COST OF PRESURGICAL EVALUATION FOR EPILEPSY SURGERY: A SINGLE-CENTER EXPERIENCE

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Abstract

Objective: To estimate the cost and time taken to evaluate adults with drug-resistant focal epilepsy for potentially curative surgery.

Methods: We reviewed data on 100 consecutive individuals at a tertiary referral center evaluated for epilepsy surgery in 2017. The time elapsed between referral and surgery or a definitive decision not to progress was measured. National Health Service tariffs applicable to our setting were used to estimate the total cost of evaluation for individuals following different routes through the pre-surgical pathway. After surgery, self-reported seizure freedom rates were obtained from each individual to assess the approximate cost of pre-surgical evaluation per additional person seizure-free.

Results: Of 100 individuals evaluated, 27 had surgery, 63 had a definitive decision not to have surgery, and ten were awaiting further investigations. The median duration of the pre-surgical evaluation was 29.7 months (IQR 18.6-44.1 months), with a median cost per person of £9,138 (IQR £6,984-£14,868). Those who proceeded to Stage Two investigations (including fluorodeoxyglucose positron emission tomography, ictal single-photon emission computerised tomography and intracranial electroencephalography) had a higher cost and extended evaluation length. After a median of 3.1 (IQR 2.3-3.7) years, 15/27 people who had surgery were seizure-free. This equated to an approximate cost of £123,500 spent per additional person seizure-free.

Conclusion: Pre-surgical evaluation is long and costly, particularly for those who require icEEG. For those with drug-resistant focal epilepsy, surgery is, however, associated with a greater chance of seizure freedom. The suitability and risk-benefit ratio of surgery should be considered at each step of the pre-surgical pathway.

Key Words: Tariff, healthcare cost, intracranial EEG

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Introduction

Surgery in selected people with drug-resistant focal epilepsy is effective. (1) The cost-effectiveness of surgery, mainly if it results in seizure freedom, has also been shown in longitudinal studies of temporal lobe epilepsy. (2-4) In these cases, reduced health expenditures offset the cost of surgery, with cost-time curves intersecting at approximately 8.5 years postoperatively. (3) There are limited data on the cost-effectiveness of surgery in extratemporal epilepsy, although approximately 40% of these individuals will also experience long-term seizure freedom. (5)

Pre-surgical evaluation to determine surgical suitability is a lengthy undertaking. (6) This is particularly so for those with extratemporal epilepsy, normal brain MRI or when imaging and electrophysiological data are discordant. The average time between initial review in an epilepsy service to surgery is between 14 and 46 months, reflecting the requirement for multiple stages of the investigation, reflection and input from a multidisciplinary team. (6-8)

It has been suggested that pre-surgical evaluation is cost-effective if the chance of proceeding to surgery is 5%. (9) This study did not, however, include extratemporal epilepsy or those requiring intracranial electroencephalography (icEEG), associated with less likely surgical suitability. (10) Intracranial EEG monitoring is a costly procedure requiring highly specialised input in the implantation and interpretation of intracranial electrodes, in addition to increased nursing and neurophysiological support on a video-EEG telemetry unit. Planning icEEG often requires

additional non-invasive investigations such as fluorodeoxyglucose positron emission tomography (FDG-PET) and ictal Single Photon Emission Computed Tomography (SPECT).

We estimated the costs of pre-surgical evaluation and surgery in a cohort of people at our center, including those requiring intracranial EEG monitoring, and the cost of various routes through the pre-surgical pathway.

Methods

We identified 100 consecutive individuals discussed in the National Hospital for Neurology and Neurosurgery epilepsy pre-surgical multidisciplinary meetings in 2017. Individuals were all adults referred by treating neurologists for consideration of epilepsy surgery. Healthcare records were reviewed to document the total time spent within the surgical pathway. Time of entry into the pathway was defined as the date individuals and treating clinicians discussed surgical treatment and agreed to perform a pre-surgical evaluation. Time of exit was defined as the date of surgery or the date a definitive decision not to proceed to surgery was made.

We identified four principal routes through the pre-surgical pathway (Figure 1). Individuals who had not received a final decision by May 2021 were excluded from the analysis. We classified the remaining individuals to each route through the pathway and reviewed the frequency of different components of the pre-surgical evaluation. Components included neurology and neurosurgical outpatient appointments and Stage One investigations, including MRI brain, language functional MRI, EEG video telemetry, elective day-case admission for neuropsychology, neuropsychiatry, and nursing assessments. Stage Two investigations included FDG-PET, ictal SPECT, additional functional or structural MRI scans, magnetoencephalography (MEG) and icEEG.

National Health Service (NHS) tariffs applicable at our center for each of these components were used to estimate the total cost of pre-surgical evaluation for individuals through each route of the pre-surgical evaluation. Tariffs are not actual costs but reference costs collected from NHS health providers in England each year for finished consultant episodes (FCEs). The NHS defines these FCEs as a continuous period of admitted care under one consultant within one healthcare provider. They reflect the average unit cost to the NHS of providing a defined service in a given financial year. (11) The providers' costings include direct costs such as drugs and clinical staff, indirect expenses such as laundry, and overhead costs such as buildings and staff working in corporate functions. The consideration of all charges in this manner is known as Full Absorption Costing. (11) A list of individual tariffs for components of the pre-surgical evaluation are displayed in Table 1.

The cost of surgical resection, including admission tariffs to the Intensive Care Unit and Neurosurgical ward, was obtained for each individual who had surgery from the Trust charge allocation server. According to the NHS National Tariff Payment System rules, this processes individual hospital activity data.

We obtained information regarding seizure outcomes for individuals who had surgery from our center Surgery Database, including annual updates on seizure occurrence obtained through direct correspondence with individuals, GPs and treating neurologists. Seizure outcomes over the last 12 months in those who did not proceed to surgery were obtained from electronic health records and direct correspondence with individuals and treating clinicians.

We assessed the duration and cost of pre-surgical evaluation for each individual and estimated cost per additional person seizure-free. Associations between these factors and different routes through the pre-surgical pathway were evaluated using Fisher's exact test for dichotomous data and two-sample t-tests of log-transformed data for continuous data with a p-value <0.05 deemed statistically significant. We used SPSS (IBM SPSS Statistics for Windows v20, Armonk, NY) for data analysis.

We used de-identified information collected as part of an audit into epilepsy surgery approved as a service evaluation by University College London Hospitals NHS Trust (registration number 45-202021-SE). As a service evaluation posing no risk, individual informed consent was not required.

Results

Of 100 people discussed in 2017, 27 had surgery (Figure 2), comprising 13 lobar resections and 14 lesionectomies. Eighteen individuals proceeded to surgery after Stage One investigations and MDT discussion (Route 1). Nine required Stage Two investigations before surgery (Route 2), with 4 having icEEG. Sixty-three individuals had a definitive decision not to proceed to surgery, of whom 18 had Stage One investigations only (Route 4) and 45 also had Stage Two investigations (Route 3), with 10 having icEEG. Table 2 shows the baseline characteristics of these individuals. We excluded ten individuals who had not received a final decision regarding surgery from further analysis.

People who had Stage Two investigations (Routes 2 and 3) were more likely to have normal neuroimaging (39% vs 4%, $p<0.001$) and extratemporal epilepsy (70% vs 33%, $p<0.001$) compared to those who did not proceed with these investigations (Routes 1 and 4). All individuals who had

surgery without requiring Stage Two investigations had a lesion on MRI, and 13/18 (72%) had temporal lobe epilepsy (Table 2).

The total estimated cost of evaluating 90 people for surgery was £1,554,015, with a median individual cost of £9,138 (IQR £6,984-£14,868). This included a total of 44 FDG-PET scans, 21 ictal-SPECT scans, 1 MEG and 14 icEEG procedures. The median duration of the pre-surgical evaluation was 30 months (IQR 19-44 months). Those who proceeded to Stage Two investigations (Routes 2 and 3) spent longer under assessment than those who did not (median duration 32.5 vs 28.4 months, $p=0.03$). This was most evident in those who had intracranial EEG as part of their evaluation (median duration 59.9 vs 28.6 months, $p<0.001$). The total cost of the 27 neurosurgical resections, including admission tariffs, was £299,011, with a median cost of £10,200 (range £8,200-£21,200).

Differences in the duration of evaluation and median cost per individual for different routes through the pre-surgical pathway, including costs of resections, are shown in Table 3.

There was no significant difference in the evaluation cost between those who had surgery and those who did not proceed. The median cost of having only Stage One investigations was £7,210 (IQR £6,420-£9,940). Stage Two investigations without icEEG added £1,930 (IQR £816-£1,943). The median evaluation cost for the 14 people who had icEEG was £49,881 (£47,505-£56,188). Of these, 4/14 went on to have surgery, with one person being seizure-free at last follow-up and two others having a >50% reduction in seizure frequency. The remaining ten individuals who had icEEG did not proceed. This was because the seizure onset zone was not adequately localised (n=4), multifocal seizure onset (n=3), declining surgery (n=2), and involvement of eloquent cortex

(n=1). The median cost of evaluation and surgery for those who were seizure-free without having icEEG was £17,960 (IQR £17,240 – £20,890) and £57,970 for the single seizure-free person who had icEEG.

After a median duration of 3.1 (IQR 2.3-3.7) years, 15/27 (56%) individuals who had surgery and 2/63 (3%) of those who did not have surgery reported being seizure-free in the preceding 12 months. The total cost of evaluating 90 people and performing surgery in 27 was £1,853,026. This equated to an approximate cost of £123,500 spent per additional person seizure-free.

Discussion

The evaluation to determine suitability for epilepsy surgery is lengthy, even for those with concordant clinical, imaging and neurophysiological data. This highlights the need to streamline referral for epilepsy surgery and improve access to Stage One investigations such as video EEG telemetry. The pre-surgical evaluation is more extended for those who require Stage Two investigations. At our center, people who required icEEG spent over two years longer in the surgical pathway on average. This emphasises the need to expand capacity to perform icEEG, which is particularly useful for those with normal neuroimaging, extratemporal epilepsy, or a lack of concordance between MRI and scalp EEG. (12)

In this sample, there was a low yield from icEEG, with less than a third of people subsequently proceeding to surgery. This was likely a result of the relatively small sample size and did not reflect the typical utility of this investigation. A recent evaluation at our center noted that 63% of individuals having icEEG proceeded to resection, with 52% being seizure-free (ILAE Outcome Score 1 or 2) at the last follow-up, which is in keeping with data from other centers. (6, 13, 14)

Pre-surgical evaluation's long duration and costs underscore the need to consider the suitability and risk-benefit ratio of surgical treatment with individuals at each step of the pathway. This may help direct the need for investigations more efficiently. For suitable individuals, surgery is much more likely to result in seizure freedom than continued medical treatment. (15) Over half of those referred for surgery, however, do not proceed, and a fifth of those eligible for resection subsequently decline the option. (6) Strategies to identify these people earlier and direct them to alternative treatments such as vagal nerve stimulation and a ketogenic diet may help reduce long waiting times for more suitable individuals.

We have used tariffs as a proxy for cost and have not evaluated the annual healthcare expenditure for individuals with and without surgery. This means that our exercise is not a cost-effectiveness study. Still, it provides a comparative assessment of surgical pathways for people with epilepsy at a specialist tertiary neurosciences center in London. There are several reasons for using a tariff to represent cost. Firstly, ‘cost’ includes indirect costs and hospital overheads that are likely to vary significantly between providers, thus reducing the transferability of findings. Despite fluctuations in tariff payments between providers (such as market forces factors and local agreements), the base tariff provides an average across NHS providers in England. It, therefore, means our study has higher external validity. Secondly, tariffs better represent the cost to the NHS instead of the individual provider, as it considers the average cost of a particular care pathway nationally. This gives a better representation of ‘cost’, i.e. what commissioners have paid for the care, than the cost to an individual provider. As we are only looking at costs within one center, the values chosen to represent cost do not affect the overall outcome and the cost savings identified. Therefore, we can still conclude the relative cost of the pre-surgical evaluation.

Higher costs were seen in those undergoing Stage Two investigations, with a substantial additional tariff for icEEG. Unsurprisingly, these individuals were more likely to have normal neuroimaging and extratemporal epilepsy. Stage Two investigations are often required in this setting to localise the epileptogenic zone accurately. For those with frontal lobe epilepsy, the need for icEEG does not always predict poorer outcomes and is often an essential step for assessing surgical suitability. The highest costs were in those who had Stage One and Two investigations, with icEEG, before proceeding to an operation. Non-invasive Stage Two investigations added approximately £2,000 to the evaluation cost, with the need for icEEG adding about £40,000. This finding reinforces the need to select the most suitable candidates for icEEG carefully.

Seizure freedom is the most critical determinant of the quality of life in epilepsy. (16) It is also a significant determinant of healthcare utilisation costs. (17) Complete seizure freedom after surgery substantially reduces the annual healthcare costs two years after surgery. (2) This is mainly due to progressively reducing anti-seizure medication (ASM) costs and removing the cost of epilepsy-related hospitalisations.

Approximately £120,000 was spent per additional seizure-free individual. Our design does not permit a direct assessment of the cost-effectiveness of epilepsy surgery; however, these figures can be viewed alongside the estimated cost of care for those who are seizure-free (£443/annum) compared with those having at least monthly seizures (£3,508/annum). (18) These annual costs were derived from 1998 data, and current costs are likely much higher. Drug-resistant epilepsy is a common cause of presentation to hospitals, with associated investigation and admission costs. (19, 20) In the United States, epilepsy-attributable direct cost estimates per individual range from

US$8,592 to US$19,749 each year. (21) This does not consider indirect costs, such as lost productivity, which account for up to three-quarters of the total epilepsy cost. (4, 22, 23)

There are limitations to our study, which was retrospective and confined to a single tertiary center. Data were observational and did not analyse the actual cost-effectiveness of surgery in the cohort. We only included costs of investigations performed during the contemporary pre-surgical evaluation and did not consider the cost or time spent at other centers for previous pre-surgical workup. Our center has local agreements for some of the tariffs we used. For instance, Telemetry unit admissions earn in addition to the regular tariff a locally agreed rate of £944. As a result, the reimbursement we receive for some procedures is likely higher than those obtained by other providers. The proportional cost differences we identified should still be applicable nationally, despite variance in the actual costs compared to other centers.

During Covid-19, most providers were switched to a 'block contract' payment system, in which a fixed sum is paid to deliver all care, rather than being reimbursed for each treatment, appointment or procedure. We moved to a 'block contract' system before Covid-19 in April 2019. We continued to use tariff as a proxy for cost throughout for consistency as it still provides the best representation of system cost.

Day case evaluation for MRI, neuropsychology and neuropsychiatry is a standard part of our pre-surgical evaluation that may not be available at other centers. Seizure freedom rates were prospectively recorded and self-reported by individuals who may under- or overestimate seizure occurrence. Our findings constitute real-world experience in a tertiary referral center with intracranial EEG availability that evaluates people with epilepsy for surgical suitability.

Conclusion

Evaluation for epilepsy surgery is lengthy and costly, particularly for those who require icEEG. For those with drug-resistant focal epilepsy, surgery is, however, associated with a greater chance of seizure freedom. The suitability and the risk-benefit ratio of surgery should be considered at each step of the pre-surgical pathway.

Highlights

- Surgery for selected people with drug-resistant focal epilepsy is associated with a higher chance of seizure freedom.
- Evaluation for epilepsy surgery is lengthy and costly, particularly for those who require intracranial EEG.
- Duration and cost of evaluation vary according to different pathways through the pre-surgical evaluation.
- Suitability and risk-benefit ratio of surgery need consideration at each pre-surgical evaluation step.

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Table 1: National Health Service (UK) tariffs for components of pre-surgical evaluation at our center

Table 2: Baseline characteristics of 90 individuals who completed pre-surgical evaluation

Table 3: Cost of different routes through the pre-surgical pathway

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Figure 1: Routes through the pre-surgical pathway

Figure 2: Status of 100 consecutive individuals discussed in epilepsy pre-surgical multidisciplinary meetings in 2017

Table 1: National Health Service (UK) tariffs for components of pre-surgical evaluation at our center	
Item	**Tariff**
Neurology clinic appointment: New	£341
Neurosurgery clinic appointment: New	£587
Neurology/Neurosurgery clinic appointment: Follow-up	£198
MRI brain, fMRI	£138
2-3xMRI sequences in the same session	£172
4xMRI sequences in the same session	£207
Daycase admission for psychology and psychiatry	£919
One week of scalp video EEG telemetry	£3,879
FDG-PET scan	£471
2x ictal SPECT scans (ictal+interictal)	£236
MEG	£600
Admission for intracranial EEG	£40,274
MDT (30min)	£289

Table 2: Baseline characteristics of 90 individuals who completed pre-surgical evaluation				
Characteristic	**Had surgery**		**Did not have surgery**	
	Route 1 (n=18) (Stage 1 investigation only)	**Route 2 (n=9) (Also Stage 2 investigations)**	**Route 3 (n=45) (Also Stage 2 investigations)**	**Route 4 (n=18) (Stage 1 investigation only)**
Female, n (%)	7 (39)	4 (44)	23 (51)	9 (50)
Age of epilepsy onset, yr, median (IQR)	12.5 (7.4-24.5)	17.0 (8.3-24.0)	11.0 (5.0-17.0)	12.5 (4.8-16.3)
Duration of epilepsy*, yr, median (IQR)	20.2 (10.1-26.8)	10.6 (7.3-27.3)	25.4 (14.6-30.0)	26.6 (12.9-40.8)
Learning disability, n(%)	2 (11)	0 (0)	11 (24)	4 (22)
History of focal to bilateral tonic clonic seizures, n (%)	13 (72)	5 (56)	28 (62)	10 (56)
Extratemporal epilepsy, n (%)	5 (28)	3 (33)	35 (78)	7 (39)
Number of anti-seizure medications, median (IQR)	2 (2-3)	3 (1.5-3.5)	3 (2-4)	3 (2-4)
Abnormal MRI, n (%)	18 (100)	7 (78)	26 (58)	17 (94)
icEEG performed, n (%)	0 (0)	4 (44)	10 (22)	0 (0)
*At time of surgery or decision not to have surgery				

Table 3: Cost of different routes through the pre-surgical pathway				
	Route 1	**Route 2**	**Route 3**	**Route 4**
Number of individuals (N=90)	18	9	45	18
Duration of pre-surgical pathway, median (IQR), months	28.6 (24.1-32.3)	31.0 (21.6-46.0)	33.2 (18.6-59.4)	26.1 (18.0-32.4)
Cost of pre-surgical evaluation / individual, median (IQR), £	7,740 (7,050-10,500)	9,140 (8,640-47,700)	11,860 (7,980-47,400)	6,720 (6,190-10,000)
Cost of surgery / individual, median (range), £	10,200 (8,200 -21,200)		n/a	
% Seizure free at last follow-up	72%	22%	0%	11%

Figure 1: Routes through the presurgical evaluation

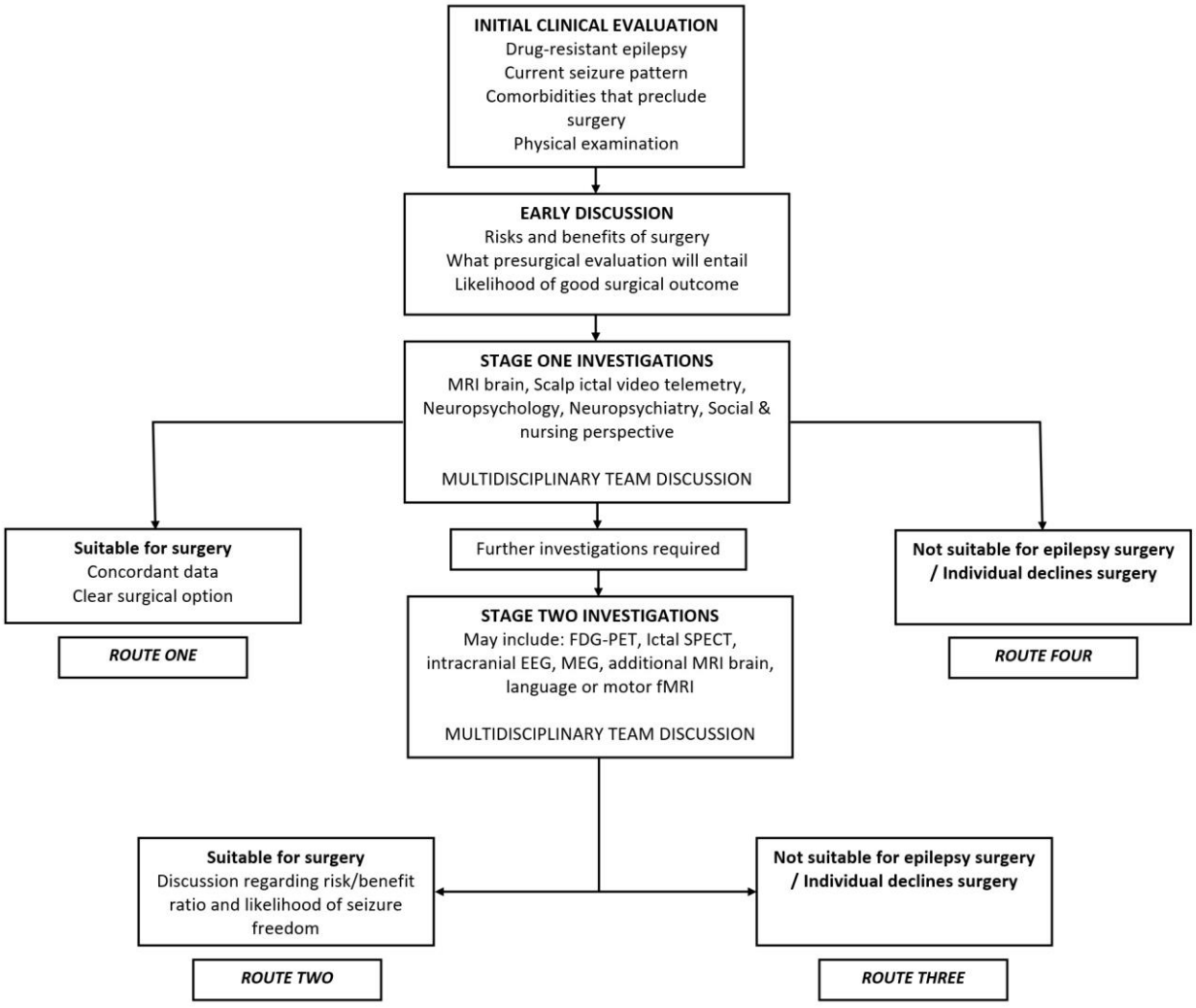

Figure 2: Status of 100 consecutive individuals discussed in epilepsy pre-surgical multidisciplinary meetings in 2017