка). B1, B2 – зона иктального периода на электроэнцефалограмме, представленная периодическими одиночными и сгруппированными в серии разрядами спайк-волн, локализованых в правой задней височной области в отведении TP8.

Integrated 2D intraoperative ultrasound with Brainlab

We used Two-dimensional (2D) FlexFocus 800 IUS (BK Medical, Denmark) as frameless neuronavigation (Figure 2C). A craniotomy localizer (Craniotomy 8862) was attached to a Linear-type convex transducer IUS probe (29×10 mm, 3.8–10 MHz). The localizer was used to affix the ultrasonic transducers in a pre-set location (Figure 2E). The patient's MRI (Epilepsy protocol) was then uploaded onto the BL navigation system Thereafter, the IUS was connected to the BL station and images were merged using the ultrasound BL program. Live 2D ultrasound images were then overlaid on preoperative MRI patient data to enable for precise correlation of

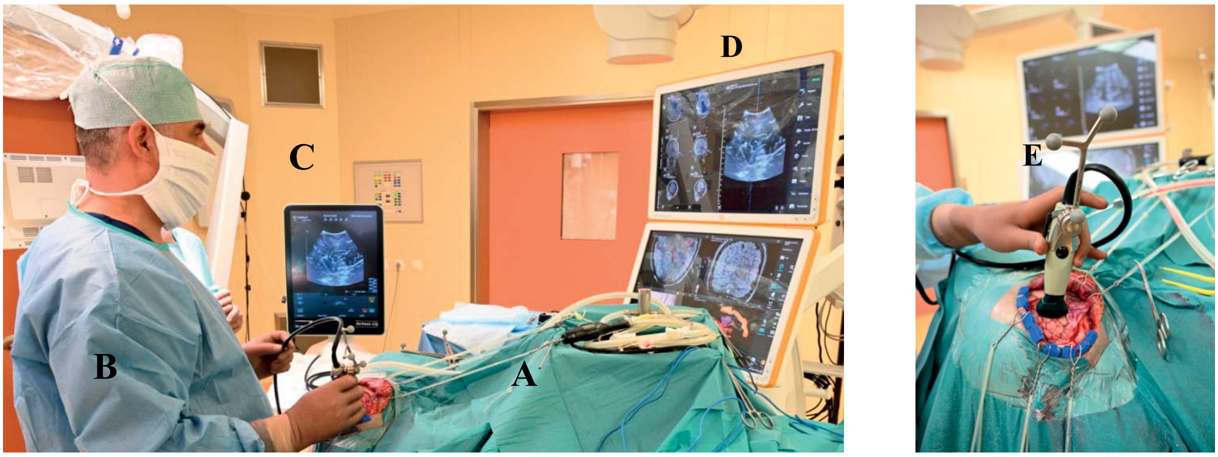

FIG. 2. Intraoperative set up.
A. Patient positioned and fixed on Mayfield clamps.
B. Neurosurgeon position.
C. 2D intraoperative ultrasound monitor.
D. Brainlab double screen with 3D images.
E. Ultrasound transducer (Craniotomy 8862) with Brainlab neuronavigation imaging.
РИС. 2. Вид операционной во время процедуры.
A. Положение пациента на операционном столе с фиксацией головы в скобе Mayfield.
B. Положение нейрохирурга.
C. Монитор для 2D-интраоперационного ультразвукового изображения.
D. Двойной экран Brainlab с 3D-изображениями.
E. Ультразвуковой датчик (Craniotomy 8862) с нейронавигационными метками Brainlab.

the intraoperative status of the lesion. After which, the volumetric dataset was accessible for 3D navigation in any reconstructed view. Ultrasound data was visualized with better quality images (920×1080 pixels) using BL IUS software in 3D (Figure 2D). The reconstructed 3D images could be reviewed in real time in coronal, sagittal and axial planes.

Surgical procedure

Integrated 2D intraoperative ultrasound plus the 3D Brainlab

The lead surgeon was Professor Albert Akramovich Sufianov. The 2D plus the 3D BL ultrasound scanner was used as a navigation to determine the location of the pathological focus, the structure and echogenicity of the pathological tissue in relation to the surrounding normal brain (Figures 3A, B1, B2, C). Elements of brain shift, lesion size and residue, were looked out for during the procedure clearly identified and evaluated. Microsurgical removal of epileptogenic tissue was performed following the boundaries of the lesion (Figure 3D).

Post-Operative evaluation

Early post-operative MRI images were conducted to ascertain the extent of resection and lesion residue (Figure 3E1, 3E2). MRI findings showed gross total resection of the lesion. Histological findings were consistent with FCD type IIb (G40.2) (Figure 4).

Post-operative follow-up was conducted by neurologist, neuro-epileptogist and neurosurgeons on the 1st, 3rd, and 6th month. The patient remained seizure-free at a 6-month follow-up (Engel I) while being maintained on a single antiepileptic drug: oxcarbazepine (600 mg BD PO).

DISCUSSION

An important clinical issue is the current inability to effectively treat many patients with refractory epilepsy caused by FCD. The main task during epilepsy surgery is to safely resect the lesion while preserving meaningful neurological faculties in the patient. The statistically significant predictor of post-operative seizure freedom is the completeness of resection. One commonly encountered explanation for incomplete resection is the inaccurate localization of the diseased tissue which is exacerbated by brain shifting that may occur at numerous stages during surgery, from the opening of dura mater, as tissue is resected and potentially throughout surgery. This is even more critical in patients with FCD as the extent of resection greatly influences postsurgical seizure outcome [11].

The use of IUS as a navigational tool in epilepsy surgery has greatly increased over the past decade [12, 13]. This has led to the development of improved and optimized solutions to the IUS images acquired during surgery. It is our opinion that the integrated 2D IUS and ultrasound installed BL systems using pre-operative MRI gives better appreciation of the lesion dimensions in the axial, coronal and sagittal planes 3D views, which can improve the extent of resection

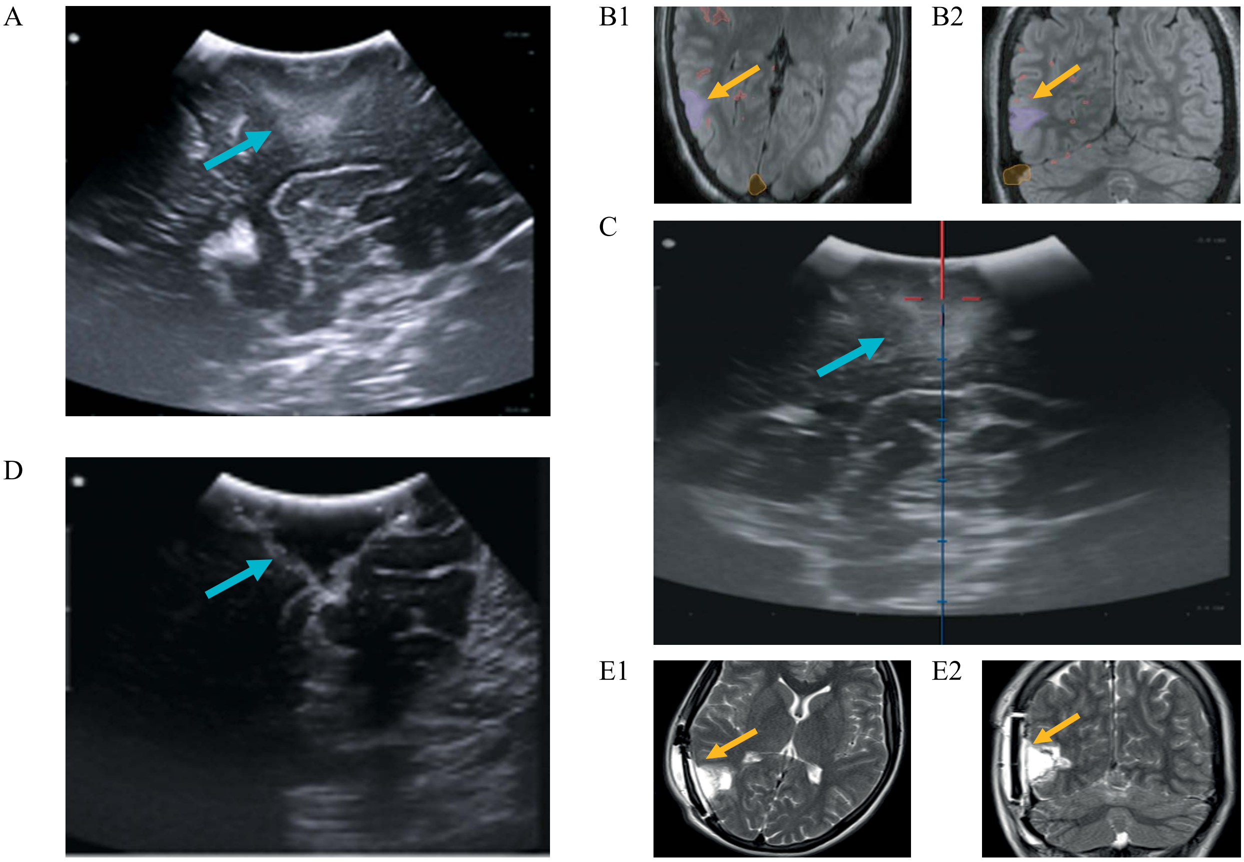

FIG. 3. Integrated 2D intraoperative ultrasound plus the 3D Brainlab.
A. IUS image of hyperechoic FCD lesion with transmantal displasia extending to close proxmity to the ventricle (blue arrow).
B1, B2, C. Axial and Coronal preoperative MRI (yellow arrows) intergrated with Brainlab showing an optimised view of FCD lesion (blue arrow).
D. IUS image depicting total resection of the FCD lesion (blue arrow).
E1, E2. Post operative MRI in Axial and Coronal views of the operative cavities (yellow arrows).
Notes. FCD – focal cortical dysplasia, IUS – intraoperative ultrasound, BL – Brainlab, MRI – magnetic resonance imaging.
РИС. 3. Интегрированное интраоперационное 2D-ультразвуковое исследование плюс 3D Brainlab.
A. УЗ-изображение гиперэхогенного участка ФКД с трансмантийной дисплазией, простирающейся по направлению к желудочку (голубая стрелка).
B1, B2, C. Аксиальная и коронарная проекции на предоперационных снимках МРТ (желтые стрелки), интегрированных с нейронавигационными изображениями Brainlab, дающие оптимизированное изображение ФКД (голубая стрелка).
D. УЗ-изображение, показывающее полную резекцию ФКД (голубая стрелка).
E1, E2. Послеоперационная МРТ в аксиальной и корональной проекции оперируемых полостей (желтые стрелки).

and the post-operative outcomes. This makes image interpretation easier because one may utilize the MRI image to better understand the US image and the general layout of the operating room.

Additionally, the use of ultrasound navigation software with BL systems integration enables the scanning and reconstruction of 3D ultrasound data noticeably faster than with intraoperative MRI, and this allows that the surgery is quicker and more efficient; this means that the surgical workflow is practically uninterrupted [14, 15]. In a study carried out at their institution, Sacino et al. investigated the use of intraoperative MRI and found that it increased the length of the procedure by 1.5 to 3 hours. The main elements that contributed to the need for more operating time included the patient's preparation, transportation, performing MRI, and return as well as the re-sterilization and re-gowning of the patient, nurses, and surgeon while returning in the operating room.

Irrespective of the user's level of IUS modality expertise, the BL automated view layouts are designed for ultrasound interpretation, making it easier to analyse ultrasound data, and thus even with minimum experience, junior surgeons can localize FCD lesions. We have been using IUS and IUS with BL systems integration at our centre for over 10 years and over 8 years, respectively. The lengthy learning curve of the initial phase can be significantly reduced with the usage of IUS with BL systems integration. Even though we observed the easy facility for the least experienced surgeons, blood

A B

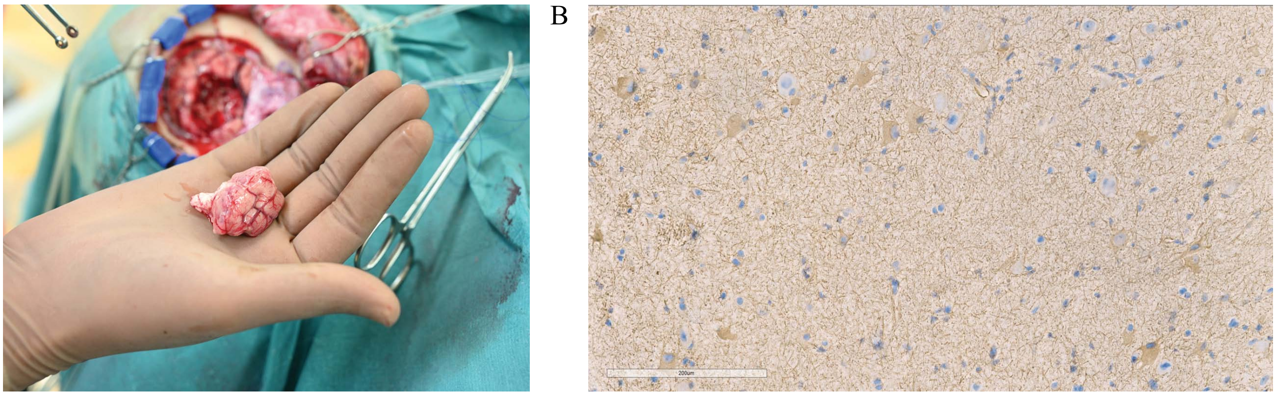

FIG. 4. Histological findings.
A. Macroscopic dysplastic cortical sample submited for hystopathology (FCD II).
B. Histological features FCD. IHC with vimentin in Balloon cells. Magnification ×400.
РИС. 4. Гистологическая характеристика.
А. Макроскопический образец диспластической коры головного мозга, отправленный на гистопатологическое исследование (ФКД II).
Б. Иммуногистохимическое окрашивание виментином в баллонных клетках. Увеличение×400.

products, and oedema can make residue interpretation a challenge.

The clinical postoperative outcome was not directly impacted by only using BL combined with IUS. However, the authors believe that the positive postoperative result was most likely influenced by the usage of IUS [16]. These results are equivalent to those attained when even more expensive neuronavigation tools (IMRI and ICT) are used.

CONCLUSION

IUS undoubtedly meets the criteria to be regarded as a good neurosurgical planning tool. The optimization of IUS with BL is a noninvasive imaging modality that offers better appreciation of FCD lesions and therefore better quality in the extent of resection. The application of these navigational tools greatly aids the reduction of seizure burden and meaningful postoperative clinical outcome.

Compliance with ethical standards

Consent statement. The patient has consented to the publication of the article “Optimization of intraoperative ultrasound navigation during focal cortical dysplasia surgery: a case report” in the Sechenov Medical Journal.

Соблюдение этических норм

Заявление о согласии. Пациент дал согласие на публикацию статьи «Оптимизация интраоперационной ультразвуковой навигации при оперативном лечении очаговой кортикальной дисплазии: клинический случай» в журнале «Сеченовский вестник».

AUTHORS CONTRIBUTIONS

Albert A. Sufianov carried out the surgical procedure described in the presented clinical case, made a major contribution to the conception and design, and supervised the scientific article writing and editing process; Keith Simfukwe participated in the development of the conception and design of the publication, preparation of materials, writing and editing the text, as well as the preparation of the illustrations. All authors approved the final version of the article and are ready to take responsibility for all aspects of the submitted publication.

ВКЛАД АВТОРОВ

А.А. Суфианов выполнил хирургическую операцию, описанную в представленном клиническом случае, внес основной вклад в концепцию и дизайн, а также руководил процессом написания и редактирования статьи. К. Симфукве участвовал в разработке концепции и дизайна статьи, подготовке материалов, написании и редактировании текста, а также подготовке иллюстраций Все авторы одобрили окончательный вариант статьи и готовы взять на себя ответственность за все аспекты представленной публикации.

REFERENCES / ЛИТЕРАТУРА

1 *Liang S., Wang S., Zhang J., et al.* Long-term outcomes of epilepsy surgery in school-aged children with partial epilepsy. Pediatr Neurol. 2012 Oct; 47(4): 284–290. https://doi.org/10.1016/j.pediatrneurol.2012.06.014. PMID: 22964443.
2 *Shurtleff H.A., Barry D., Firman T., et al.* Impact of epilepsy surgery on development of preschool children: identification of a cohort likely to benefit from early intervention. J Neurosurg Pediatr. 2015 Oct; 16(4): 383–392. https://doi.org/10.3171/2015.3.PEDS14359. Epub 2015 Jul 3. PMID: 26140458.
3 *Skirrow C., Cross J.H., Owens R., et al.* Determinants of IQ outcome after focal epilepsy surgery in childhood: A longitudinal case-control neuroimaging study. Epilepsia. 2019 May; 60(5): 872–884. https://doi.org/10.1111/epi.14707. Epub 2019 Apr 10. PMID: 30968956.
4 *Akeret K., Bellut D., Huppertz H.J., et al.* Ultrasonographic features of focal cortical dysplasia and their relevance for epilepsy surgery. Neurosurg Focus. 2018 Sep; 45(3): E5. https://doi.org/10.3171/2018.6.FOCUS18221. PMID: 30173618.

5 *Martinoni M., Marucci G., Meletti S., et al.* Ultrasound assisted awake epilepsy surgery for type IIB focal cortical dysplasia in eloquent areas. J Neurosurg Sci. 2021 Feb; 65(1): 75–77. https://doi.org/10.23736/S0390-5616.17.04186-8. Epub 2017 Sep 28. PMID: 28959876.
6 *Miller D., Carney P., Archer J.S., et al.* Intraoperative definition of bottom-of-sulcus dysplasia using intraoperative ultrasound and single depth electrode recording – A technical note. J Clin Neurosci. 2018 Feb; 48: 191–195. https://doi.org/10.1016/j.jocn.2017.10.045. Epub 2017 Nov 11. PMID: 29137921.
7 *Miller D., Knake S., Menzler K., et al.* Intraoperative ultrasound in malformations of cortical development. Ultraschall Med. 2011 Dec; 32 Suppl 2: E69–74. https://doi.org/10.1055/s-0031-1273490. Epub 2011 Jul 20. PMID: 21776582.
8 *Tringali G., Bono B., Dones I., et al.* Multimodal approach for radical excision of focal cortical dysplasia by combining advanced magnetic resonance imaging data to intraoperative ultrasound, electrocorticography, and cortical stimulation: A preliminary experience. World Neurosurg. 2018 May; 113:e 738–e746. https://doi.org/10.1016/j.wneu.2018.02.141. Epub 2018 Mar 3. PMID: 29510282.
9 *Cheng-Chia Lee., Chun-Fu Lin., Hsiang-Yu Yu., et al.* Applications of intraoperative ultrasound in epilepsy surgery for focal cortical dysplasia, Journal of Medical Ultrasound, 2014; 22(1): 43–46, https://doi.org/10.1016/j.jmu.2014.02.004.
10 *Bayer S., Maier A., Ostermeier M., Fahrig R.* Intraoperative imaging modalities and compensation for brain shift in tumor resection surgery. Int J Biomed Imaging. 2017; 2017: 6028645. https://doi.org/10.1155/2017/6028645. Epub 2017 Jun 5. Erratum in: Int J Biomed Imaging. 2019 Oct 1;2019:9249016. PMID: 28676821.
11 *Sastry R., Bi W.L., Pieper S., et al.* Applications of ultrasound in the resection of brain tumors. J Neuroimaging. 2017 Jan; 27(1): 5–15. https://doi.org/10.1111/jon.12382. Epub 2016 Aug 19. PMID: 27541694.
12 *Prada F., Gennari A.G., Quaia E., et al.* Advanced intraoperative ultrasound (ioUS) techniques in focal cortical dysplasia (FCD) surgery: A preliminary experience on a case series. Clin Neurol Neurosurg. 2020 Nov; 198: 106188. https://doi.org/10.1016/j.clineuro.2020.106188. Epub 2020 Aug 26. PMID: 32956988.
13 *Krsek P., Maton B., Jayakar P., et al.* Incomplete resection of focal cortical dysplasia is the main predictor of poor postsurgical outcome. Neurology. 2009 Jan 20; 72(3): 217–223. https://doi.org/10.1212/01.wnl.0000334365.22854.d3. Epub 2008 Nov 12. PMID: 19005171.
14 *Roessler K., Kasper B.S., Heynold E., et al.* Intraoperative magnetic-resonance tomography and neuronavigation during resection of focal cortical dysplasia type ii in adult epilepsy surgery offers better seizure outcomes. World Neurosurg. 2018 Jan; 109: e43–e49. https://doi.org/10.1016/j.wneu.2017.09.100. Epub 2017 Sep 23. PMID: 28951272.
15 *Terra V.C., Thomé U., Rosset S.S., et al.* Surgery for focal cortical dysplasia in children using intraoperative mapping. Childs Nerv Syst. 2014 Nov; 30(11): 1839–1851. https://doi.org/10.1007/s00381-014-2459-7. Epub 2014 Oct 9. PMID: 25296545.
16 *Algethami H., Poghosyan V., Baksh E., Alhameed M.* Focal cortical dysplasia and generalized epileptiform discharges: case report and literature review. Med Arch. 2021 Dec; 75(6): 462–466. https://doi.org/10.5455/medarh.2021.75.462-466. PMID: 35169375.

INFORMATION ABOUT THE AUTHORS / ИНФОРМАЦИЯ ОБ АВТОРАХ

Keith Simfukwe, postgraduate student in neurosurgery, Sechenov First Moscow State Medical University (Sechenov University); Federal Centre of Neurosurgery.
ORCID: https://orcid.org/0000-0003-3611-3720

Кейт Симфукве, аспирант по специальности «Нейрохирургия» ФГАОУ ВО «Первый МГМУ им. И.М. Сеченова» Минздрава России (Сеченовский Университет); ФГБУ «Федеральный центр нейрохирургии» Минздрава России.
ORCID: https://orcid.org/0000-0003-3611-3720

Albert A. Sufianov✉**,** Dr. of Sci. (Medicine), Professor, Corresponding Member of RAS, Head of Federal Centre of Neurosurgery; Head of the Department of Neurosurgery, Sechenov First Moscow State Medical University (Sechenov University); Professor, Peoples' Friendship University of Russia (RUDN University).
ORCID: https://orcid.org/0000-0001-7580-0385

Суфианов Альберт Акрамович✉**,** д-р мед. наук, профессор, член-корреспондент РАН, главный врач ФГБУ «Федеральный центр нейрохирургии» Минздрава России; зав. кафедрой нейрохирургии ФГАОУ ВО «Первый МГМУ им. И.М. Сеченова» Минздрава России (Сеченовский Университет); профессор ФГАОУ ВО «Российский университет дружбы народов».
ORCID: https://orcid.org/0000-0001-7580-0385

✉ Corresponding author / Автор, ответственный за переписку