Received: 20 March 2025 | Revised: 25 May 2025 | Accepted: 2 July 2025

DOI: 10.1111/epi.18558

Epilepsia®

RESEARCH ARTICLE

Trends in epilepsy surgery in Italy before and after the COVID-19 pandemic: A nationwide study

Giuseppe Didato[1] | Federico Vigevano[2] | Laura Tassi[3] | Renzo Guerrini[4,5] | Marco de Curtis[1] | Luca De Palma[6] | Giancarlo Di Gennaro[7] | Lino Nobili[8,9] | Matteo Martinoni[10,11] | Stefano Meletti[12,13] | Domenica Battaglia[14,15] | Elisabetta Cesaroni[16] | Roberta Vittorini[17] | Laura Grisotto[18] | Giuseppe d'Orsi[19] | Robertino Dilena[20] | Valeria Pingue[21,22] | Antonio Nardone[21,22] | Federica Ranzato[23] | Claudio Zucca[24] | Paolo Bonanni[25] | Pietro Mattioli[9,26] | Gianpiero Tamburrini[27] | Michela Quintiliani[14] | Michele Luzi[28] | Roberto Trignani[28] | Francesca Torta[17] | Giovanni Morana[29,30] | Matteo Pugnaghi[13] | Anna Elisabetta Vaudano[12,13] | Francesca Bisulli[11,31] | Elena Pasini[11] | Alessandro Consales[9,32] | Giulia Nobile[8] | Vincenzo Esposito[7,33] | Pier Paolo Quarato[7] | Elena Freri[34] | Carlo Efisio Marras[35] | Flavio Giordano[4,36] | Veronica Pelliccia[3] | Laura Castana[3] | Nicola Specchio[6,37] | Umberto Costantino[19] | Mauro Pluderi[38] | Michele Rizzi[39] | Diana Polo[23] | Stefania Zambrano[24] | Alberto Danieli[25] | Flavio Villani[26] | Carmen Barba[4,5] | Italian Epilepsy Surgery Collaborative Group

Correspondence
Giuseppe Didato, Fondazione IRCCS Istituto Neurologico Carlo Besta, Via Celoria 11, 20133 Milan, Italy.
Email: giuseppe.didato@istituto-besta.it

Carmen Barba, Meyer Children's Hospital IRCCS, viale Pieraccini 24, Florence, Italy.
Email: carmen.barba@meyer.it

Abstract

Objective: To study the current practice of epilepsy surgery in Italy and the relative impact of coronavirus disease 2019 (COVID-19) pandemic on it.

Methods: We launched a survey through the Italian National Virtual Epilepsy Institute, to identify centers with epilepsy surgery programs and collect data on the current preoperative and surgical practices. We reported changes in surgical volumes and complications and seizure outcomes between 2018 and 2022, that is, before and after the COVID-19 pandemic in Italy.

See Appendix A for full list of the Italian Epilepsy Surgery Collaborative Group.

Roberta Di Giacomo, Roberto Mai, Francesca Gozzo, Claudia Accolla, Elena Cavallini, Alfredo D'Aniello, Chiara Panzini, Stefano Francione, Lorenzo Ferri, Lidia Di Vito, Giada Giovannini, Niccolò Orlandi, Federico Bianchi, Massimo Valerio, Nicoletta Zanotta, Gianmarco Duma, Irene Pappalardo, Alessandro De Benedictis, Marco Locatelli, Domenico Tortora, Maria Camilla Rossi Espagnet, Ernesto Losavio, Luigi Giovanni Manfredi, Pietro Zeppa, Filomena Fuggetta, Massimo Carella, Paola Mattaliano, Anna Bellini.

For affiliations refer to page 4194.

Results: A total of 21 of the 26 surveyed centers (80.7%) responded. Eleven centers (52.4%) reported having an established epilepsy surgery program, with most performing complex procedures, such as multilobar, disconnective, and hemispheric interventions. However, only a few carry out minimally invasive surgeries. Presurgical evaluation protocols vary across centers, but in keeping with international standards. Globally, 618 surgeries were performed in children and 621 in adults (total 1239) between 2018 and 2022. The most frequent type of surgery was unilobar extratemporal lobectomy for children (38.7%, $p<0.0001$) and unilobar temporal lobectomy for adults (63.3%, $p<0.0001$). Hemispheric surgeries were more frequent in children than in adults (11.5% vs 2.1%, $p=0.001$), whereas interventions in unrevealing magnetic resonance (MRI) cases were more frequent in adults than in children ($p=0.030$). At the onset of COVID-19outbreak in Italy (March 2020), we observed a significant decrease in the total number of operations compared to 2019, especially for hemispheric interventions ($p=0.027$). Surgical volumes resumed in 2021, particularly for temporal lobe epilepsies and in adult cohorts. Surgical complications increased significantly in 2020 (Incidence Rate Ratio [IRR] = 13.13), whereas seizure outcome did not change significantly between 2018 and 2022.

Significance: Advanced pre- and postsurgical evaluation protocols are currently implemented across Italy, with a great variability between centers. Starting in 2021, epilepsy surgery volumes have regained their pre-pandemic levels, albeit with a slight loss of complexity, whereas seizure outcome has remained stable.

KEYWORDS

adults, children, outcome, surgical volumes, survey

1 | INTRODUCTION

Epilepsy surgery represents the optimal treatment option for up to 40% of patients with drug-resistant epilepsy (DRE).[1] The best outcomes and the lowest complication rates are attained when the pathway from presurgical evaluation to postsurgical follow-up encompasses a complete workup, including the use of advanced diagnostic tools and surgical techniques in tertiary epilepsy surgery centers.[2–4]

However, presurgical evaluation and surgical approaches can vary among centers, not only depending on epileptological and surgical expertise, but also on local facilities and protocols, which may influence seizure, cognitive, and behavioral outcomes.[5–7]

During and after the coronavirus disease 2019 (COVID-19) pandemic, presurgical and epilepsy surgery activities were severely affected, due to the reduction of elective procedures and the need to prioritize admissions of COVID-19 patients in most hospitals.[8–14] These aspects were particularly dramatic in Italy, one of the first heavily affected countries in Europe since 2020, with a recorded toll of 26 948 813 infected people as of November 13, 2024.[15]

Key points

1. We launched a national survey on epilepsy surgery activity and pre- and postsurgical protocols.
2. Unilobar extratemporal lobectomy and hemispheric surgeries are more frequent in children, whereas unilobar temporal lobectomy prevails in adults.
3. A significant decrease in the number of operations with increased surgical complications occurred in 2020, with stable seizure outcome.
4. The coronavirus disease 2019 (COVID-19) pandemic increased barriers to epilepsy surgery in Italy but only for a limited time.

Based on these premises, the Epilepsy Surgery Task Force of the National Virtual Epilepsy Institute, member of the "Istituti di Ricovero e Cura a Carattere Scientifico (IRCCS - Scientific Institutes for Hospitalization and Treatment)"

Network of Neurosciences and Neurorehabilitation as identified by the Italian Health Ministry), recognized the need to collect information on the current practice of preoperative and surgical activities after the COVID-19 pandemic and the possible changes in surgical volumes, complications, and outcomes determined by this public health emergency in Italy. For this purpose, the Italian hospitals being part of the IRCCS Network of Neurosciences and Neurorehabilitation and associated Centers, identified through the Commission of Epilepsy Surgery of the Italian League against Epilepsy (LICE), were surveyed. Here we report the results of this survey.

2 | MATERIALS AND METHODS

2.1 | Data collection

We sent a questionnaire via email to the 21 epilepsy centers of the IRCCS Network of Neurosciences and Neurorehabilitation and to five other associated centers, identified through the Italian League against Epilepsy, to determine whether they conducted presurgical evaluations of surgical candidates and performed surgical interventions on site.

As a second step, we sent a follow-up questionnaire only to centers with a comprehensive epilepsy surgery program, to collect data on the volumes and types of surgical interventions, complications, and seizure outcomes between 2018 and 2022, that is, before and after the outbreak of the COVID-19 pandemic in 2020. In fact, the Italian Ministry of Health declared the onset of the lockdown from March 9, 2020, with most centers regaining their habitual trends from June 2021.

We identified multilobar, disconnective, and hemispheric interventions as complex procedures.

We assessed seizure outcome at each visit using Engel's outcome classification scale.[16]

Complications were classified as severe (including a postoperative event requiring surgery or a new and unexpected permanent neurological deficit, lasting more than 6 months, or a combination of them) or minor (transient neurological deficit).[17]

We analyzed data from adult and pediatric (<18 years of age) centers separately.

As a final step, to better understand the fluctuations of surgical volumes during the pandemic, we gathered additional data from the 11 centers performing on-site surgeries. This included information on staffing reallocation, shifts in operational priorities and presurgical evaluations, the duration of the suspension of epilepsy surgical procedures, and changes in the waiting list for presurgical evaluation and epilepsy surgery throughout 2020.

The questionnaires and details regarding their construction are provided in the Appendices S1, S2, and S3 and Data S1.

2.2 | Statistical analysis

We described data using means ± standard deviations (SDs) for continuous variables and as numbers and proportions for categorical variables. In addition, we presented appropriate graphs to summarize the results. We used simple Poisson regressions to examine the relationship between outcomes and calendar years (2019 ref. vs 2018, 2020, 2021, and 2022) and adults vs children. Additional Poisson analyses explored the relationship between outcomes, calendar year, and macro areas as defined by Italian National Institute of Statistics (ISTAT): Northern (Emilia-Romagna, Liguria, Lombardia, and Piemonte) vs Central-Southern Italy (Lazio, Marche, Molise, and Toscana). To assess macro-area–specific temporal trends, we stratified models by macro area.

We did not carry out further disaggregation by region and/or by age group (children vs adults) due to small sample sizes, which would have compromised statistical power and precision.

To compare staffing dynamics, and changes in the waiting list for presurgical evaluation and epilepsy surgery between 2020 and 2019, we performed a paired Student's *t* test.

3 | RESULTS

Twenty-one (80%) of 26 queried centers participated in the survey, with 10 centers evaluating pediatric patients only, seven adult patients only, and four both children and adults. In the first phase of the study, we identified 16 epilepsy centers managing potential surgical candidates, five of which carry out only pre- and post-surgical evaluations and 11 with comprehensive epilepsy surgery programs. Of these latter, six perform pediatric surgeries only, three adult patient surgeries only, and two treat both adults and children. Six (54.5%) epilepsy surgery centers are located in Northern Italy, four (36.4%) in central regions, and only one (9.1%) is in the south (Table 1 and Figure 1).

3.1 | Adults

3.1.1 | Indications for surgery

Most centers do not consider DRE a prerequisite for surgery in case of suspected low-grade epilepsy-associated

TABLE 1 Presurgical and surgical facilities at the participating centers.

	Adults (5 centers)—*N* (%)			Children (8 centers)—*N* (%)		
	No	Selected cases	Always	No	Selected cases	Always
DR mandatory for surgery	2 (40.0)	3 (60.0)	0 (0.0)	2 (25.0)	5 (62.5)	1 (12.5)
1 h EEG	1 (20.0)	1 (20.0)	3 (60.0)	0 (0.0)	3 (37.5)	5 (62.5)
1–12 h video-EEG	1 (20.0)	1 (20.0)	3 (60.0)	0 (0.0)	4 (50.0)	4 (50.0)
LTM	0 (0.0)	2 (40.0)	3 (60.0)	0 (0.0)	6 (75.0)	2 (25.0)
Stereo-EEG	3 (60.0)	2 (40.0)	0 (0.0)	3 (37.5)	5 (62.5)	0 (0.0)
Subdural grids	3 (60.0)	2 (40.0)	0 (0.0)	8 (100.0)	0 (0.0)	0 (0.0)
FOE	4 (80.0)	1 (20.0)	0 (0.0)	8 (100.0)	0 (0.0)	0 (0.0)
1.5 Tesla MRI				2 (25.0)	1 (12.5)	5 (62.5)
3 Tesla MRI	0 (0.0)	1 (20.0)	4 (80.0)	0 (0.0)	4 (50.0)	4 (50.0)
7 Tesla MRI	4 (80.0)	1 (20.0)[a]	0 (0.0)	6 (75.0)	2 (25.0)	0 (0.0)
MRI post-processing	2 (40.0)	0 (0.0)	3 (60.0)	3 (37.5)	2 (25.0)	3 (37.5)
Functional MRI	0 (0.0)	5 (100.0)	0 (0.0)	0 (0.0)	8 (100.0)	0 (0.0)
EEG-fMRI	2 (40.0)	3 (60.0)	0 (0.0)	8 (100.0)	0 (0.0)	0 (0.0)
HDEEG	1 (20.0)	4 (80.0)	0 (0.0)	2 (25.0)	6 (75.0)	0 (0.0)
MEG	4 (80.0)	1 (20.0)	0 (0.0)	7 (87.5)	1 (12.5)	0 (0.0)
ESI	3 (60.0)	2 (40.0)	0 (0.0)	5 (62.5)	1 (12.5)	2 (25.0)
FDG-PET	0 (0.0)	3 (60.0)	2 (40.0)	0 (0.0)	8 (100.0)	0 (0.0)
SPECT	0 (0.0)	0 (0.0)	0 (0.0)	7 (87.5)	1 (12.5)	0 (0.0)
Preoperative angiography	3 (60.0)	1 (20.0)	1 (20.0)	4 (50.0)	1 (12.5)	3 (37.5)
Pre-Stereo-EEG angiography	3 (60.0)	0 (0.0)	2 (40.0)	4 (50.0)	0 (0.0)	4 (50.0)
Wada test	0 (0.0)	0 (0.0)	0 (0.0)	4 (50.0)	4 (50.0)	0 (0.0)
Genetic testing (blood)	0 (0.0)	5 (100.0)	0 (0.0)	0 (0.0)	4 (50.0)	4 (50.0)
Genetic testing (tissue)	0 (0.0)	4 (80.0)	1 (20.0)	2 (25.0)	5 (62.5)	1 (12.5)
Genetic testing (electrode)	3 (60.0)	2 (40.0)	0 (0.0)	6 (75.0)	2 (25.0)	0 (0.0)
Genetic testing (CSF)	2 (40.0)	3 (60.0)	0 (0.0)	6 (75.0)	2 (25.0)	0 (0.0)
NPS testing	0 (0.0)	0 (0.0)	5 (100.0)	0 (0.0)	0 (0.0)	8 (100.0)
IQ testing	1 (20.0)	2 (40.0)	2 (40.0)	1 (12.5)	0 (0.0)	7 (87.5)
CBCL	—	—	—	1 (12.5)	2 (25.0)	5 (62.5)
Psychiatric evaluation	1 (20.0)	4 (80.0)	0 (0.0)	1 (12.5)	1 (12.5)	6 (75.0)
Psychological evaluation[b]	1 (20.0)	2 (40.0)	2 (40.0)	—	—	—
ECoG	1 (20.0)	3 (60.0)	1 (20.0)	0 (0.0)	6 (75.0)	2 (25.0)
Intraoperative Stereo-EEG	1 (20.0)	4 (80.0)	0 (0.0)	4 (50.0)	4 (50.0)	0 (0.0)
IOM	0 (0.0)	4 (80.0)	1 (20.0)	0 (0.0)	4 (50.0)	4 (50.0)
Awake surgery	1 (20.0)	4 (80.0)	0 (0.0)	4 (50.0)	4 (50.0)	0 (0.0)
Intraoperative MRI	4 (80.0)	1 (20.0)	0 (0.0)	6 (75.0)	2 (25.0)	0 (0.0)
Intraoperative CT	5 (100.0)	0 (0.0)	0 (0.0)	4 (50.0)	4 (50.0)	0 (0.0)
Intraoperative ultrasound	2 (40.0)	2 (40.0)	1 (20.0)	3 (37.5)	3 (37.5)	2 (25.0)
Neuropathologist for ES	3 (60.0)	0 (0.0)	2 (40.0)	6 (75.0)	0 (0.0)	2 (25.0)
General neuropathologist	3 (60.0)	0 (0.0)	2 (40.0)	6 (75.0)	0 (0.0)	2 (25.0)
General pathologist	4 (80.0)	0 (0.0)	1 (20.0)	4 (50.0)	0 (0.0)	4 (50.0)
Postoperative EEG	1 (20.0)	0 (0.0)	4 (80.0)	2 (25.0)	0 (0.0)	6 (75.0)
Postoperative 1 h video-EEG	2 (40.0)	3 (60.0)	0 (0.0)	1 (12.5)	2 (25.0)	5 (62.5)
Postoperative LTM	0 (0.0)	4 (80.0)	1 (20.0)	0 (0.0)	6 (75.0)	2 (25.0)

TABLE 1 (Continued)

	Adults (5 centers)—*N* (%)			Children (8 centers)—*N* (%)		
	No	Selected cases	Always	No	Selected cases	Always
Postoperative MRI	0 (0.0)	0 (0.0)	5 (100.0)	0 (0.0)	0 (0.0)	8 (100.0)
Postoperative NPS testing	0 (0.0)	0 (0.0)	5 (100.0)	0 (0.0)	0 (0.0)	8 (100.0)
Postoperative psychiatric evaluation	1 (20.0)	4 (80.0)	0 (0.0)	2 (25.0)	2 (25.0)	4 (50.0)
Postoperative psychological evaluation[b]	1 (20.0)	2 (40.0)	2 (40.0)	—	—	—
Postoperative rehabilitation	1 (20.0)	4 (80.0)	0 (0.0)	4 (50.0)	3 (37.5)	1 (12.5)

Note: Facilities available during the presurgical and surgical phases at the 11 epilepsy centers managing surgical candidates, as identified through the survey.

Abbreviations: CBCL, Child Behavior Checklist; CT, computed tomography; DR, drug resistance; ECoG, (intraoperative) electrocorticography; EEG, electroencephalography; ES, epilepsy surgery; ESI, electrical source imaging; FDG-PET, 18F-fluoro-deoxyglucose-positron emission tomography; FOE, foramen ovale electrode; HDEEG, high-density EEG; IOM, intraoperative neurophysiologic monitoring; IQ, intelligence quotient; LTM, long-term video-EEG monitoring; MEG, magnetoencephalography; NPS testing, neuropsychological testing; Stereo-EEG, stereo-electroencephalography; SPECT, single-photon emission computed tomography.

[a]Only ex vivo 7 T MRI.

[b]Only adult patients.

neuroepithelial tumors (LEATs). However, two centers (Niguarda and Besta) do not deem it necessary even for focal cortical dysplasia type II (FCD II) in non-eloquent areas and antero-mesial temporal epilepsy with hippocampal sclerosis (Table 1). Of note, Niguarda Hospital may even proceed to surgery before initiating antiseizure medications (ASMs) in the above-mentioned conditions. For the remaining centers, the minimum requirement is the failure of at least two ASMs before surgery. All centers can operate on patients with unrevealing MR when presurgical electroclinical data point to a definite epileptogenic zone (EZ) (Table 2).

3.1.2 | Presurgical evaluation

The main findings regarding presurgical evaluation protocols in the various centers are summarized in Table 1.

EEG investigations

All participating centers conduct long-term video-EEG (electroencephalography) monitoring (LTM), in all patients in three centers and only in selected cases (i.e., unrevealing brain magnetic resonance imaging [MRI] or discrepancies between clinical, interictal EEG, and/or anatomic data) in two. In addition, four centers perform 1-h or 12-h video-EEG. Stereo-EEG and subdural grids are carried out by two centers each. Moreover, one center employs intracranial foramen ovale electrodes in selected cases (difficult to lateralize temporal lobe seizures on scalp EEG).

Four of five centers use high-density EEG (HDEEG), two centers perform electric source imaging (ESI), and one center utilizes magnetoencephalography (MEG).

Neuroimaging

All five centers have a 3 T brain MRI, but one uses it only in selected cases, that is, when 1.5 T MRI is unrevealing or inconclusive, the remaining four in all cases. All centers follow a standardized protocol (HARNESS)[18] for imaging acquisition and three perform post-processing analyses before surgery, using three-dimensional (3D) brain imaging reconstruction, Morphometric Analysis Program (MAP),[19] and Standardized workflow for advanced neuroimaging in epilepsy (SWANe).[20] Functional brain MRI (fMRI) for language and motor tasks is available in all centers, with EEG-fMRI implemented in three. Two centers use 18F-fluoro-deoxyglucose positron emission tomography (FDG-PET) in all patients and the remaining three in selected cases (i.e., unrevealing brain MRI or ill-defined lesions). Some carry out FDG-PET in associated nuclear medicine centers. Single-proton emission computed tomography (SPECT), both interictal and ictal, is no longer used in any center. Only two centers use preoperative angiography, one center in all patients and the other one in selected cases of surgery in highly vascularized brain areas, like insula, or in eloquent areas.

Genetic testing

All centers but one perform genetic testing on blood and on tissue specimens in selected cases (i.e., Focal cortical dyplasia-FCD, tumors, mild malformationn of cortical development with oligodendroglial hyperplasia-MOGHE, family history of epilepsy, or clinical data supporting a suspicion of genetic epilepsy), whereas the remaining center tests all patients. Two centers also perform genetic testing on material obtained from intracerebral electrodes and three on cerebrospinal fluid in selected cases (i.e., for research purposes).

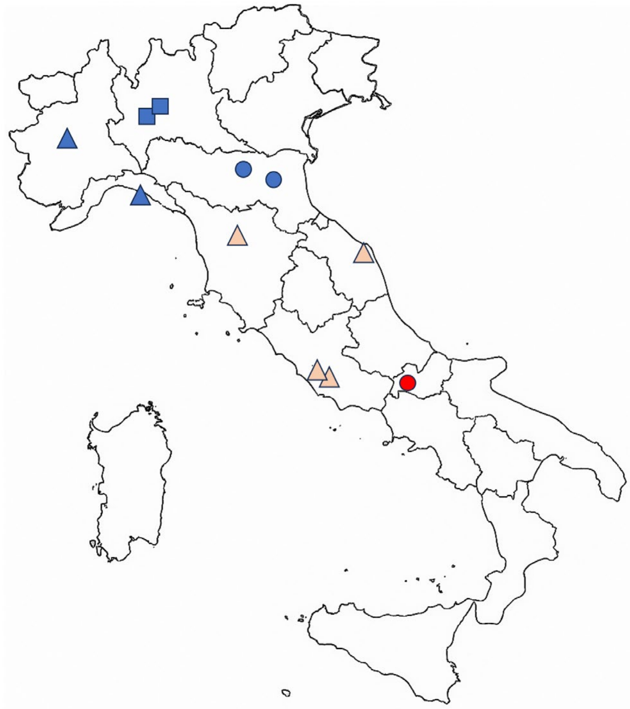

FIGURE 1 Geographical distribution of the epilepsy surgery centers in Italy. Six (54.5%) epilepsy surgery centers are located in Northern Italy, four (36.4%) in central regions, and only one (9.1%) is in the south. Circles, adult centers; triangles, pediatric centers; squares, centers treating both adult and pediatric patients. Color legend: blue, Northern Italy; pink, Central Italy; red, Southern Italy.

Neuropsychological and psychopathological assessment

All centers use a standardized neuropsychological protocol for multidomain cognitive evaluation, with variability in type and number of functions explored and tools utilized across centers. Four centers perform psychiatric assessment only in selected cases (i.e., in the presence of clinical evidence of psychopathology), whereas two centers carry out psychological evaluation in all patients and two in selected cases (same as psychopathological assessment). Wada test for language dominance lateralization is no longer performed in any center.

Finally, all fully established epilepsy surgery centers organize weekly or monthly multidisciplinary meetings to discuss surgical cases.

3.1.3 | Surgery

Types of surgeries

All centers perform standard surgical procedures, that is, anteromesial temporal lobectomy, lesionectomy, and lobar resections. In addition, three centers perform multilobar resections and disconnections and two centers perform hemispherotomy, hemispherectomy, and endoscopic disconnection. Stereo-EEG –guided radiofrequency thermocoagulation (RF-THC) is available in two centers and MRI-guided laser interstitial thermal therapy (LiTT) in one. Regarding palliative surgery, three centers perform vagus nerve stimulation (VNS), one deep brain stimulation (DBS), and one callosotomy (Table 2). Intraoperative monitoring (IOM) is used in all centers, electrocorticography (ECoG) in four. Moreover, four centers perform intraoperative Stereo-EEG and awake surgery, whereas three centers use intraoperative ultrasound (iUS). Intraoperative MRI is available in only one center (Table 1).

Histopathology

Only two centers have a neuropathologist specifically dedicated to epilepsy surgery, whereas the remaining three centers have a general neuropathologist (two) or a general pathologist dedicated to epilepsy surgery (one) (Table 1).

3.1.4 | Postoperative assessment

All centers perform at least one brain MRI and one neuropsychological testing after surgery. Four centers carry out postoperative EEG and three centers 1 h video-EEG in select cases (i.e., persistence of daily seizures with high frequency); four centers perform LTM in select cases (i.e., reported persistent seizures) and one center in all patients.

Four centers perform postsurgical psychiatric evaluation if psychopathology is detected after surgery, whereas two centers do psychological evaluation in all patients (Table 1).

Postsurgical rehabilitation is available in four centers.

3.1.5 | Volumes of surgical activity between 2018 and 2022

We collected data from 621 adults (range 81–167 per year). Engel class Ia outcome was achieved in 67.5% of patients at last follow-up; the percentage of severe complications was 3.5%.

The most frequent resective surgeries were unilobar temporal lobectomy (393 patients, 63.3%), unilobar extratemporal (129, 20.8%), multilobar (86, 13.8%), and hemispheric surgeries (13, 2.1%). Sixty-three patients were operated with unrevealing MRI (10.1%) and 145 (23.3%) underwent invasive recording, mainly Stereo-EEG.

Regarding palliative treatments, 128 VNS implantations were performed; no DBS or callosotomy was carried out in the observation period (Table 3).

TABLE 2 Types of surgeries since 2018–2022 at epilepsy surgery centers.

	Adults (5 centers)—*N* (%)			Children (8 centers)—*N* (%)		
	No	Selected cases	Yes/always	No/never	Selected cases	Yes/always
Lesionectomies	0 (0.0)	0 (0.0)	5 (100.0)	0 (0.0)	7 (87.5)	1 (12.5)
SAH	2 (40.0)	0 (0.0)	3 (60.0)	2 (25.0)	5 (62.5)	1 (12.5)
Antero-mesial temporal lobectomies	0 (0.0)	0 (0.0)	5 (100.0)	0 (0.0)	7 (87.5)	1 (12.5)
Lobar neocortical resections	0 (0.0)	5 (100.0)	0 (0.0)	1 (12.5)	6 (75.0)	1 (12.5)
Multilobar neocortical resections	2 (40.0)	3 (60.0)	0 (0.0)	3 (37.5)	5 (62.5)	0 (0.0)
Unrevealing MRI surgeries	0 (0.0)	5 (100.0)	0 (0.0)	4 (50.0)	4 (50.0)	0 (0.0)
Disconnections	2 (40.0)	3 (60.0)	0 (0.0)	2 (25.0)	6 (75.0)	0 (0.0)
Hemispherectomies	3 (60.0)	2 (40.0)	0 (0.0)	4 (50.0)	4 (50.0)	0 (0.0)
Hemispherotomies	3 (60.0)	2 (40.0)	0 (0.0)	1 (12.5)	7 (87.5)	0 (0.0)
Endoscopic disconnections	3 (60.0)	2 (40.0)	0 (0.0)	6 (75.0)	2 (25.0)	0 (0.0)
RF-THC	3 (60.0)	2 (40.0)	0 (0.0)	4 (50.0)	4 (50.0)	0 (0.0)
LiTT	4 (80.0)	1 (20.0)	0 (0.0)	5 (62.5)	3 (37.5)	0 (0.0)
FUS	5 (100.0)	0 (0.0)	0 (0.0)	7 (87.5)	1 (12.5)	0 (0.0)
Callosotomies	4 (80.0)	1 (20.0)	0 (0.0)	3 (37.5)	5 (62.5)	0 (0.0)
VNS	2 (40.0)	3 (60.0)	0 (0.0)	2 (25.0)	6 (75.0)	0 (0.0)
DBS	4 (80.0)	1 (20.0)	0 (0.0)	7 (87.5)	1 (12.5)	0 (0.0)
MST	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Closed loop	4 (80.0)	1 (20.0)	0 (0.0)	4 (50.0)	4 (50.0)	0 (0.0)

Note: Standard and complex surgical procedures performed at the 11 centers with comprehensive surgical programs, as identified through the survey.

Abbreviations: DBS, deep brain stimulation; FUS, focused ultrasound; LiTT, MRI-guided laser interstitial thermal therapy; MST, multiple subpial transection; RF-THC, (Stereo-EEG-guided) radio-frequency thermal coagulation; SAH, selective amygdalo-hippocampectomy; VNS, vagus nerve stimulation.

3.2 | Children

3.2.1 | Indications for surgery

Five of eight centers treating children do not consider DRE as a prerequisite in cases of suspected tumors or FCD II, whereas Niguarda and Gaslini centers do not consider DRE a prerequisite in any case. Only one center operates on only DRE patients, independently from etiology. In seven centers, the mean number of ASMs to be tried before surgery is 2–3, whereas Niguarda may proceed to surgery before initiating ASMs in the above-mentioned etiologies. All centers but four operate on select patients with unrevealing MRI in case of electroclinical data pointing to a definite EZ.

3.2.2 | Presurgical evaluation

EEG investigations

All participating centers perform at least 1 h EEG, 1–12-h video-EEG, and LTM before surgery; however, LTM is performed in all patients in two centers and in select cases (i.e., unrevealing brain MRI or discordant anatomic-electro-clinical correlations) in the remaining six. Five centers carry out Stereo-EEG and functional mapping when non-invasive investigations do not allow the delineation of the area to be resected/disconnected or for functional mapping. Grid implantation is no longer performed in any center. Six centers perform HDEEG and only one center carries out MEG in select patients. Two centers use ESI in all patients and one in select cases, that is, for research purposes (Table 1).

Neuroimaging

All centers perform at least one preoperative brain MRI: 3 T, 1.5 T, or both (see Table 1 for details). Two centers perform 7 T MRI in ccooperative children older than 8 years. The HARNESS protocol[18] is used in two centers, whereas center-specific protocols including at least 3D T1, 3D fluid-attenuated inversion recovery (FLAIR), and coronal and axial T2 sequences are used in the remaining five. Post-processing analysis (MAP or SWANe) is performed in all patients in three centers and in select cases (i.e., extratemporal epilepsy or surgery close to eloquent areas) in two centers. All centers perform fMRI during language and motor tasks in case of proximity of epileptogenic lesion and/or EZ to eloquent areas and if the patient can cooperate with the task.

TABLE 3 Volumes of activity since 2018–2022 at epilepsy surgery centers.

Year	2018	2019	2020	2021	2022	Total in 5 years
	Adults (5 centers)					
Unilobar temporal surgeries	78	66	49	88	112	393 (63.3%)
Unilobar extratemporal surgeries	24	27	18	26	34	129 (20.8%)
Multilobar surgeries	25	15	11	14	21	86 (13.8%)
Hemispheric surgeries	1	6	3	3	0	13 (2.1%)
Total surgeries per year	*128*	*114*	*81*	*131*	*167*	*621*
Unrevealing MRI surgeries	14	13	10	11	15	63 (10.1%)
Callosotomies	0	0	0	0	0	0
VNS	29	25	21	25	28	128
DBS	0	0	0	0	0	0
Stereo-EEG/subdural grids	27	39	15	27	37	145 (23.3%)
Engel Ia outcome at last FU – *N* (%)	83 (64.8)	74 (64.9)	57 (70.4)	90 (68.7)	119 (71.2)	423 (67.5)
Engel non-Ia outcome at last FU – *N* (%)	45 (35.2)	40 (35.1)	24 (29.6)	41 (31.3)	48 (28.8)	198 (32.5)
Major complications – *N* (%)	4 (3.1)	1 (0.8)	4 (4.9)	6 (4.6)	7 (4.2)	22 (3.5)
	Children (8 centers)					**Total in 5 years**
Unilobar temporal surgeries	51	35	37	28	40	191 (30.9%)
Unilobar extratemporal surgeries	45	48	52	57	44	246 (39.8%)
Multilobar surgeries	23	24	17	25	19	108 (17.5%)
Hemispheric surgeries	11	21	8	14	19	73 (11.8%)
Total surgeries per year	*130*	*128*	*114*	*124*	*122*	*618*
Unrevealing MRI surgeries	4	6	3	3	4	20 (3.2%)
Callosotomies	0	0	1	1	0	2
VNS	25	17	28	24	24	118
DBS	0	0	0	0	0	0
Stereo-EEG/subdural grids	25	19	19	26	22	111 (17.9%)
Engel Ia outcome at last FU – *N* (%)	90 (70.3)	90 (72.0)	78 (69.1)	90 (72.6)	85 (71.4)	433 (71.1)
Engel non-Ia outcome at last FU – *N* (%)	38 (29.7)	35 (28.0)	35 (30.9)	34 (27.4)	34 (28.6)	176 (28.9)
Major complications – *N* (%)	3 (2.3)	0 (0.0)	6 (5.3)	4 (3.2)	5 (4.1)	18 (2.9)

Note: Changes in surgical volumes and complications, and seizure outcomes between 2018 and 2022, that is, before and after the COVID-19 pandemic in Italy.

Abbreviations: DBS, deep brain stimulation; FU, follow-up; VNS, vagus nerve stimulation.

All centers perform FDG-PET only in select cases, that is, unrevealing brain MRI or ill-defined lesions, some in associated nuclear medicine centers, with six (75.0%) performing it also under sedation. Brain SPECT is performed in only one center.

Genetic testing

Four centers perform genetic testing on blood in all patients, and four only in select cases, that is, family history of epilepsy, personal history of febrile seizures, or malformation of cortical development (MCD). Genetic testing on brain tissue is performed in all cases in one center and in select cases in five centers (suspected FCD or hemimegaloencephaly or MOGHE). Genetic testing on electrode-derived material and cerebrospinal fluid (CSF) are performed for research purposes in only two centers (Table 1).

Neuropsychological assessment

All centers but one assess the intellectual quotient (IQ)/developmental quotient (DQ) in all patients, whereas all centers test specific functions such as memory, language, attention and executive functions in selected patients depending on the EZ localization, age, and cooperation. All centers but one administer the Child Behavior Checklist (CBCL), five in all patients and two in those with behavioral problems, and all but one carry out a complete neuropsychiatric evaluation but with great variability concerning the tools and measures utilized.

Wada test is available in four centers in select cases, that is, cooperative patients in which fMRI and/or MEG has not allowed the lateralization of language to be defined (Table 1).

3.2.3 | Surgery

Types of surgeries

All centers perform lesionectomies and antero-mesial temporal lobectomies, neocortical resections (seven centers), hemispherotomies (seven centers), unilobar/multilobar disconnections (six centers), and multilobar resections (five centers). Only two centers carry out endoscopic disconnections. Four centers perform RF-THC and three perform LiTT. Six centers perform VNS; five centers carry out callosotomy and one performs DBS (Table 2).

All centers use IOM, including ECoG in case of proximity of the epileptogenic lesion and/or EZ to eloquent areas. In addition, four centers each perform intraoperative Stereo-EEG and awake surgery. Five centers use iUS, four use intraoperative CT scan, and two use intraoperative MRI (Table 1).

Histopathology

Histopathology is carried out by a general neuropathologist and by a neuropathologist specifically dedicated to epilepsy surgery in two centers each, whereas the remaining four centers have a general pathologist dedicated to epilepsy (Table 1).

3.2.4 | Postoperative follow-up

All centers perform at least one postoperative MRI and one neuropsychological evaluation after surgery. Seven centers perform a postoperative video-EEG (in five centers in all cases and in two centers in case of seizure recurrence or of specific epilepsy syndromes such as epileptic spasms), and six centers perform at least a postoperative EEG. LTM is performed in all patients in two centers and in case of recurrence in the remaining six. Six centers carry out postsurgical neuropsychiatric evaluation (two only in selected cases, i.e., when there is evidence of behavioral problems) with the same protocol used for the preoperative evaluation (Table 1). Postoperative rehabilitation is available, when needed, in four centers.

3.2.5 | Volumes of surgical activity between 2018 and 2022

Regarding curative surgeries, we collected data from 618 children (range 114–130 per year) (Figure S1). Engel class Ia outcome was achieved in 71.1% of patients at last follow-up, whereas the percentage of major complications was 2.9%.

The most frequent type of curative surgery was unilobar extratemporal (246 patients, 39.8%) followed by unilobar temporal (191 patients, 30.9%), multilobar (108, 17.5%), and hemispheric surgeries (73, 11.8%). Only 20 patients with unrevealing MRI (3.2%) underwent surgery. Finally, 111 patients (17.9%) underwent Stereo-EEG.

Concerning palliative treatments, two callosotomies, 124 VNS, and no DBS were reported (Table 3).

4 | PRESURGICAL, SURGICAL, AND STAFFING DYNAMICS DURING THE PANDEMIC

All centers suspended elective clinical activity, with most of them providing mainly urgent care based on medical judgment. Due to the need of taking care of both COVID+ and COVID− patients in mixed wards, most centers adjusted their operations. Elective epilepsy surgeries were halted from March to May or September 2020, with only urgent or selected procedures performed. In the second half of 2020, surgery volumes remained below normal but largely resumed by early 2021. In a few centers (two in Northern Italy and one in Central Italy), some medical staff and EEG technicians were reassigned to COVID wards. Presurgical evaluations, especially LTM, decreased by about 15% overall and by 23.3% in northern centers during 2020. Invasive presurgical evaluations (mainly Stereo-EEG) dropped by up to 48%, especially in northern and adult centers. There was a significant increase in waiting times for presurgical evaluation in all centers. The waiting lists for surgical interventions were also delayed, although the increase was not statistically significant. Both presurgical and surgical waiting times lengthened more notably in centers treating adults or both adults and children compared to centers treating only children. This trend was more pronounced in northern than in central-southern regions (see Table S1 for details).

TABLE 4 Trends in volume of surgeries, seizure outcome and complications between 2018 and 2022 at epilepsy surgery centers.

	2018	2020	2021	2022	Adults
No. total surgeries	1.07 (0.89–1.27) $p=0.474$	0.81 (0.67–0.97) **$p=0.025$**	1.05 (0.88–1.26) $p=0.560$	1.19 (1.01–1.42) **$p=0.042$**	1.00 (0.90–1.12) $p=0.932$
No. unilobar T surgeries	1.18 (0.91–1.53) $p=0.219$	1.10 (0.83–1.47) $p=0.519$	1.06 (0.81–1.38) $p=0.676$	1.17 (0.91–1.51) $p=0.215$	2.03 (1.71–2.42) **$p<0.0001$**
No. unilobar ExtraT surgeries	0.88 (0.63–1.22) $p=0.429$	1.12 (0.81–1.55) $p=0.494$	1.08 (0.79–1.47) $p=0.637$	0.93 (0.68–1.28) $p=0.661$	0.53 (0.43–0.65) **$p<0.0001$**
No. multilobar surgeries	1.16 (0.76–1.77) $p=0.489$	0.87 (0.54–1.43) $p=0.606$	0.96 (0.61–1.49) $p=0.851$	0.88 (0.57–1.37) $p=0.571$	0.80 (0.60–1.06) $p=0.114$
No. hemispheric surgeries	0.43 (0.22–0.85) **$p=0.015$**	0.47 (0.23–0.95) **$p=0.035$**	0.63 (0.34–1.16) $p=0.141$	0.69 (0.38–1.24) $p=0.213$	0.18 (0.10–0.32) **$p<0.0001$**
No. surgeries in pts with unrevealing MRI	0.87 (0.45–1.65) $p=0.660$	0.90 (0.45–1.83) $p=0.778$	0.67 (0.34–1.33) $p=0.253$	0.75 (0.40–1.42) $p=0.378$	3.19 (1.93–5.29) **$p<0.0001$**
Engel Ia outcome	0.99 (0.80–1.23) $p=0.928$	1.02 (0.81–1.28) $p=0.866$	1.04 (0.84–1.29) $p=0.697$	1.05 (0.85–1.28) $p=0.675$	0.97 (0.85–1.11) $p=0.654$
Major surgical complications	6.54 (0.80–53.12) $p=0.079$	12.54 (1.60–98.00) **$p=0.016$**	9.41 (1.21–73.56) **$p=0.033$**	9.85 (1.28–75.84) **$p=0.028$**	1.20 (0.64–2.26) $p=0.560$

Note: Statistical analysis indicates a significant decrease in the total number of operations, particularly hemispheric interventions, between 2019 and 2020, along with a significant increase in complications in all the years compared to 2019. Trends between 2018 and 2022 are referred to calendar year 2019. Trend in adults are referred to those in children. Significant results are in bold.

Abbreviations: ExtraT, extratemporal; Pts, patients; T, temporal.

5 | STATISTICAL RESULTS

Table 4 shows that as far as the temporal trend is concerned, a significant decrease is observed in the total number of operations and, specifically, in the number of hemispheric interventions between 2019 and 2020. Significant increases in complications are observed in all years, with 2020 recording the most negative trend (IRR = 12.54). Seizure outcome remained stable over time.

When comparing adults and children, independently from the temporal effect, the total number of the extratemporal unilobar and hemispheric surgeries was higher in children, whereas unilobar temporal resections and interventions with unrevealing MRI findings were more frequent in adults.

As shown in Table S2, the number of surgical interventions was significantly higher in the northern macro area compared to central-southern regions. Multilobar surgeries and procedures in patients with non-revealing MRI findings were significantly more frequent in the northern regions, whereas unilobar extratemporal resections were relatively more common in the central-southern areas. No statistically significant differences were found between the two macro areas for the remaining surgical variables (see Table S2).

In addition, our sub-analysis demonstrated a slightly more pronounced decline in the volumes of surgeries after COVID in Northern Italy compared to the central-southern regions (see Table S3).

6 | DISCUSSION

This study is the report of a nationwide survey aiming to assess the current common practice in epilepsy surgery in Italy and the impact of the COVID-19 pandemic on epilepsy surgery activities after this emergency.

The survey identified 11 centers equipped with a comprehensive epilepsy surgery program. More centers treat children than adults and most of them are located in Northern and Central Italy. This confirms the trends described in a previous survey on pediatric epilepsy surgery in Italy,[21] with possible limited access or delayed referral of patients from Southern Italy and the main islands.

Presurgical evaluation varies considerably across centers, except for basal EEG investigations and structural neuroimaging acquisition protocols. LTM is available at all centers and usually performed before surgery, although some centers only use it when history, imaging, and/or interictal EEG are not concordant. Advanced EEG investigations, such as HDEEG or MEG, are available in a minority of centers, mostly for research purposes.

All centers own advanced equipment for morphological and functional neuroimaging acquisition, while in most cases metabolic studies (FDG-PET) are carried out in associated centers, due to the lack of on-site medicine nuclear facilities. Standardized protocols are utilized for morphological MRI and PET scans, whereas there is more variability for fMRI and diffuse tensor imaging (DTI) protocols. Other advanced techniques (i.e., image post-processing, EEG-fMRI, and SPECT) are available in only a few centers.

Genetic testing is performed only in select cases in most centers and mainly on blood samples. Array-comparative genomic hybridization (Array-CGH) and next-genome sequencing (NGS) for the epilepsy genes are the most common types of genetic investigations; however, there is an increased use of exome sequencing. This finding is in line with recent studies[22,23] indicating that genetic testing is not yet systematically included in the pre-surgical assessment of patients with drug-resistant focal epilepsies, despite its potential implications for surgical planning and prognostication.

Neuropsychological and psychiatric protocols for evaluating cognitive functions and behavioral disorders vary widely in terms of the tests used and the functions assessed, mainly based on patient's age, type of surgery most frequently performed at the center, and local expertise. In recent years, national and international recommendations have been published on best practices for the neuropsychological and behavioral assessment in surgical candidates, especially in children.[3,24–26] However, challenges such as limited resources—in particular, the lack of neuropsychologists and psychiatrists with expertise in epilepsy surgery and of appropriate facilities for in-person evaluations—along with the need for multiple hospital visits and the impact of geographical distance, make it difficult to conduct comprehensive assessments in both the pre-surgical and post-surgical phases. In this context, teleconsultation could be a promising opportunity to provide regular evaluations for people with epilepsy.

We confirmed a different distribution of the types of surgeries among children and adults, with a consequent different impact of the COVID-19 pandemic. This may also be explained partly by the fact that adults were disproportionately affected by COVID compared to children. The higher number of unilobar extratemporal surgeries in children is in line with previous reports[6] and may be partly related to the preferential location of the most common etiologies in pediatric surgical candidates.

We observed a significant decrease in the total number of curative surgeries during 2020 compared to 2019, especially hemispheric surgeries, together with an increase in the percentage of complications and a general stability of seizure outcome. By 2021, the number of interventions started to recover. However, as shown in Table 3 and Figure S1, this recovery was driven mainly by an increase in temporal lobe epilepsy surgeries, especially in adults, whereas in children, the number of multilobar and hemispheric surgeries remained below 2019 figures. Invasive recordings also decreased during the COVID pandemic, with a more substantial reduction in adults than in children. Conversely, the impact on VNS was less evident, probably due to the minimally invasive nature of this surgical procedure.

We analyzed possible reasons for the observed reduction in surgical volume activities including the reduction in epilepsy referral, prolongation of waiting lists for presurgical evaluation and surgeries, and changes in the medical workforce. During the early phase of the pandemic, all centers suspended elective clinical and surgical activities, maintaining only urgent care based on medical judgment, and adapted workflows to manage both COVID+ and COVID− patients in shared wards. The mean waiting list for presurgical evaluation and surgery were notably delayed. Taken together, these data suggest that the reduction of volume activity was primarily due to decreased referrals driven by prioritization toward urgent procedures and subsequent delayed wait times rather than a simplification of presurgical evaluation process or reduced personnel availability. The stability of seizure outcome over time supports this interpretation.

In addition, we observed differences in trends between Northern and Central-Southern Italy, which appear to be driven more by the markedly uneven impact of the COVID-19 pandemic across regions than by inherent disparities in regional health care infrastructure. In fact, northern regions—particularly Lombardy, Emilia-Romagna, and Veneto—were hit significantly harder than central and southern areas. For instance, as of mid-2020, Lombardy alone accounted for over 35% of the country's total COVID-19 cases and nearly 50% of deaths, whereas southern regions reported much lower incidence and mortality rates.[15]

Overall, our results suggest a prioritization of less complex cases to help restore surgical volumes. We also observed that complication rates increased in 2020 compared to year 2019, which may be partly related to the multiple challenges encountered in Italian hospitals during the COVID period. In particular, delays in surgical scheduling and prioritization of urgent cases during the pandemic may have contributed to these figures.

Finally, our data confirm that epilepsy surgery is still an underused treatment, despite being the best treatment option for many patients with DRE.[27–29] Despite an estimated 180 000 patients with DRE in Italy, only a small number are treated in surgical centers each year.[30] Different types of barriers to proper referral do exist, from misconception to economic issues.[1,5,7,31] The COVID-19 pandemic further increased the under-referral to epilepsy surgery in Italy, one of the most affected countries by the pandemic.[8–14,32]

7 | CONCLUSION

This study is limited by its retrospective nature, the heterogeneity of collected data, and the relatively short observation period. Although some neurosurgical centers with no established epilepsy surgery programs were not included in this survey, our results represent the most complete Italian report to date. This survey describes the impact of the COVID-19 outbreak on epilepsy surgery activity in Italy, highlighting a transient decrease in surgical volumes and complexity and an increase in postoperative complications. However, by 2021, we observed a gradual recovery of pre-COVID figures, as reflected in current advanced presurgical and postsurgical evaluation protocols and stable good surgical results, which align with international practices.

AUTHOR CONTRIBUTIONS

Conception and design of the study: Giuseppe Didato, Carmen Barba, and Federico Vigevano. *Data acquisition*: Giuseppe Didato, Laura Tassi, Luca De Palma, Giancarlo Di Gennaro, Alfredo D'Aniello, Lino Nobili, Matteo Martinoni, Stefano Meletti, Domenica Battaglia, Elisabetta Cesaroni, Roberta Vittorini, Giuseppe d'Orsi, Robertino Dilena, Valeria Pingue, Federica Ranzato, Claudio Zucca, Paolo Bonanni, Elena Freri, Flavio Villani, and Carmen Barba. *Data analysis, drafting of the manuscript, and preparation of the figures*: Giuseppe Didato, Carmen Barba, and Laura Grisotto. *Statistical analysis*: Laura Grisotto. All other authors contributed to reviewing the text and approved the final version of the manuscript.

AFFILIATIONS

[1]Epilepsy Unit, Fondazione IRCCS Istituto Neurologico Carlo Besta, Milan, Italy
[2]Department of Paediatric Neurorehabilitation, IRCCS San Raffaele, Rome, Italy
[3]"C. Munari" Epilepsy Surgery Center, Niguarda Hospital, Milan, Italy
[4]Pediatric Neurology Unit, Neuroscience and Human Genetics Department, Meyer Children's Hospital IRCCS, Florence, Italy
[5]Neurofarba Department, University of Florence, Florence, Italy
[6]Neurology, Epilepsy and Movement Disorders Unit, Bambino Gesù Children's Hospital, IRCCS, Full Member of European Reference Network EpiCARE, Rome, Italy
[7]IRCCS NEUROMED, Pozzilli, Italy
[8]Child Neuropsychiatry Unit, Full Member of European Reference Network EpiCARE, IRCCS Istituto Giannina Gaslini, Genoa, Italy
[9]Department of Neurosciences, Rehabilitation, Ophthalmology, Genetics and Maternal and Child Health (DINOGMI), University of Genova, Genoa, Italy
[10]Division of Neurosurgery, IRCCS Istituto Delle Scienze Neurologiche di Bologna, Bologna, Italy
[11]IRCCS Istituto Delle Scienze Neurologiche di Bologna, Full Member of the European Reference Network for Rare and Complex Epilepsies EpiCARE, Bologna, Italy
[12]Department of Biomedical, Metabolic, and Neural Sciences, University of Modena and Reggio Emilia, Modena, Italy
[13]Neuroscience Department, Neurophysiology Unit and Epilepsy Centre, AOU Modena, Modena, Italy
[14]Pediatric Neurology, Department of Woman and Child Health and Public Health, Child Health Area, Fondazione Policlinico Universitario Agostino Gemelli, IRCCS, Rome, Italy
[15]Catholic University of the Sacred Heart, Rome, Italy
[16]U.O.Child Neurology and Psychiatric Unit, Pediatric Hospital G. Salesi, AOU delle Marche, Ancona, Italy
[17]SSD Neurologia Pediatrica, AOU Città Della Salute e Della Scienza di Torino, Turin, Italy
[18]Department of Environmental Science and Prevention, University of Ferrara, Ferrara, Italy
[19]Neurology Unit, Fondazione IRCCS Casa Sollievo Della Sofferenza, San Giovanni Rotondo, FG, Italy
[20]Neurophysiopathology Unit, Fondazione IRCCS Ca' Granda Ospedale Maggiore Policlinico, Milan, Italy
[21]Department of Clinical-Surgical, Diagnostic and Pediatric Sciences, University of Pavia, Pavia, Italy
[22]Istituti Clinici Scientifici Maugeri IRCCS, Neurorehabilitation and Spinal Units of Pavia Institute, Pavia, Italy
[23]Centro per la Diagnosi e Il Trattamento Delle Epilessie, Vicenza, Italy
[24]Clinical Neurophysiology Unit, Scientific Institute IRCCS E. Medea, Bosisio Parini, Italy
[25]Epilepsy and Clinical Neurophysiology Unit, Scientific Institute, IRCCS Eugenio Medea, Treviso, Italy
[26]Division of Neurophysiology and Epilepsy Centre, IRCCS San Martino Policlinic Hospital, Genoa, Italy
[27]Pediatric Neurosurgery, Institute of Neurosurgery, Fondazione Policlinico Gemelli, IRCCS, Università Cattolica del Sacro Cuore, Rome, Italy
[28]Department of Hospital Neurosurgery, AOU Ospedali Riuniti, Ancona, Italy
[29]Division of Neuroradiology, Department of Diagnostic Imaging and Radiotherapy, "Città Della Salute E Della Scienza" University Hospital, Turin, Italy
[30]Department of Neurosciences, University of Turin, Turin, Italy
[31]Department of Biomedical and NeuroMotor Sciences (DIBINEM), University of Bologna, Bologna, Italy
[32]Pediatric Neurosurgery Unit, IRCCS Istituto Giannina Gaslini, Genoa, Italy
[33]Department of Human Neurosciences "Sapienza" University of Rome, Rome, Italy
[34]Department of Pediatric Neuroscience, Fondazione IRCCS Istituto Neurologico Carlo Besta, Milan, Italy
[35]Neurosurgery Unit, Bambino Gesù Children's Hospital, IRCCS, Rome, Italy
[36]Center of Epilepsy Surgery, Functional and Stereotactic Neurosurgery—Neuroscience and Medical Genetics Department, Meyer Children's Hospital IRCCS, Florence, Italy
[37]University Hospitals KU Leuven, Leuven, Belgium
[38]Unit of Neurosurgery, Foundation IRCCS Ca' Granda Ospedale Maggiore Policlinico, Milan, Italy
[39]Functional Neurosurgery Unit, Department of Neurosurgery Fondazione, IRCCS Istituto Neurologico Carlo Besta, Milan, Italy

ACKNOWLEDGMENTS

This work was supported by the Italian National Virtual Epilepsy Institute, of the Neurosciences and Rehabilitation IRCCS Network and the Commission of Epilepsy Surgery of the Italian League against Epilepsy. L.D.P. and N.S. were also supported by Current Research Funds of Italian Ministry of Health. Open access funding provided by BIBLIOSAN.

CONFLICT OF INTEREST STATEMENT

None of the authors has any conflict of interest to disclose. We confirm that we have read the Journal's position on issues involved in ethical publication and affirm that this report is consistent with those guidelines.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

Giuseppe Didato https://orcid.org/0000-0002-4812-6310
Federico Vigevano https://orcid.org/0000-0001-7513-0051
Renzo Guerrini https://orcid.org/0000-0002-7272-7079
Marco de Curtis https://orcid.org/0000-0001-7443-6737
Lino Nobili https://orcid.org/0000-0001-9317-5405
Stefano Meletti https://orcid.org/0000-0003-0334-539X
Valeria Pingue https://orcid.org/0000-0001-9376-4699
Michela Quintiliani https://orcid.org/0000-0002-8278-6953
Francesca Bisulli https://orcid.org/0000-0002-1109-7296
Elena Pasini https://orcid.org/0000-0001-6298-455X
Alessandro Consales https://orcid.org/0000-0002-4354-6906
Nicola Specchio https://orcid.org/0000-0002-8120-0287
Umberto Costantino https://orcid.org/0000-0003-2325-4137
Michele Rizzi https://orcid.org/0000-0002-7936-6536
Carmen Barba https://orcid.org/0000-0001-5445-5842

REFERENCES

1. Engel J. The current place of epilepsy surgery. Current opinion in neurology. 2018;31:192–7.
2. Cross JH, Jayakar P, Nordli D, Delalande O, Duchowny M, Wieser HG, et al. Proposed criteria for referral and evaluation of children for epilepsy surgery: recommendations of the subcommission for pediatric epilepsy surgery. Epilepsia. 2006;47(6):952–9.
3. Guerrini R, Scerrati M, Rubboli G, Esposito V, Colicchio G, Cossu M, et al. Overview of presurgical assessment and surgical treatment of epilepsy from the Italian league against epilepsy. Epilepsia. 2013;54:35–48.
4. Jayakar P, Gaillard WD, Tripathi M, Libenson MH, Mathern GW, Cross JH. Diagnostic test utilization in evaluation for resective epilepsy surgery in children. Epilepsia. 2014;55(4):507–18.
5. Baud MO, Perneger T, Rácz A, Pensel MC, Elger C, Rydenhag B, et al. European trends in epilepsy surgery. Neurology. 2018;91(2):e96–e106.
6. Barba C, Cross JH, Braun K, Cossu M, Klotz KA, De Masi S, et al. Trends in pediatric epilepsy surgery in Europe between 2008 and 2015: country-, center-, and age-specific variation. Epilepsia. 2020;61(2):216–27.
7. Samanta D, Singh R, Gedela S, Scott Perry M, Arya R. Underutilization of epilepsy surgery: part II: strategies to overcome barriers. Epilepsy and behavior. 2021;117:107853.
8. Granata T, Bisulli F, Arzimanoglou A, Rocamora R. Did the COVID-19 pandemic silence the needs of people with epilepsy? Epileptic Disord. 2020;22(4):439–42.
9. Noureldine MHA, Pressman E, Krafft PR, Greenberg MS, Agazzi S, van Loveren H, et al. Impact of the COVID-19 pandemic on neurosurgical practice at an academic tertiary referral center: a comparative study. World Neurosurg. 2020;139:e872–e876.
10. Wirrell EC, Grinspan ZM, Knupp KG, Jiang Y, Hammeed B, Mytinger JR, et al. Care delivery for children with epilepsy during the COVID-19 pandemic: an international survey of clinicians. J Child Neurol. 2020;35(13):924–33.
11. Agrawal M, Tripathi M, Samala R, Doddamani R, Ramanujan B, Chandra PS. Epilepsy surgery in COVID times-a unique conundrum. Childs Nerv Syst. 2021;37:3219–24. https://doi.org/10.1007/s00381-021-05048-4
12. Kuroda N. Epilepsy and COVID-19: updated evidence and narrative review. Epilepsy Behav. 2021;116:107785.
13. Kuroda N, Kubota T, Horinouchi T, Ikegaya N, Kitazawa Y, Kodama S, et al. Impact of COVID-19 pandemic on epilepsy care in Japan: a national-level multicenter retrospective cohort study. Epilepsia Open. 2022;7(3):431–41.
14. Ahrens SM, Ostendorf AP, Lado FA, Arnold ST, Bai S, Bensalem-Owen MK, et al. Impact of the COVID-19 pandemic on epilepsy center practice in the United States. Neurology. 2022;98(19):E1893–E1901.
15. https://www.salute.gov.it/portale/nuovocoronavirus/dettaglioContenutiNuovoCoronavirus.jsp?area=nuovoCoronavirus&id=5351&lingua=italiano&menu=vuoto.
16. Engel J Jr. VNPRTOLM. Outcome with respect to epileptic seizures. In: Engel J Jr, editor. Surgical treatment of the epilepsies. New York: Raven Press; 1993. p. 609–21.
17. D'Orio P, Rizzi M, Mariani V, Pelliccia V, Lo Russo G, Cardinale F, et al. Surgery in patients with childhood-onset epilepsy: analysis of complications and predictive risk factors for a severely complicated course. J Neurol Neurosurg Psychiatry. 2019;90(1):84–9.
18. Bernasconi A, Cendes F, Theodore WH, Gill RS, Koepp MJ, Hogan RE, et al. Recommendations for the use of structural magnetic resonance imaging in the care of patients with epilepsy: a consensus report from the international league against epilepsy neuroimaging task force. Epilepsia. 2019;60(6):1054–68.
19. Huppertz HJ, Grimm C, Fauser S, Kassubek J, Mader I, Hochmuth A, et al. Enhanced visualization of blurred gray–white matter junctions in focal cortical dysplasia by voxel-based 3D MRI analysis. Epilepsy Res. 2005;67(1–2):35–50.
20. Genovese M, Arcasensa A, Morbelli S, Lenge M, Barba C, Mirandola L, et al. SWANe: standardized workflow for advanced neuroimaging in epilepsy. SoftwareX. 2024;26:101703.
21. Barba C, Specchio N, Guerrini R, Tassi L, De Masi S, Cardinale F, et al. Increasing volume and complexity of pediatric epilepsy surgery with stable seizure outcome between 2008 and 2014: a nationwide multicenter study. Epilepsy Behav. 2017;75:151–7.
22. Moloney PB, Dugan P, Widdess-Walsh P, Devinsky O, Delanty N. Genomics in the presurgical epilepsy evaluation. Epilepsy Res. 2022;184:106951.
23. Straka B, Splitkova B, Vlckova M, Tesner P, Rezacova H, Krskova L, et al. Genetic testing in children enrolled in epilepsy surgery program. A real-life study. Eur J Paediatr Neurol. 2023;47:80–7.

24. Laguitton V, Boutin M, Brissart H, Breuillard D, Bilger M, Forthoffer N, et al. Neuropsychological assessment in pediatric epilepsy surgery: a French procedure consensus. Rev Neurol. 2024;180(6):494–506.
25. Baxendale S, Wilson SJ, Baker GA, Barr W, Helmstaedter C, Hermann BP, et al. Indications and expectations for neuropsychological assessment in epilepsy surgery in children and adults: report of the ILAE neuropsychology task force diagnostic methods commission: 2017–2021 neuropsychological assessment in epilepsy surgery. Epileptic Disord. 2019;21(3):221–34.
26. Consales A, Casciato S, Asioli S, Barba C, Caulo M, Colicchio G, et al. The surgical treatment of epilepsy. Neurol Sci. 2021;42:2249–60. https://doi.org/10.1007/s10072-021-05198-y
27. Erba G, Moja L, Beghi E, Messina P, Pupillo E. Barriers toward epilepsy surgery. A survey among practicing neurologists. Epilepsia. 2012;53:35–43.
28. Kaiboriboon K, Malkhachroum AM, Zrik A, Daif A, Schiltz NM, Labiner DM, et al. Epilepsy surgery in the United States: analysis of data from the National Association of epilepsy centers. Epilepsy Res. 2015;116:105–9.
29. Engel J. What can we do for people with drug-resistant epilepsy? Neurology. 2016;87(23):2483–9.
30. https://www.reteneuroscienze.it/epilessia-priorita-non-eludibile-600-mila-casi-solo-in-italia/
31. Hatoum R, Nathoo-Khedri N, Shlobin NA, Wang A, Weil AG, Fallah A. Barriers to epilepsy surgery in pediatric patients: a scoping review. Seizure. 2022;102:83–95.
32. Germanò A, Raffa G, Angileri FF, Cardali SM, Tomasello F. Coronavirus disease 2019 (COVID-19) and neurosurgery: literature and neurosurgical societies recommendations update. World Neurosurg. 2020;139:e812–e817.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Didato G, Vigevano F, Tassi L, Guerrini R, de Curtis M, De Palma L, et al. Trends in epilepsy surgery in Italy before and after the COVID-19 pandemic: A nationwide study. Epilepsia. 2025;66:4183–4197. https://doi.org/10.1111/epi.18558

APPENDIX A

Italian Epilepsy Surgery Collaborative Group: Roberta Di Giacomo: Epilepsy Unit, Fondazione IRCCS Istituto Neurologico Carlo Besta, Milan, Italy; Roberto Mai: "C. Munari" Epilepsy Surgery Center, Niguarda Hospital, Milan, Italy; Francesca Gozzo: "C. Munari" Epilepsy Surgery Center, Niguarda Hospital, Milan, Italy; Claudia Accolla: Pediatric Neurology Unit, Neuroscience and Human Genetics Department, Meyer Children's Hospital IRCCS, Florence, Italy; Elena Cavallini: Pediatric Neurology Unit, Neuroscience and Medical Genetics Department, Meyer Children's Hospital IRCCS, Florence, Italy; Neurofarba Department, University of Florence, Florence, Italy; Alfredo D'Aniello: IRCCS NEUROMED, Pozzilli (IS), Italy; Chiara Panzini: IRCCS NEUROMED, Pozzilli (IS), Italy; Stefano Francione: Child Neuropsychiatry Unit, Full Member of European Reference Network EpiCARE, IRCCS Istituto Giannina Gaslini, Genova, Italy; Lorenzo Ferri: IRCCS Istituto delle Scienze Neurologiche di Bologna, full member of the European Reference Network for Rare and Complex Epilepsies EpiCARE, Bologna, Italy; Department of Biomedical and NeuroMotor Sciences (DIBINEM), University of Bologna, Bologna, Italy; Lidia Di Vito: IRCCS Istituto delle Scienze Neurologiche di Bologna, full member of the European Reference Network for Rare and Complex Epilepsies EpiCARE, Bologna, Italy; Giada Giovannini: Neurophysiology Unit and Epilepsy Centre, Neuroscience Department, AOU Modena, Modena, Italy; Niccolò Orlandi: Neurophysiology Unit and Epilepsy Centre, Neuroscience Department, AOU Modena, Modena, Italy; Federico Bianchi: Pediatric Neurology, Department of Woman and Child Health and Public Health, Child Health Area, Fondazione Policlinico Universitario Agostino Gemelli, IRCCS, Rome Italy; Massimo Valerio: SSD Neurologia Pediatrica, AOU Città della Salute e della Scienza di Torino, Turin, Italy; Nicoletta Zanotta: Clinical Neurophysiology Unit, Scientific Institute IRCCS E. Medea, Bosisio Parini, Italy; Gianmarco Duma: Epilepsy and Clinical Neurophysiology Unit, Scientific Institute, IRCCS Eugenio Medea, Conegliano, Treviso, Italy; Irene Pappalardo: Division of Neurophysiology and Epilepsy Centre, IRCCS San Martino Policlinic Hospital, Genoa, Italy; Alessandro De Benedictis: Neurosurgery Unit, Bambino Gesù Children's Hospital, IRCCS, Rome, Italy; Marco Locatelli: Unit of Neurosurgery, Foundation IRCCS Ca′ Granda Ospedale Maggiore Policlinico, 20122 Milan, Italy; Domenico Tortora: Neuroradiology Unit, IRCCS Istituto Giannina Gaslini, Genoa, Italy; Maria Camilla Rossi Espagnet: Neuroradiology Unit, Bambino Gesù Children's Hospital, IRCCS, Rome, Italy; Ernesto Losavio: Istituti Clinici Scientifici Maugeri-IRCCS, Institute of Bari, Via Generale Bellomo 73/75, 70124 Bari, Italy; Luigi Giovanni Manfredi: Parkinson's Disease and Movement Disorders Center, Neurology Service, Humanitas San Pio X, Milan, Italy; Pietro Zeppa: S.C. Neurochirurgia Pediatrica, AOU Città della salute e della Scienza di Torino, Turin, Italy; Filomena Fuggetta: Department of Neurosurgery, Fondazione Policlinico Universitario Agostino Gemelli

IRCCS, 00168 Rome, Italy; Massimo Carella: Division of Medical Genetics, Fondazione IRCCS Casa Sollievo della Sofferenza—S. Giovanni Rotondo (Fg); Paola Mattaliano: Department of Cardiovascular, Neural and Metabolic Sciences, IRCCS Istituto Auxologico Italiano, Milan, Italy; Anna Bellini: Neurophysiology Service, Istituto di Ricovero e Cura a Carattere Scientifico (IRCCS) Ospedale San Raffaele, Milan, Italy and Neurology Unit, Istituto di Ricovero e Cura a Carattere Scientifico (IRCCS) Ospedale San Raffaele, Via Olgettina, 60, 20132, Milan, Italy.