Diagnostic evaluation of infants, children and adolescents with epilepsy for surgery candidacy and the role of magnetoencephalography (MEG)

A retrospective, single-centre, descriptive chart review to characterize the health system utilization patterns associated with the neurological evaluation for surgery of children and adolescents referred to an epilepsy monitoring unit (EMU) for video electroencephalogram (vEEG) and to characterize the role of magnetoencephalography (MEG) in this process.

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Disclaimer

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Executive Summary

Purpose In response to a recommendation made by the Ontario Health Technology Advisory Committee (OHTAC), the purpose of this study was to examine the utilization of magnetoencephalography (MEG), which provides high-resolution recordings and images of cortical neuronal function and dysfunction. MEG is used in the diagnostic evaluation for determination of the candidacy of infants, children and adolescents with medically refractory epilepsy for surgical removal of their epileptic focus.

Methods A retrospective chart review of all infants, children and adolescents referred to the Epilepsy Monitoring Unit (EMU) for elective prolonged video electroencephalography (vEEG) at the Hospital for Sick Children between April 1, 2004 and March 31, 2006 was conducted. These children were followed up following the EMU admission through a surgical decision making process and, if surgery was performed, through the surgery and postoperatively. Data were abstracted from the medical records regarding referral patterns, frequency and wait times of pre-surgical diagnostic tests, physician visits, multidisciplinary seizure conferences, timing of surgical candidacy decisions and subsequent surgical interventions and associated health care resource utilization.

Results: Of the 463 referrals identified during the study period, 349 (75.4%) received prolonged vEEG. The remaining 114 cases (24.6%) that were referred to the EMU at SickKids received a vEEG lasting less than 8 hours, and no further information was available concerning these referrals. Normalized referral patterns identified higher referral rates from northern/central areas of the province (46 to 60 referrals/1,000,000 population) where vEEG is not available. Further evaluation for surgical candidacy in 160 (34.6%) children identified 64 (13.8%) surgical candidates. The median diagnostic test wait times for the majority of assessments was 100 days or more which contributed to a median time to surgical candidacy decision of 9 months following referral. In surgical candidates, MEG supported the surgical candidacy decision in the majority of children (N=59; 91%) and 32 children (54.2%) did not require invasive electroencephalography prior to surgery. In the non-surgical candidates (N=96; 20.7%) MEG supported the decision not to proceed to surgery in 40 (41.7%) of children. Use of MEG prior to initial multidisciplinary seizure conference resulted in a shorter time to

surgical candidacy decision (median = 193 days, N=41) as compared to later use of MEG following first conference (median = 482 days, N=18).

Discussion: The characterization of the use of MEG, to provide evidence to inform policy decision making, resulted in the identification of other healthcare resource and waiting time issues. The evaluation of diagnostic medical technologies along with their utilization within the healthcare system can result in the identification of additional system related problems that can be addressed. The results of the study identified system inefficiencies, a need for coordinated care/services and standardization.

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ABBREVIATIONS

CCHS	Canadian community health survey
CCU	Critical care unit
CT	Computed tomography
ECoG	Electrocorticography
EEG	Electroencephalography
EMU	Epilepsy monitoring unit
EP	Evoked potentials
FBI	Functional brain imaging
fMRI	Functional magnetic resonance imaging
FSA	Forward sortation area
fs MRI	Full sequence magnetic resonance imaging
HQO	Health Quality Ontario
HTPA	Health Technology Policy Assessment
iEEG	Invasive electroencephalography
LHIN	Local Health Integration Network
MAS	Medical Advisory Secretariat
MEG	Magnetoencephalography
MOHLTC	Ontario Ministry of Health & Long-Term Care
MRI	Magnetic resonance imaging
NPA	Neuropsychological assessment
NPHS	National population health survey
OHTAC	Ontario Health Technology Advisory Committee
PACU	Post-anaesthetic care unit
PET	Positron emission tomography
SD	Standard deviation
SPECT	Single-photon emission computed tomography
vEEG	Video electroencephalography
VNS	Vagal nerve stimulation

1.0 BACKGROUND AND RATIONALE

1.1 Introduction

A seizure may be defined as a sudden and abnormal paroxysmal discharge of electricity in the brain leading to an alteration in behaviour, consciousness, movement, perception and/or sensation. Epilepsy is a chronic disorder characterized by more than one spontaneous, unprovoked seizure, i.e. spontaneous recurrent seizures.##Epilepsy is a condition which may have a variety of aetiologies that range from genetic/developmental anomalies, to multiple types of brain trauma (injury, stroke, tumour). For some individuals, there also may be no apparent cause. Seizures are classified by location, foci and aetiology. The prevalence of epilepsy in Canada among children and adolescents has been estimated to range between 2.5 to 5.7 per 1000 depending on the age category and the Canadian-based population health surveys.[1] The rate of epilepsy, based on the results of the 1998-1999 National Population Health Survey (NPHS) in Canada is 5.2 cases per 1,000 population (95% CI, 4.9-5.4) and 5.6 cases per 1000 population (95% CI, 5.1-6.0) from the 2001 Canadian Community Health Survey (CCHS).[1] Based on these prevalence estimates there is an estimated 65,000 individuals (10,000 children and 55,000 adults) in Ontario (population approximately 13,000,000) who suffer from epilepsy. Of these individuals, an estimated 30% will have medically-intractable epilepsy, defined as frequent ongoing seizures that do not respond to 2 or more antiepileptic medications and where other treatment alternatives are required. Therefore in Ontario there are approximately 20,000 individuals with epilepsy where pharmacotherapy is not able to control their seizures. For these individuals epilepsy surgery with resection of the epileptic foci provides a viable treatment option for eligible candidates.

1.2 Evaluation of surgical candidacy at Sick Kids

Infants, children and adolescents (which will be collectively referred to as children or child throughout this report) from Ontario, other provinces and countries maybe referred to the Hospital for Sick Children (SickKids) in Toronto, Ontario for evaluation for the surgical treatment of their epilepsy. Following referral, the initial diagnostic evaluation occurs in the epilepsy monitoring unit (EMU) where the infants, children and

adolescents are assessed using video electroencephalography (vEEG). An EEG is a technology which entails placement of electrodes on the scalp in order to record the electrical activity of large aggregates of nerve cells in the brain. When a seizure occurs, it is readily evident on the EEG. The vEEG involves videotaping the patient continuously with a time-locked EEG in order to provide an opportunity for their seizures and associated behaviours, so called ictal events, to be monitored. The duration of the vEEG can be for varying periods of time (8 hours to 5 days).[2] Prior to the vEEG, children are temporarily taken off any antiepileptic medication. The within province and out of province demand for assessment through the EMU at SickKids is greater than the capacity. Therefore, waiting lists exist for children to begin assessment for surgical candidacy. It was estimated that in 2008, the wait time from EMU referral to vEEG evaluation was up to 1 year in duration. In addition to the vEEG, further diagnostic evaluation may also be completed as a component of the initial pre-surgical assessment including magnetic resonance imaging (MRI), magnetoencephalography (MEG), neuropsychological assessment (NPA) and functional MRI (fMRI).[2;3] As with the vEEG, wait lists also exist for each of these diagnostic evaluations which adds to the delay in surgical candidacy determination. Some children referred to the EMU may not be surgical candidates based on the results of the vEEG, and are returned to the care of their referring physician. For these children who are not deemed to be surgical candidates, recommendations are made for alternative treatments (e.g. vagal nerve stimulation, ketogenic diet or continued medical management). The evaluation of children with medically-intractable epilepsy at SickKids has been described previously.[3;4]

For those individuals where surgery may be a possible treatment for their epilepsy, a full assessment is completed and all resultant data are discussed at a multidisciplinary seizure conference meeting. The multidisciplinary team that is assembled for these seizure conferences consists of epileptologists, neurosurgeons, neuropsychologists, psychometrists, radiologists, nurses, nurse practitioners, social workers, pharmacists, EEG technologists, as well as other professionals. At a typical seizure conference a complete review is conducted of the patient's medical history (e.g., seizure frequency, seizure medications, diseases) is presented, followed by a review of the MRI, MEG,

vEEG, the results of the NPA to assess if a patient's language, motor, behavioural or sensory function are affected by their seizures and fMRI. The latter refers to functional MRI which is a technique by which language and motor function can be lateralized and localized in the brain.[2] The child's surgical candidacy is determined through this multidisciplinary decision process. If surgery is recommended, the kind of surgery most suitable to stop the seizures is decided upon.[3] Surgical procedures that are used at SickKids include: intracranial EEG (iEEG) monitoring from electrodes surgically placed on and within the brain, followed by focal cortical excision, lesionectomy with or without intraoperative electrocorticography, extratemporal lesionectomy, temporal lobectomy or selective amygdalohippocampectomy, corpus callosotomy vagal nerve stimulation and functional hemispherecotomy.[2]

Because of the medical complexity of children who are undergoing evaluation for epilepsy surgery and the importance of getting the decision right, multiple seizure conferences may be required to determine surgical candidacy. If this is the case, additional diagnostic evaluations may be ordered to provide further information to assess the possibility of surgery for the child or adolescent. Depending on the complexity of the case, an estimated 9-12 months of further additional evaluation can occur following the initial EMU admission in order to determine surgical candidacy. Finally, once an individual is determined to be a surgical candidate, depending on surgical capacity and availability of human resources, additional waiting for surgical procedures occurs. Overall, from the time of initial EMU referral to surgical procedure, and estimated 2-3 years can elapse.

1.3 Magnetoencephalography

In 2006, the Ontario Ministry of Health and Long-Term Care (MOHLTC) received several requests to fund various Functional Brain Imaging (FBI) methods including MEG and magnetic resonance spectroscopy. The decision to evaluate all FBI methods in one Health Technology Policy Assessment (HTPA) was made by the Medical Advisory Secretariat (MAS) and Ontario Health Technology Advisory Committee (OHTAC) in light of the multiple requests.[5] Evidence regarding FBI was reviewed in context of the following conditions: Alzheimer's disease, brain tumours, epilepsy, multiple sclerosis and Parkinson's disease.[5] In 2007, following the presentation of this FBI HTPA, the recommendation was made by OHTAC that "A field evaluation should be conducted in Ontario to determine the potential substitutive role of MEG vs. invasive EEG for the treatment of epilepsy."[6] To identify which research methods were most appropriate and feasible to address the OHTAC recommendation, the PATH Research Institute worked in collaboration with the Division of Neurology and the Centre for Brain and Behaviour at The Hospital for Sick Children in Toronto to examine the place of MEG in the determination of surgical candidacy. During the course of these discussions, it became clear that in order to examine how MEG can potentially avert iEEG procedures, it was also necessary to examine the utilization and sequencing of diagnostic tests and evaluations, capacity related issues associated with the EMU and other diagnostic tests, associated wait times, and finally surgical intervention and clinical outcomes. Thus evaluation of MEG could not be completed alone and in isolation from the other components of the surgical candidacy decision; rather it had to be examined within the context of its place in the entire evaluation process and capacity within the system. The role of MEG in context with other diagnostic evaluation has been discussed in detail by Grondin et al.[7]

2.0 STUDY OBJECTIVES

2.1 Primary Objective

To characterize potential barriers and wait times in determining surgical candidacy of infants, children and adolescents admitted to the EMU (receiving video EEG) at SickKids.

2.2 Secondary Objectives

1. To characterize the demographics of infants, children and adolescents referred for vEEG including the geographic distribution of referrals and demand for the EMU; and classification of seizure type and location.
2. To characterize the healthcare utilization and evaluation patterns of infants, children and adolescents referred to the EMU including diagnostic tests and evaluations, seizure conference evaluations and surgical intervention.
3. To determine the utilization of MEG by EMU admissions and describe the subsequent need for further epileptic foci characterization and localization with iEEG prior to surgical intervention.
4. To describe long-term outcomes of surgery (i.e. seizure frequency, medication utilization, subsequent tests, evaluations) for infants, children and adolescents treated at SickKids.
5. To ascertain healthcare costs per subject associated with the diagnostic evaluation for referrals to the EMU to determine surgical candidacy.

3.0 METHODS

3.1 Study Design

This study was a single centre, descriptive, retrospective chart review of both manual and electronic medical charts of children and adolescents referred to the EMU) at SickKids for a vEEG between April 1, 2004 and March 31, 2006. Health practitioners (M.H., J.I.) familiar with the current evaluation process for determining the suitability of infants, children and adolescents referred to the EMU for surgical intervention completed the data abstraction. The review was completed in 2 phases: a screening phase and a full chart abstraction. All charts were screened for the inclusion criteria in phase 1. In Phase 2, for charts that met the inclusion criteria, data abstraction from vEEG reports, EMU reports, seizure conference reports (includes a detailed summary of the subjects' complete seizure and medical history, diagnostic tests results, growth and development, procedures and recommendations for surgery), diagnostic reports, surgical/pathology reports, neurology clinical notes, general letters and any additional physician notes was conducted. Information from the medical chart review was used to describe the referral pattern to the EMU at SickKids, the clinical evaluation process, the sequence and timing between the diagnostic tests, including wait-times, as well as associated healthcare utilization for the entire process from EMU referral to surgical decision and surgery. Where available the long-term outcomes (at least 1 year of follow-up post-surgery) were determined. The study was reviewed by the Research Ethics Boards of both St. Joseph's Healthcare Hamilton and SickKids. The childrens' personal information was kept confidential. Only M.H., J.I. and I.E. had access to the medical charts for data abstraction and all case report forms were received at PATH in a de-identified manner. Seizure conference recommendations related to surgical candidacy were abstracted from each available conference report and assigned into one of the following status categories: (1) surgical candidate (temporal lobectomy, lesionectomy, extratemporal lesionectomy, corpus callostomy, hemispherectomy) with or without iEEG (2) not a surgical candidate (3) not a surgical candidate at this time (further technical diagnostic testing and investigations required). For those individuals that were not considered surgical candidates, the recommendation for one or more of the following therapies was also abstracted from the medical record (1) continue with

medical management (2) vagal nerve stimulation (VNS), (3) ketogenic diet or (4) other recommend treatment strategies.

3.2 Phase 1

3.2.1 Screening

In Phase 1, all medical charts of children and adolescents referred to Sick Kids epilepsy monitoring unit (EMU) between April 1, 2004 and March 31, 2006 for elective vEEG were screened. For all screened charts, basic demographic and referral data was abstracted (e.g., gender, month and year of birth, previous EMU referral, forward sortation area (FSA) of place of residence) to describe the overall demand and geographical referral patterns for the program. No further review or data abstraction was completed for those charts of children and adolescents not meeting the inclusion criteria outlined below. The following inclusion criteria were applied to determine if further data abstraction was required in Phase 2 of the review.

Inclusion Criteria:

1. Age < 19 years old at time of first EMU admission
2. Date of EMU admission is between April 1, 2004 and March 31, 2006
3. Referred for elective vEEG and/or overnight with vEEG for greater than 8 hours

The time interval for the chart review was selected: to ensure sufficient case volume and time duration (2 years of EMU referrals) to be able to meet the study objectives. The choice of the time horizon for selection of the medical charts were based on an estimate of 2-3 years from EMU admission to surgical intervention and to increase the likelihood that surgical candidates identified in the chart review would have least 1 year of clinical follow-up data available following surgery. The infants, children and adolescents that meet the inclusion criteria formed the complete medical chart review cohort.

3.3 Phase 2

All medical charts for patient referrals that met the study inclusion criteria had a detailed chart abstraction during Phase 2 of the study. Charts were abstracted in sequential

order starting at EMU admissions from April 1, 2004 to permit maximum opportunity for follow-up time for those admitted in fiscal 2005/06. Three documented patient care paths were identified a priori to categorize the degree and time frame of diagnostic evaluation provided for the children and adolescents that were referred for surgical candidacy determiniation: (1) vEEG greater than 8 hours with vEEG report only, (2) EMU Report (no seizure conference), (3) Seizure conference evaluation. For subjects with multiple admissions to the EMU the initial referral was considered the index admission and each were documented in order of occurrence.

3.3.1 vEEG Report and EMU Admission Details

Details regarding the EMU admission (e.g., reason for vEEG, who requested vEEG) and vEEG results (e.g., duration of vEEG, seizure types identified, sedation required) were abstracted. For those charts where the subject only had a vEEG with a report of the evaluation only, no further information was abstracted as these individuals were not seen further at SickKids. In subjects that returned to the EMU and had subsequent vEEGs, EMU reports or seizure conference reports, further chart abstraction was completed.

3.3.2 Seizure and Medical History

For subjects who had an EMU report or seizure conference report, the data abstraction included the collection of additional demographic details (e.g., height and weight), history details (e.g., date of first seizure, date of last seizure prior to seizure type, frequency and location, functional limitations (e.g., academic cognitive, behavioural, social, gross and fine motor limitations), technical and diagnostic tests, investigations, evaluations (e.g., neuropsychological exam), and seizure related medications prior to EMU admission.

3.3.3 EMU Report

For subject charts where no seizure activity was detected during the initial vEEG session and for which only the EMU report is available (no seizure conference report at time of first EMU admission), the vEEG findings/recommendations (e.g., medical management, no epileptic seizures) was documented. No further abstraction was

completed from these charts unless as outlined above these subjects returned to the EMU to have subsequent vEEGs, EMU reports or seizure conference reports.

3.3.4 Seizure Conference Report

Seizure conference reports formed the foundation for the data abstraction process to describe the seizure candidacy evaluation process. A review of medical notes, referrals and consult notes, diagnostic and laboratory results and other components of the chart were completed to confirm the content of the seizure conference details. For each seizure conference report available, data was collected related to the following: seizure frequency; number, type and timing of technical and diagnostic tests (e.g., functional MRI, subsequent vEEG, iEEG or MEG); investigations (neuropsychological exam); developmental changes; number and timing of appointments (e.g., general practitioner, specialist visits); medication changes since the time of EMU admission or previous seizure conference report. The recommendations of the seizure conference were obtained and categorized as follows: (1) surgical candidate (temporal lobectomy, lesionectomy, extratemporal lesionectomy, corpus callostomy, hemispherectomy) with or without iEEG (2) not a surgical candidate (3) not a surgical candidate at this time (further technical diagnostic testing and investigations required). For subjects that had more than 1 seizure conference report, the changes in the above recommendations were captured. Also abstracted from the medical chart was the subsequent family decision, where available, and acceptance of the management strategy secondary to the seizure conference recommendation.

3.3.5 Surgery and Post-Operative Conference Report

For those subjects where surgical intervention was initiated, details regarding the date admitted to hospital and date of surgery were abstracted. Details regarding any seizure-related technical diagnostic tests, investigations, appointments, seizure status and medications up to the surgery were also documented. Information regarding the surgery type (e.g., lesionectomy, lobectomy), the use of iEEG to detect or localize seizure foci, and surgical complications were obtained. Post-operative care details including post-operative hospital location (i.e. post-anaesthetic care unit (PACU), critical care unit (CCU), and neurosurgical ward), duration of stay in post-op unit and any post-operative complications or seizures as well as the need for post-operative diagnostic tests, medication prescribed were also abstracted. Additional hospitalization details were captured including additional post-op locations, any rehabilitation therapy during the initial hospitalization associated with the surgical intervention (e.g., physical therapist, occupational therapist, dietician, child life worker, speech-language pathologist), complications leading to subsequent intensive care stay, test, investigations, date of discharge, discharged location and medications ordered at the time of discharge.

3.3.6 Long-term Follow-up

Long-term follow-up for visits that occurred at SickKids were reviewed to obtain seizure status (presence or absence) and seizure frequency, functional status (academic, behavioural, gross motor and fine motor) as well as any other clinically relevant consequences secondary to surgical intervention. Where available, the need for further epilepsy related technical diagnostic test, evaluations, appointments, medication and behavioural changes since the time of surgery were obtained. The time of last follow-up documented in the chart was also captured.

3.4 Study Outcomes

3.4.1 Demographics & Referral Patterns

To describe the subjects being referred to the EMU, all charts were screened to obtain basic demographic data (e.g., gender, date of birth, previous EMU admission) and geographical information of place of residence as captured by the first three characters of the postal code or the forward sortation area (FSA). In order to assess geographic referral patterns from across the province to SickKids, the subjects' area of residence was matched to one of the 14 Local Health Integration Networks (LHIN) in Ontario. The referral patterns were normalized based on population and reported number of referrals per 1,000,000 population within the LHIN. Population estimates for each LHIN were obtained from the publically available profiles for each health network. All referrals were identified and all charts were reviewed to capture the total demand for the EMU program over the 2 year period.

Further demographic and clinical characterization was captured for those subjects that underwent vEEG including the seizure type, frequency and time of last seizure, epileptic foci location, reason(s) for vEEG, location and specialty of requesting physician, previous diagnostic tests and medication use. The proportion of subjects that experienced a seizure during the vEEG was calculated. Characterization of a child's final surgical candidacy outcome following the evaluation process were described by determining the proportion that were treated by each of the captured medical and surgical interventions, specifically as it related to the seizure conference recommendations.

3.4.2 Wait Times & Barriers

The diagnostic/clinical pathway was captured for all subjects the wait time associated with the pathway was determined by calculating the time from initial referral to the determination of surgical candidacy and/or surgical intervention. Sub-components of the healthcare process timing were also calculated such as the time from EMU referral to EMU admission, time from EMU admission to vEEG completion, time from seizure conference recommendation to surgical intervention. Time measures were reported as medians and 90th percentiles associated with each interval described above.

3.4.3 Healthcare Resource Utilization

Healthcare resources that were used by subjects during the course of their surgical candidacy evaluation from EMU referral to surgical decision were abstracted. These resources included diagnostic tests, neuropsychological evaluations, seizure conferences, healthcare visits (e.g. specialists, social work, and neurology clinic), surgical procedures and follow-up visits. The frequency of use per subject of each healthcare resource was determined. Utilization of healthcare resources by patients following the previously outlined care paths are outlined (i.e. mean number of seizure conferences for subjects undergoing surgical intervention). The frequency of repeat diagnostic evaluations and the mean number of diagnostic tests per subject were also determined. In subjects undergoing a surgical intervention, the type of intervention, overall length of stay associated with the surgery, as well as the duration of time spent in each hospital care unit (e.g. critical care unit, neuroscience ward) was evaluated.

3.4.4 Utilization of MEG and iEEG

The utilization of MEG, as a part of the diagnostic evaluation of subjects was calculated by determining the proportion of children admitted to the EMU that had MEG. The timing of MEG relative to the index seizure conference was also examined and categorized as either “early MEG” if the MEG diagnostic evaluation was completed prior to the first seizure conference or “late MEG” if the MEG was completed after the first seizure conference. Of those subjects that had MEG, the proportion that was recommended for surgical intervention was calculated. Similarly the proportion of subjects where surgical intervention was not recommended and MEG was used as a part of the diagnostic evaluation was also determined. To examine the relationship between iEEG utilization and MEG, the proportion of surgical intervention subjects that received MEG followed by iEEG was determined. The use of iEEG for those children undergoing surgical intervention that did not undergo MEG was also calculated.

3.4.5 Long-Term Clinical Outcomes

For all surgical subjects where long-term follow-up was available, the presence or absence of seizures was captured at each follow-up visit. Seizure frequency was captured throughout the chart review process at various time points as a frequency by

either: day, week or month with temporal context (e.g., 1 month ago, 6 months ago etc.). Evaluation of surgical success was calculated as the proportion of subjects that were seizure free at 1 year and also by determining the proportion with reduced seizure frequency from time of surgery, recognizing that for some individuals, the ability to surgically remove the complete epileptic focus may not have been possible. Further evaluation of surgical success was determined by examining the changes in functional outcomes from time of initial EMU referral to last follow-up visit. The overall proportion of children receiving surgical intervention with 1 or more functional limitation was calculated at baseline and at the last available follow-up. In addition, each type of functional outcome (academic, behavioural, gross motor and fine motor) was examined in a similar manner.

3.4.6 Healthcare Costs

Unit costs for the healthcare resource utilization items were applied to the resources identified for each patient to estimate the total direct healthcare costs associated with the evaluation of surgical candidacy for subjects referred to the EMU. Where possible, unit costs were obtained from the SickKids case costing system and were inflated to 2010 Canadian dollars. The Ontario Schedule of Benefits for Physician's Services was used to estimate the cost of specialists' visits. Estimates for neurology clinic visits, hotel costs, and personnel costs associated with conducting seizure conferences, neuropsychological assessments, social work visits and preparing EMU reports were provided by SickKids. The mean direct healthcare costs per subject associated with the diagnostic evaluation for surgical candidacy was calculated.

4.0 RESULTS

4.1 EMU Referral Patterns

This report presents findings based on a cohort of children referred to Sick Kids EMU. The cohort includes 463 children referred to the EMU over the two year period from April 1, 2004 to March 31, 2006. Children were referred mainly from within the province of Ontario (n=447, 96.5%) with some out of province referrals (n=10, 2.2%) from Newfoundland & Labrador, Prince Edward Island, New Brunswick and British Columbia. Out of country referrals (n= 6, 1.3%) included those from Barbados, Nigeria, Mexico and Trinidad. The percent of the children that were male was 56.4% and the average age of the children referred to Sick Kids EMU in the referral cohort was 8.7 years ranging from less than 1 year to 18 years old. The characteristics of the children referred and location of referral are summarized in Table 1.

Table 1. Demographics and geographic region of referrals to SickKids Epilepsy Monitoring Unit from between April 1, 2004 to March 31, 2006.

	N=463
Age	8.7 ± 5.1
Gender (male)	261 (56.4%)
Ontario Resident	447 (96.5%)
Eastern Ontario	25 (5.4%)
Central Ontario	198 (42.8%)
Toronto	152 (32.8%)
Southwestern Ontario	39 (8.4%)
Northern Ontario	33 (7.1%)
Other Provinces	10 (2.2%)
Other Country	6 (1.3%)

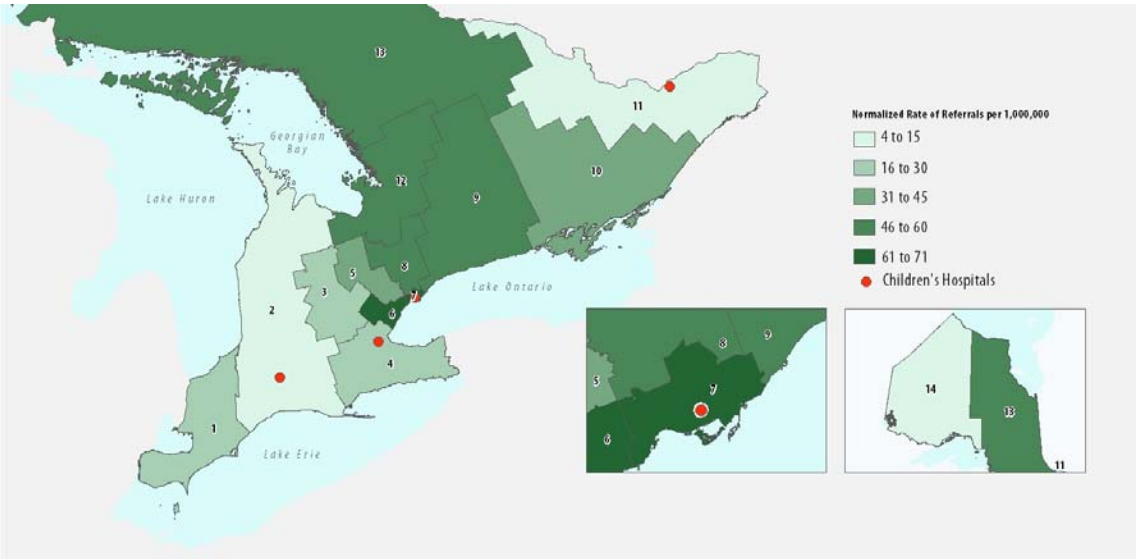
Further examination of the referral patterns by geographic region from within Ontario was completed for the 447 individuals that were referred to the EMU by examining the distribution of by LHIN. The overall referral rate per 1,000,000 inhabitants was 36 children. Comparing this rate across the LHINs identifies compared to the provincial rate of referral greater rates for 6 LHINs: Mississauga /Halton, Toronto Central, Central, Central East, North Simcoe/Muskoka and North East as outlined in Table 2.

Table 2. Referrals Patterns from Ontario to the SickKids Epilepsy Monitoring Unit from between April 1, 2004 to March 31, 2006.

Location	Number of EMU referrals	EMU referral per 1,000,000 population	Rate Normalized
Ontario	447	36	1.00
Erie St.Clair	14	22	0.60
South West	6	6	0.18
Waterloo Wellington	11	16	0.44
Hamilton Niagara Haldimand Brant	29	21	0.59
Central West	23	32	0.88
Mississauga Halton	66	63	1.75
Toronto Central	81	71	1.95
Central	80	52	1.43
Central East	70	48	1.33
South East	14	32	0.87
Champlain	5	4	0.12
North Simcoe Muskoka	19	46	1.26
North East	27	48	1.32
North West	2	8	0.23

The EMU referral rates when normalized by population are outlined in Table 2 and also displayed in Figure 1. The highest referral rate as may be expected is from Toronto Central (71 referrals/1,000,000 population) and from Mississauga-Halton (63 referrals/1,000,000 population). As may be seen in Figure 1, the next highest referral rates are from the Central, Central East and North Simcoe/Muskoka and North East LHINs of the province all of which have greater referral rates to SickKids EMU than the provincial rate.

Figure 1. SickKids EMU referral pattern by Local Health Integration Network (LHIN) April 1, 2004-March 31, 2006 (N=447)



4.2 Identification of children receiving prolonged video electroencephalography

Of the 463 children referred to the EMU, 349 (75.4%) had prolonged vEEG. The remaining 114 cases (24.6%) that were referred to the EMU at SickKids received a vEEG lasting less than 8 hours, and no further information was available concerning these referrals. Day vEEG is intended to clarify (sometimes used to determine the presence of daytime seizures) or exclude epilepsy status. If during the day procedures seizures were detected that required further assessment, the child would be recommended to receive prolonged vEEG. The remainder of this report provides results from the 349 individuals who all had prolonged vEEG.

Further classification of the remaining 349 children into 4 groups was then completed based on the extent of their follow-up at SickKids and surgical candidacy status. One-hundred and eighty-nine children (54.2%) received a prolonged vEEG in the EMU and their cases were not reviewed at a seizure conference. For some of these children (N=59) however additional documentation related to their vEEG in the form of an EMU report was available and further details regarding their epilepsy was obtained. Further evaluation for surgical intervention candidacy, with the discussion of their case and

diagnostic tests, at seizure conference was identified for 160 children (45.8%) (Table 3). Of these children, 96 were considered not to be surgical candidates and 64 were surgical candidates. The geographic referral patterns for children undergoing a prolonged vEEG are outlined in Table 3.

Table 3. The geographic referral pattern for children undergoing a prolonged video encephalography.

	Overnight vEEG only		Seizure Conference		Overall (N=349)
	No EMU report (N=130)	EMU report (N=59)	Not a surgical candidate (N=96)	Surgical candidate (N=64)	
Ontario:					
Eastern Ontario	5	7	1	7	20 (5.7%)
Central Ontario	53	22	46	25	146 (41.8%)
Toronto	51	18	28	12	109 (31.2%)
Southwestern Ontario	12	5	13	5	35 (10%)
Northern Ontario	8	6	5	10	29 (8.3%)
Out of Ontario	1		1	3	5 (1.4%)
Out of country		1	2	2	5 (1.4%)

Of the 349 children undergoing prolonged vEEG during the reason for referral is outlined in the Table 4. The majority of the referrals to the EMU 318/349 (91%) were from a neurologist. Multiple reasons for referral were provided in the EMU referral notes. Most commonly provided reason for referral was for “diagnosis” for 175/349 (50.1%) of the children or “pre-surgical assessment” for 83/349 (23.8%) of the cases. Frequently, other reasons were provided by the referring physician and included: to assess of physiological events (N=54), cause of staring spells (N=40), to characterize and isolate source of seizures (N=43), assess nocturnal seizures (N=41), behavioural events such as rage (N=14), or assess autism or rule out Landau-Kleffner syndrome, a seizure disorder that may mimic autism (N=7).

Table 4. Demographics, reason for referral to Epilepsy Monitoring Unit and index video electroencephalography characteristics.

	Overnight vEEG only		Seizure Conference		
	No EMU report (N=130)	EMU report (N=59)	Not a surgical candidate (N=96)	Surgical candidate (N=64)	Overall (N=349)
Male N(%)	83 (63.9%)	33 (55.9%)	55 (57.3%)	28 (43.7%)	199 (57.0%)
Who requested vEEG?					
Neurosurgeon	1	0	5	7	13
Neurologist	116	55	90	57	318
Other	13	4	1	0	18
Reasons for first indexed vEEG (>1 can apply)					
Pre-surgical	3	3	25	52	83
Diagnosis	72	44	50	9	175
Medical Management	6	2	4	3	15
Re-operation	0	0	1	4	5
Other	110	56	83	45	294
All vEEGs	140	62	108	80	390
Duration of vEEG days Mean (SD) (min, max)	1.1 (0.3) (1.0, 2.0)	2.4 (1.1) (1.0, 5.0)	2.5 (1.1) (1.0, 4.0)	2.8 (1.2) (1.0, 8.0)	2.0 (1.2) (1.0,8.0)
Special electrodes (Yes)	4	14	28	36	82
Sedation requested	7	0	3	1	11
Intramuscular sedation	6	0	2	1	9
Oral	1	0	1	0	2

The average duration of the prolonged vEEG was 2.0 days with minimum of 1 day and maximum of 8 days. Some of the children had multiple prolonged vEEGs, with 360 initial procedures being completed. With the prolonged vEEG, special electrodes were requested in 82/360 procedures. In addition, 11/360 children were included with a special request for sedation, intramuscular (N=9) or oral (n=2). No statistical differences exist for age, sex or residential status between children for prolonged vEEG, EMU report, seizure conference and surgery.

4.3 Time from first onset of seizures to index referral to the Epilepsy Monitoring Unit

The average age of the children at the time of their first seizure was 4.5 years of age, while the average age at EMU admission was 9.6 years. The time between first seizure and first EMU referral was a median of 4.7 years, mean of 5.5 years, with 90% of the referrals occurring within 12.0 years.(Table 5) The difference in time was longer for children considered surgical candidates where the time between first seizure and first EMU referral was a median of 4.5 years, mean of 5.6 years, and 90% occurring within 12.6 years. In addition, for the surgical candidates (N=64), the average age at the time of first EMU admission was 11.1 years. This creates a time between first seizure and surgery date with a mean of 5.4 years, median 6.8 years and 90% occurring within 14.5 years.

Table 5. Time from initial seizure to Epilepsy Monitoring Unit referral

	Overnight vEEG only		Seizure Conference		Overall (N=349)
	No EMU Report (N=130)	EMU Report (N=59)	Not a surgical candidate (N=96)	Surgical Candidate (N=64)	
mean (SD) (min, max)					
Age at first seizure.		5.0 (4.1) (<0.1, 14.5)	4.0 (3.9) (<0.1, 15.2)	5.0 (4.5) (<0.1, 16.1)	4.5 (4.2) (<0.1, 16.1)
Age at first EMU admission	8.3 (4.7) (0.5, 18.6)	10.5 (4.5) (0.4, 18.3)	9.8 (4.2) (0.7, 17.3)	11.1 (4.8) (0.5, 17.7)	9.6 (4.7) (0.4, 18.6)
(min, median, mean, 90pct, max)					
Time between first seizure and first EMU referral (years)		0.3, 3.9, 5.1, 11.3, 15.9	0.0, 5.1, 5.4, 11.7, 14.1	0.0, 4.5, 5.6, 12.6, 16.2	0.0, 4.7, 5.5, 12.0, 16.2
Time between first EMU referral to first EMU admission (days)	0.0, 112, 115, 206, 441	1.0, 123, 127, 238, 266	0.0, 93, 119, 239, 431	0.0, 85, 100, 202, 326	0.0, 101, 115, 218, 441
Time between first seizure and surgery (years)				0.7, 5.4, 6.8, 14.5, 16.6	

As well, there are important differences when the age groups are broken down into categories of ages 0 to 5 years (n=69), 6 to 10 years (n=110), 11 to 15 years (n=109) and 16 to 18 years (n=56). The time between first seizure and surgery date for ages 0 to 5 years is a mean of 2.3 years. For 6 to 10 years the mean time between first seizure and surgery rises to 6.0 years, for 11 to 15 years the mean time between first seizure

and surgery rises to 9.2 years, and for children seen at Sick Kids who were 16 or 17 years, the mean time between first seizure and surgery was 8.7 years.(Table 6)

Table 6. Time from initial seizure to Epilepsy Monitoring Unit referral by age.

Age cohorts	Overnight vEEG only		Seizure Conference		Overall (N=349)
	No EMU report (N=130)	EMU Report (N=59)	Not a surgical candidate (N=96)	Surgical Candidate (N=64)	
(min, median, mean, 90pct, max)					
0 to 5 (N)	38	8	13	10	69
Time between first seizure and first EMU referral (years)		0.3, 0.9, 1.1, 3.1 , 3.1	0.2, 1.1, 1.4, 2.9, 4.7	0, 1.0, 1.3, 2.8, 3.1	0.0, 1.0, 1.3, 3.0, 4.7
Time between first EMU referral to first EMU admission (days)	10, 112, 111, 193, 294	27, 88, 102, 242, 242	11, 93, 87, 125, 152	0, 64, 92, 274, 326	0, 91, 103, 183, 326
Time between first seizure and surgery (years)				0.7, 2.3, 2.4, 4.5, 5.1	
6 to 10 (N)	41	15	38	16	110
Time between first seizure and first EMU referral (years)		0.7, 3.1, 3.4, 7.1, 8.7	0, 4.5, 4.2, 6.8, 9.0	0.6, 4.5, 4.4, 8.3, 8.4	0.0, 4.3, 4.1, 7.4, 9.0
Time between first EMU referral to first EMU admission (days)	3, 93, 109, 156, 441	25, 138, 153, 261, 266	0, 84, 112, 250, 277	0, 89, 99, 166, 294	0, 94, 114, 245, 441
Time between first seizure and surgery (years)				1.9, 6.0, 6.0, 9.4, 11.6	
11 to 15 (N)	35	24	28	22	109
Time between first seizure and first EMU referral (years)		0.8, 6.3, 6.5, 12.6, 12.9	0.0, 7.8, 7.8, 12.1, 14.1	0.3, 8.9, 7.5, 13.0, 14.1	0, 7.8, 7.3, 12.7, 14.1
Time between first EMU referral to first EMU admission (days)	0, 129, 123, 225, 300	11, 58, 138, 218, 243	16, 132, 138, 214, 431	12, 87, 102, 184, 265	0, 127, 126, 214, 431
Time between first seizure and surgery (years)				1.0, 9.2, 8.4, 15.5, 16.4	
16,17 (N)	13	12	15	16	56
Time between first seizure and first EMU referral (years)		1.9, 8.8, 7.7, 15.9, 15.9	0.3, 7.0, 7.5, 13.3, 13.6	0.6, 8.1, 8.2, 14.1, 16.2	0.3, 8.1, 7.9, 14.1, 16.2
Time between first EMU referral to first EMU admission (days)	10, 115, 125, 333, 372	1, 89, 88, 169, 203	14, 84, 129, 301, 411	30, 84, 97, 171, 259	1, 91, 110, 244, 411
Time between first seizure and surgery (years)				1.7, 8.7, 9.0, 16.4, 16.6	

4.4 Baseline clinical characteristics

4.4.1 Seizure characteristics

The extent to which epilepsy affects the patient is characterized by the type of seizures, frequency and duration of seizures as well as the number of co-morbid functional

limitations that may exist. This information was available in the chart review for 219 cases.(Table 7)

Table 7. Characterization of seizure type, duration and frequency at time of admission to the Epilepsy Monitoring Unit

		Seizure Conference		
	EMU Report (N=59)	Not a surgical candidate (N=96)	Surgical Candidate (N=64)	Overall (N=219)
Cases (N)	59	96	64	219
Generalized	18	35	17	70
Tonic-clonic	8	21	7	36
Tonic	2	8	7	17
Myoclonic	1	3	2	6
Typical Absence	4	2	0	6
Clonic	2	0	0	2
Atypical Absence	1	1	0	2
Atonic	0	1	1	2
Partial	8	19	39	66
Simple	1	2	11	14
Complex	3	16	20	39
Complex with secondary generalization	4	2	8	14
Non-epileptic (physiologic events)	1	3	0	4
Status Epilepticus	1	0	3	4
Other (shaking, staring, hallucinations, rage)	28	41	6	75
Seizures per day Mean (SD) (Min, Max)	7.7 (37.4) (0.0, 240.)	4.5 (14.9) (0.0, 90.0)	1.7 (4.0) (0.0, 30.0)	4.3 (20.3) (0.0, 240.0)
Seizure frequency (minutes) Mean (SD) (Min, Max)	3.8 (5.9) (0.0, 25.0)	5.4 (12.5) (0.0, 99.0)	3.5 (5.4) (0.0, 20.0)	4.4 (9.3) (0.0, 99.0)

Generalized seizures were reported in 70/219 (32.0%) of cases, partial seizures were reported in 66/219 (30.1%) of cases, and non-epileptic events (N=4) and status epilepticus (N=4) were also identified. Other non-classified types of seizures including shaking, staring, hallucinations, or rage were reported in 75/219 (34.2%) of cases. The mean number of seizures per day was 4.3 ranging from zero to 240 seizures per day as reported in the chart. The mean duration of the seizures was 4.4 minutes ranging from less than a minute to more than 99 minutes.

The location of the seizure foci was identified in 161/349 cases (46.1%) of children following vEEG.(Table 8). The number of lobes/regions that were the source of the seizures ranged from 1 to 5 regions, and when the source of seizure was identified it

involved 1.80 lobes/regions with 95/161 (59.0%) having 2 or more lobes/regions. The most common lobes/regions were frontal 74/161 (46.0%), temporal 55/161 (34.2%), central 36/161 (32.3%), and hemispheric 36/161 (22.4%).

Table 8 . Seizure location identified during index video electroencephalography at Index EMU

	Overnight vEEG only		Seizure Conference		Overall (N=349)
	No EMU report (N=130)	EMU Report (N=59)	Not a surgical candidate (N=96)	Surgical Candidate (N=64)	
Seizure location captured (Yes)	28	12	60	61	161
Number of lobes or regions					
0	102	47	36	3	188
1	16	4	28	27	76
2	7	4	22	27	62
3	4	2	9	6	24
4	1	2	1	1	9
5	102	47	36	3	188
Lobes or regions (> 1 can apply)					
Frontal	16	3	30	25	74
Temporal	3	8	16	28	55
Central	7	4	22	19	52
Hemisphere	5	1	20	10	36
Parietal	3	3	5	9	20
Occipital	3	3	3	5	14
Midline	3	2	3	5	13
Posterior	2	0	4	1	7
Generalized	4	1	0	1	6
Parasagittal	0	0	1	1	2
Central Posterior	0	0	0	1	1
MISF (Multiple Independent Seizure Foci)	0	1	0	0	1
Posterior temporal	0	0	0	1	1

4.4.2 Baseline functional limitations of children

Functional limitations at baseline were abstracted from the medical chart for 219 of the subjects. The mean number of limitations was 1.7, with the most common type of limitations being academic or cognitive (72.6%) and behavioural (39.7%). The majority of children (117/219: 53.4%) had more than one limitation.(Table 9)

Table 9. Functional limitations reported at time of referral to the Epilepsy Monitoring Unit by Group

	EMU Report (N=59)	Seizure Conference		Overall (N=219)
		Not a surgical candidate (N=96)	Surgical Candidate (N=64)	
Number of Limitations				
0	12	18	15	45
1	20	21	16	57
2	16	25	24	65
3	5	21	5	31
4	6	11	4	21
Type of Limitations (>1 may apply)				
Cognitive or academic	42	72	45	159
Behavioural/social	25	40	22	87
Fine motor	10	35	15	60
Gross motor	14	31	13	58
Number of limitations Mean (SD) (Min, Max)	1.5 (1.2) (0, 4)	1.9 (1.3) (0, 4)	1.5 (1.1) (0, 4)	1.7 (1.2) (0, 4)

4.4.3 Medication history

Another important element to describe the epilepsy is the past and prior experience with medications. At the time of EMU admission, the children were taking an average of 1.6 unique medications with some receiving up to 4 different drugs.(Table 10) The use of pharmacotherapy was slightly higher in the seizure conference and surgical groups but not statistically different. Overall, at the time of EMU admission, the average number of drugs over the life time (i.e including past and present drugs) was 3.2 unique medications used at one time or another, with some children having been on 12 different medications for the management of their epilepsy. The most commonly drugs used in this patient population were carbamazepine 71/219 (32.4%) and valproic acid 70/219 (32.0%).

Table 10. Past medication history at time of admission to Epilepsy Monitoring Unit

	EMU Report (N=59)	Seizure Conference		Overall (N=219)
		Not a surgical candidate (N=96)	Surgical Candidate (N=64)	
carbamazepine	13	21	37	71
valproic acid	17	32	21	70
clobazam	6	21	18	45
lamotrigine	6	18	7	31
levetiracetam	4	13	12	29
topiramate	5	11	13	29
oxcarbazepine	2	12	6	20
phenobarbital	2	8	5	15
phenytoin	2	4	3	9
clonazepam	0	4	4	8
gabapentin	0	3	3	6
ethosuximide	0	2	2	4
nitrazepam	0	2	2	4
zonisamide	1	2	1	4
vigabatrin	0	3	0	3
Current medications used Mean (SD) (Min, Max)	1.0 (1.9) (0,3)	1.6 (1.0) (0,4)	2.1 (0.8) (1,4)	1.6 (1.0) (0,4)
Total past and current medications Mean (SD) (Min, Max)	2.3 (2.1) (0,9)	3.4 (2.4) (0,12)	3.9 (2.0) (1,8)	3.2 (2.3) (0,12)

4.5 Epilepsy Monitoring Unit Report Recommendations

For those 59 children who underwent a prolonged vEEG with an EMU report only and that did not proceed to seizure conference review, the findings or recommendations from review of the vEEG were as follows: initiate medical management (27/59: 46%), or no recommendations (30/59: 51%) which included maintenance on current medical therapy (n=17) or that epileptic seizures have been ruled out (n=13). Other recommendations were made for 2 children (3.3%).

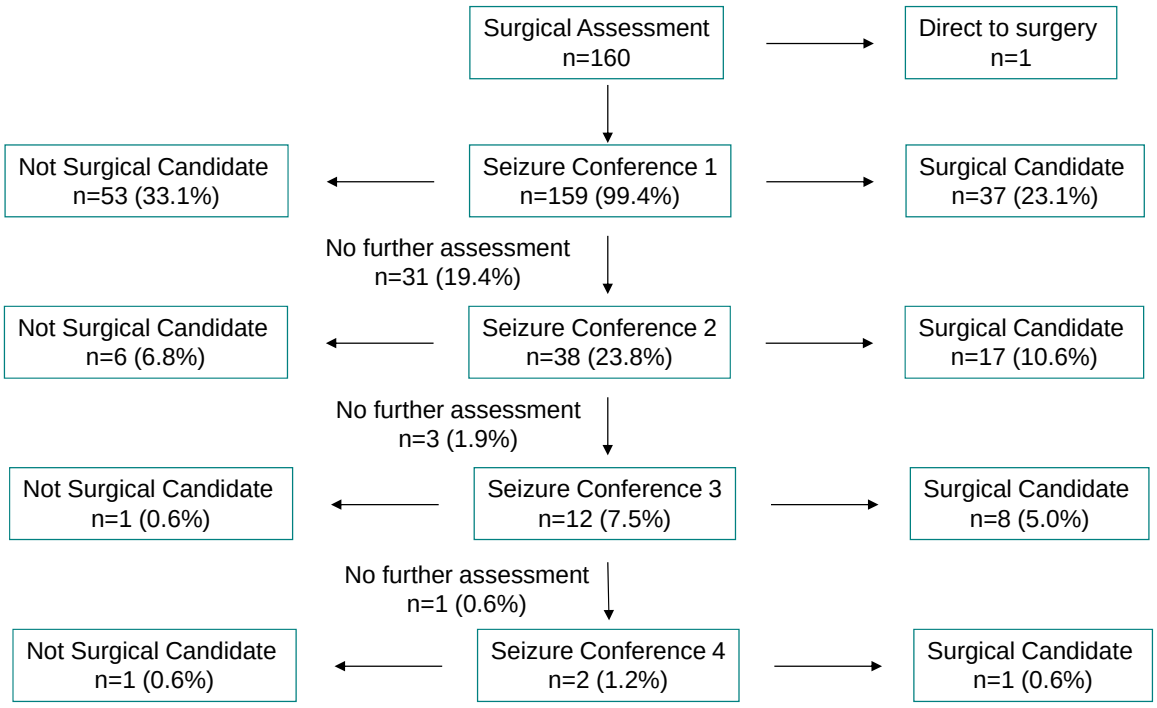
4.6 Seizure Conference Recommendations

Assessment for surgical candidacy is a sequential and iterative process. Of the 349 children that were evaluated with a prolonged vEEG, 159 individuals were reviewed at seizure conference for determination for surgery candidacy, with some of the children

requiring multiple seizure conferences and subsequent diagnostic tests. One child did not require a seizure conference as the need for surgical intervention was apparent based on the child's initial presentation. Of the children that were reviewed at seizure conference, only 1 seizure conference was necessary in the majority of children (90/159 (56.6%)). with.(Figure 2)

Overall 229 seizure conference reviews were required to assess the 159 children. Following the initial seizure conference, 37 (23.1%) children were affirmed for surgery and 53 (33.1%) were determined not to be surgical candidates, however, surgical candidacy could not be determined for 69 (43.4%) children based on the diagnostic information available at the initial conference and additional diagnostic tests were recommended. At this time however 31 children (19.4%) did not continue assessment. Further assessment for 38 (23.8%) children was completed with the results reviewed at a second seizure conference. After the second seizure conference review, surgical candidacy was determined in an additional 23 children (14.4%). Further evaluation was required in 12 children (7.5%) progressing onto a third seizure conference and 2 (1.2%) had 4 seizure conferences.(Figure 2)

Figure 2. Flow diagram of children referred to seizure conference for assessment of surgical candidacy



Examining the seizure conference recommendations indicates that in 81 out of the 229 (35.3%) seizure conferences, the diagnostic information available for review at the time were still inconclusive in order to determine suitability for surgery for some children and further tests were required. Similarly 81/229 (35.3%) seizure conferences recommended surgery, of which 45/81 (56%) had a request of a grid to help localize the seizure pre-operatively. Surgery was ruled out 67/229 (29%) of the time.(Table 11)

Table 11. Summary of all individual seizure conference surgical candidacy decisions

	Not a surgical candidate (N=96)	Surgical candidate (N=64)	Overall (N=160)
Number of Seizure Conferences	111	118	229
Surgical candidacy decision:			
No, not at this time	45	36	81
No, not a surgical candidate	66	1	67
Yes		81	81
Surgery with grid		45	

The total time to surgical decision was dependent on the number of seizure conferences, among other factors such as wait times for tests. The average wait time between EMU referral and vEEG was 110 days, and wait time from EMU referral to first seizure conference was 196.7 days. In those children who had multiple seizure conferences, the average time between seizure conferences ranged from 184 to 258 days (6-8 months). From the time of the index EMU referral to surgery was on average 437 days or 1.2 years.(Table 12) Following a recommendation for surgery at seizure conference, the time for the response from the family after discussions with their neurologist was on average 74.2 days with some families responding the next day and others waiting up to a maximum of 303 days.

Table 12. Summary of time between Index Epilepsy Monitoring Unit referral and seizure conference and surgery

Time Interval	N	Mean (min, max) (days)
Index EMU referral to EMU admission	160	110 (0,431)
Index EMU referral to First Seizure Conference	157	196.7 (0,1567)
First to Second Seizure Conference	52	258.3 (49, 954)
Second to Third Seizure Conference	19	213.3 (45, 560)
Third to Fourth Seizure Conference	5	183.6 (28, 574)
Index EMU referral to last Seizure Conference	158	203.2 (2, 1483)
Index EMU Referral to Surgery	56	437.0 (7, 1403)

For those children considered possible candidates for surgery, MRI, MEG and neuropsychological assessment were generally conducted between seizure conferences. The mean number of tests that occurred between seizure conference 1 and 2 was 2.2 tests, between seizure conference 2 and 3 were 1.9 tests, and between seizure conference 3 and 4 were 2.0 tests.(Table 13)

Table 13. Total Tests completed up to last Seizure Conference (Surgery cases only)

	Pre EMU Report (n=64)	Up to SC1 (n=63)	Up to SC2 (n=35)	Up to SC3 (n=16)	Up to SC4 (n=4)	Total tests (n=64)
MEG	13	22	20	4	2	61
MRI	23	16	9	2	0	50
NPA	4	11	14	3	0	32
fMRI	3	10	11	6	0	30
vEEG	1	1	3	5	3	13
EEG	8	0	1	1	0	10
FS MRI	0	0	6	2	0	8
Wada	1	0	2	2	0	5
CT	2	0	0	0	0	2
EP	0	0	0	0	1	1
SPECT	0	1	0	0	0	1
ECoG	0	0	0	0	0	0
iEEG	0	0	0	0	0	0
PET	0	0	0	0	0	0
Other	2	0	10	5	2	19
Number of Tests:						
Mean (SD) (Min, Max)	0.9 (1.2) (0,5)	1.0 (1.2) (0,4)	2.2 (1.2) (0,4)	1.9 (0.9) (1,4)	2.0 (0.8) (1,3)	3.6 (2.4) (0,11)
0	34	35	4	0	0	7
1	13	6	7	6	1	6
2	11	13	8	7	2	9
3	3	7	11	2	1	8
4	2	2	5	1	0	14
>4	1	0	0	0	0	20

Overall, the time of index EMU referral to surgical intervention depended on the number of seizure conferences. If only one seizure conference occurred, then the time to surgery was a mean of 300 days. With 2 seizure conferences, the mean time to surgery was 664 days and with 3 seizure conferences was 814 days. Whether or not an additional pre-operative iEEG was required did not appear to affect wait times.(Table 14)

The number of seizure conferences and the use of MEG and pre-operative iEEG affected the wait time to surgery date. When the MEG was completed for children with one seizure conference, the mean time to surgery was 269 days, while without MEG the time was 331 days. If MEG and pre-operative intracranial EEG were both required the mean time to surgery time was 311 days.(Table 14)

Table 14. Time to surgical intervention from index Epilepsy Monitoring Unit referral by number of seizure conferences

		N	Mean time (days)	Min (days)	Max (days)
1 Seizure Conference	without MEG; without grid	5	331	15	1262
	with MEG; without grid	11	269	7	600
	with MEG; with grid	19	311	248	413
2 Seizure Conference	without MEG; without grid	0			
	with MEG; without grid	8	612	221	1106
	with MEG; with grid	5	749	543	1026
3 Seizure Conferences	without MEG; without grid	0			
	with MEG; without grid	3	886	523	1403
	with MEG; with grid	3	742	608	970

4.7 Healthcare Resource Utilization

4.7.1 Diagnostic Tests

Prior to referral to SickKids, EMU documentation of previous diagnostic evaluations was abstracted for 219 individuals. Children who were reviewed at seizure conference had previously received on average 1.8 diagnostic evaluations for the non-surgical candidates or 2.7 diagnostic tests for the surgical candidates prior to EMU referral. Overall, there was an average of 1.9 diagnostic tests completed per child with a maximum of 6 prior diagnostic tests.(Table 15)

Table 15. Frequency of diagnostic evaluation prior to Epilepsy Monitoring Unit admission

Number of pre EMU referral tests	EMU Report (N=59)	Seizure Conference		Overall (N=219)
		Not a surgical candidate (N=96)	Surgical Candidate (N=64)	
0	21	17	8	46
1	20	20	10	50
2	9	33	14	56
3	6	16	11	33
4	2	8	10	20
5	1	2	6	9
6	0	0	5	5
Mean (SD) (min, max)	1.2 (1.2) (0,5)	1.8 (1.3) (0,5)	2.7 (1.8) (0,6)	1.9 (1.5) (0,6)

Diagnostic tests that occurred prior to EMU referral were completed well before the index EMU referral. As an example, 26 children had MEG completed prior to the index EMU referral, suggesting that they had already been seen previously at SickKids. The average time between the MEG evaluation and the time of the index EMU referral was 501 days (16.5 months) suggesting that these children, although previously seen at SickKids, were being referred for a second evaluation. Overall, in the 219 cases, the most frequently completed diagnostic test prior to EMU referral included MRI (159/219: 72.6%) and EEG (136/219: 62.1%), while previous vEEG (33/219: 15.1%), MEG (26/219: 11.9%), or CT (24/219: 11.0%) where less common.(Table 16)

Table 16. Timing of previous diagnostic test completion prior to Epilepsy Monitoring Unit referral

	N	Mean (days)	Median (days)	Minimum (days)	Maximum (days)	90th Percentile (days)
MRI	159	467	316	3	4,635	1,050
EEG	136	442	221	2	4,059	1,075
vEEG	33	781	616	42	2,449	1,751
MEG	26	501	404	86	1,807	883
CT	24	530	312	20	2,126	1,379
NPA	17	675	541	17	2,295	1,900
fMRI	9	329	153	90	1,129	1,129
PET	8	1,644	1,515	113	3,866	3,866
Wada	2	465	465	47	883	883
EP	1	2,822	2,822	2,822	2,822	2,822
SPECT	1	448	448	448	448	448
FS MRI	0					

Following the index vEEG subsequent diagnostic evaluations are ordered prior to the first seizure conference. Some of the time delay between the initial EMU visit and first seizure conference may be attributed to the wait-time for diagnostic tests to be ordered and completed. The time interval from ordering of the diagnostic tests to when they were completed (wait-time) for all of the diagnostic tests captured in this study is summarized in Table 17. As may be expected the most frequently ordered test for these children was a vEEG (n=512) followed by an MRI (n=299), then an EEG (n=221) and finally a MEG (n=130).

Table 17. Wait times of diagnostic tests for all children referred to the EMU excluding post-operative diagnostic evaluations (in days)

Diagnostic Test	N	Mean	Median	Min	Max	90th Percentile	% completed in 28 days	% completed in 12 weeks
vEEG	512	101	61	0	441	295	30%	63%
MRI	299	123	102	1	370	246	16%	44%
EEG	221	175	175	0	651	354	8%	27%
MEG	130	108	77	3	443	256	17%	56%
NPA	76	155	139	14	400	302	6%	33%
fMRI	50	141	120	36	456	273	0%	37%
CT	39	28	15	0	126	126	67%	89%
fsMRI	16	147	118	15	392	273	13%	25%
PET	10	116	116	65	166	166	0%	50%
Wada	10	140	126	36	309	309	0%	43%
EP	4	82	70	65	111	111	0%	67%
SPECT	3	159	159	6	188	159	50%	50%
ECOG	1	22	20	159	159	40	0%	
other	3			5	40		67%	100%
Total							14%	44%

The median and 90th percentile for the most common tests were vEEG (median 61 days, 90th percentile 295 days), MRI (median 102 days, 90th percentile 246 days), EEG (median 175 days, 90th percentile 354 days), and MEG (median 77 days, 90th percentile 256 days). The percentage of cases that receive diagnostic tests within 12 weeks (3 months) was on average 44%. Over half of the diagnostic evaluation for both MEG (56%) and vEEG (63%) were completed with a 12 week period.

In some children, diagnostic tests were repeated. Specifically, for the children who were determined to be surgical candidates, 56 out 64 cases (88%) had at least one test repeated, while 40% of seizure conference cases and 20% of cases with EMU report only had tests repeated.(Table 18) The need to conduct a second MRI was required in 66% of the children who were surgical candidates however a repeated MEG was needed in only 22% of children who were surgical candidates.

Table 18. Children with at least 1 repeated diagnostic test by group (including pre-EMU referral diagnostic tests and between EMU-referral and surgery)

Repeated Diagnostic Test	EMU Report (N=59)	Seizure Conference	
		Not a surgical candidate (N=96)	Surgical candidate (N=64)
	n (%)		
Any test	12 (20%)	38 (40%)	56 (88%)
MRI	4 (7%)	23 (24%)	42 (66%)
MEG	0 (0%)	4 (4%)	14 (22%)
EEG	8 (14%)	16 (17%)	12 (19%)
NPA	0 (0%)	0 (0%)	7 (11%)
vEEG	0 (0%)	1 (1%)	5 (8%)
fMRI	0 (0%)	1 (1%)	2 (3%)
CT	0 (0%)	0 (0%)	1 (2%)
PET	0 (0%)	1 (1%)	0 (0%)
Other	0 (0%)	0 (0%)	1 (2%)

When a test was repeated for a child in any of the groups, the average time between tests was determined. Of the most frequently repeated tests, the mean time between repeat tests was more than one year for MRI (535 days), vEEG (483 days), EEG (405 days), and MEG (588 days).(Table 19)

The 90th percentiles for times were 1,102 days (2.8 years) for MRI, 1056 days (2.9 years) for vEEG, 1037 days (2.8 years) for EEG, and 1,077 days (2.9 years) for MEG. The greatest time between repeat tests was for neuropsychological assessment (n=7), with a mean time of 1,235 days (3.4 years) and a 90th percentile of 3,712 days (10.2 years).(Table 19)

Table 19. Time between repeated diagnostic tests (in days).

Diagnostic Test	N	Mean	Median	Minimum	Maximum	90th Percentile
MRI	91	535	370	8	3458	1102
vEEG	91	483	365	0	2526	1056
EEG	41	405	196	7	2362	1037
MEG	19	588	462	39	2172	1077
NPA	7	1235	917	81	3712	3712
fMRI	3	511	336	280	916	916
CT	1	249	249	249	249	249
fs MRI	1	149	149	149	149	149
PET	1	1794	1794	1794	1794	1794
Other	1	182	182	182	182	182

4.7.2 Access to medical personnel

The time to complete diagnostic testing was also a function of how long the wait time was for medical visits. Medical visits included visits to neurologists, as well as visits for assessment and treatment of functional limitations (vision, mobility, etc.) that may have been present. Outlined below is a summary of the wait time to be seen by selected medical personnel where information was available in the charts. The mean wait times to visit a neurosurgeon was 144 days, an epileptologist 86 days, psychiatry 118 days, and orthoptics 67 days. Ninety-percent of children were able to see a neurosurgeon within 337 days, an epileptologist within 168 days and a psychiatrist within 235 days, and orthoptics within 130 days. Longer delays are seen with seeing a Social Worker (90^{th} percentile 323 days).

Table 20. Appointment wait times for medical personnel (includes pre and post-surgery) in days

	N	Mean	Median	Min	Max	90th Percentile
Neurosurgeon	169	144	105	1	680	337
Epileptologist	34	86	62	6	368	168
Psychiatry	20	118	102	1	309	235
Orthoptics	10	67	54	16	134	130
Neurologist	10	59	61	8	132	115
Social Work	10	139	119	0	462	323
Opthalmology	6	135	118	51	274	274
Developmental Assessment	2	81	81	21	140	140

4.8 Utilization of magnetoencephalography in the determination of surgical candidacy

For cases that had a seizure conference (n=160), MEG was used as a part of the diagnostic evaluation for surgical candidacy decisions in 61.5% of cases. Amongst those who became candidates for surgery, for whom MEG was used as a part of the diagnostic work-up, 32/59 (54.2%) went directly to surgery, averting the use of invasive extraopertive electroencephalography. In the 64 cases where surgical candidacy was determined, MEG was used in all but 5 cases (92%). In these 5 cases, the surgery was a corpus callosotomy, where the use of MEG was not necessary. In non-surgical candidates (N=61), and the subjects without further assessment (N=35), MEG was used in 40 (41.6%) children as a part of the diagnostic evaluation.

Table 21. Frequency of use of magnetoencephalography for the determination of surgical candidacy.

	Number of children (N=160)	% of group
Surgical Candidate*	64	
Surgery with MEG and no grid	32	50.0%
Surgery with MEG and grid	27	42.2%
Surgery with no MEG and grid	0	0.0%
Surgery with no MEG and no grid	5	7.8%
Not a surgery candidate	61	
With MEG	22	36.1%
Without MEG	39	63.9%
No further assessment	35	
With MEG	18	51.4%
Without MEG	17	48.6%
Total utilization of MEG	98	61.5%

The wait time to surgical decision was also affected by the use of MEG. When MEG was used early in the diagnostic pathway, i.e. before the first seizure conference, the median wait-time to a negative surgery decision was reduced by 154 days. When a positive surgery decision was made, cases that had early MEG had a median reduction of 289 days to the affirmative surgery decision.(Table 22)

Table 22. Time to surgical candidacy decision based on utilization of MEG prior to first seizure conference “Early” or “Late”, in days

	Early MEG	**Late MEG**	**Difference**
Non-surgical children (not a surgical candidate)	14	8	
Median time (days)	251	405	-154
Non-surgical children (no further assessment)	14	3	
Median time (days)	235	418	-183
Surgical candidates	41	18	
Median time (days)	193	482	-289

For the surgical candidates, the median time from index EMU to surgery was 296 days when the utilization of MEG in the diagnostic work-up for surgical candidacy was prior to the first seizure conference or "Early" (n=39) compared to 702 days in surgical cases where MEG was completed later in the diagnostic process (N=12). Similarly, the time from index EMU referral to the last seizure conference was shorter in the "Early" MEG group.(Table 23)

Table 23. Timing between diagnostic events based on utilization of MEG.

	N	Mean	Median	Min	Max	90th Percentile
Time between Index EMU to Surgery						
Early MEG	39	370	296	7	1403	826
Late MEG	12	700	702	22	1106	1026
Time between Index EMU referral to last seizure conference						
Early MEG	43	252	193	0	1129	504
Late MEG	15	492	517	233	769	713

4.9 Healthcare Costs

Total direct healthcare costs associated with the neurological evaluation of patients referred to the EMU to determine surgical candidacy were estimated using the patient-specific healthcare resource utilization captured in the study. Table 24 lists selected unit costs that were applied to resource utilization data to calculate the overall direct costs.

Table 24. Unit Costs

Resource item	Unit Cost (2010 $CAN)	Source
ASSESSMENTS		
Video EEG (First day)	$3,852	OHIP SOB; SickKids
Video EEG per day	$3,610	OHIP SOB; SickKids
Seizure conference	$206	SickKids
Neuropsychological assessment	$575	SickKids
DIAGNOSTIC TESTS		
EEG	$521	OHIP SOB; SickKids
CT	$248	OHIP SOB; SickKids case costing system
MRI	$445	OHIP SOB; SickKids case costing system
EP	$8,566	OHIP SOB; SickKids case costing system
Wada	$2,128	OHIP SOB; SickKids case costing system
SURGERY-RELATED		
Grid insertion	$14,352	OHIP SOB; SickKids case costing system
Craniotomy with or without grid removal	$7,978	OHIP SOB; SickKids case costing system
Grid hardware	$5,208	SickKids
Strips hardware	$6,342	SickKids
Depth electrodes hardware	$163	SickKids
iEEG day	$1,710	SickKids case costing system average
CCU day	$1,229	SickKids case costing system average
Ward day	$1,188	SickKids case costing system average
APPOINTMENTS & FOLLOW UP VISITS		
Neurologist	$171	OHIP SOB
Neurosurgeon	$121	OHIP SOB
Opthalmology	$71	OHIP SOB
Orthoptics	$25	OHIP SOB
Psychiatry	$186	OHIP SOB
Social Work	$39	SickKids
Neurology clinic visit, Pre-surgical	$257	SickKids
Neurology clinic visit, Post-surgical	$123	SickKids
Follow up visit, Non-surgical cases	$27	SickKids

OHIP SOB: Ontario Health Insurance Schedule of Benefits for Physician's Services

Table 25 presents the average cost of a MEG procedure. The average direct cost of MEG was obtained from the SickKids case costing system. The annual operating cost for MEG included the personnel cost for the MEG technician, scheduling clerk, and maintenance employee to refill helium once per week. The cost of annual maintenance, helium (150L per week) and other consumables were also included. No costs have

been assigned for the neuroradiologists time as there is currently no OHIP billing code for the MEG procedure.

Table 25. Unit cost of magnetoencephalography evaluation

Resource item	Unit Cost (2010 $CAN)	Details
Procedure Cost	$21,589	Average direct cost for MEG procedure
Neurophysiologist	$807	Average cost for analysis and interpretation of MEG
Annual operating costs	$1,497	Average annual cost for personnel, maintenance, and consumables (including helium)
Total Cost of MEG Procedure	**$23,893**	

Source: SickKids

As the health care resources used in the evaluation of surgical candidacy will vary depending on the suitability for surgery each of the patient groups costs were completed separately.(Table 26) In children who had at least one seizure conference, the mean total cost per patient for those individuals where surgery was not recommended was $23,705. For children who received a surgical recommendation, the mean total cost including any surgical interventions was estimated to be $89,945.

Table 26. Mean costs per patient by patient group

Mean cost per patient	Overnight vEEG only		Seizure Conference	
	No EMU report (n=130)	EMU Report (n=59)	Not a Surgical Candidate (n=96)	Surgical Candidate (n=64)
Diagnostic tests pre-EMU referral	-	$1,257	$1,424	$5,037
Diagnostic tests post-EMU referral	$4,454	$9,887	$11,272	$15,661
MEG	-	$405	$10,702	$32,106
EMU reports	-	$14	$14	$14
Seizure conferences	-	-	$251	$379
Appointments	-	-	$14	$64
Follow-up visits	-	-	$27	$672
Surgical interventions	-	-	-	$32,715
Post-surgery tests	-	-	-	$3,061
Post-surgery appointments	-	-	-	$236
Mean Total Cost Per Patient	**$4,454**	**$11,563**	**$23,705**	**$89,945**

4.10 Surgical Outcomes

Of the index cohort, 56 surgeries were performed between July 26, 2004 and August 18, 2008. The most common types of surgeries were temporal lobectomy (39.3%) or lesionectomy (21.4%). The mean time from EMU referral to surgery day was 437 days. The time varied from 151 days for frontal resections to 569 days for temporal lobectomy, not including the 2 non-resection surgeries (972 days). Two surgical cases were initiated with an iEEG, leading to surgical resection, however following the findings of the iEEG the childrens' families chose not to pursue epilepsy surgery. The surgical interventions are outlined in Table 27.

Table 27. Surgical interventions in those individuals accepting surgical options (N=56)

Surgery Intervention	N	% of Cases	Mean Time to Surgery (days)	% MEG	% Grid
Temporal Lobectomy	22	39.3%	569	95%	50%
with extratemporal resection	8		543	100%	88%
Lesionectomy	12	21.4%	360	83%	8%
Extratemporal resection	9	16.1%	366	100%	89%
Frontal	4	7.1%	151	100%	75%
Corpus Callosotomy	3	5.4%	243	33%	0%
Hemispherectomy	2	3.6%	309	100%	0%
No Resection	2	3.6%	972	100%	100%
Other (Gyrectomy, Cortical Resection)	2	3.6%	220	100%	50%
	56		437	91%	46%

The percentage of children that were seizure free 1 year following surgery was 73%.(Table 28) Of those with available one-year post surgery follow-up, 94% of children had a reduction in the frequency of their seizures.

Table 28. One-year seizure frequency for children by surgical intervention

Surgery	N	% with Seizure Frequency Reduction	% Seizure Free at 1 year
Temporal Lobectomy	22	91%	82%
Extratemporal resection	8	88%	75%
Lesionectomy	12	92%	75%
Extratemporal	9	100%	78%
Frontal*	3	100%	67%
Corpus Callosotomy^	2	100%	0%
Hemispherectomy	2	100%	50%
No Resection	2	0%	0%
Other (Gyrectomy, Cortical Resection)	2	100%	50%
Overall (N=54)		91%	70%
With Resection (N=52)		94%	73%

* post operative mortality (N=1)
^ no follow-up data available (N=1)

Overall clinical improvement occurred in the majority of children. The average number of seizures per day fell from 3.6 per day at the time of referral to 0.36 per day at one year.(Table 29) In addition, the number of limitations fell from an average of 1.5

limitations pre-surgery to 0.5 limitations post-surgery. The greatest gains in functional limitations were the almost elimination of fine motor limitations (11/12, 91.7%), and the elimination of the majority of cognitive/academic limitations (28/39, 71.8%). Overall, 21 children that previously had a limitation were free of limitations at one year.(Table 29)

Table 29. Seizure and functional limitations prior to and 1 year following surgery (n=56)

	Prior to Surgery	1 year following Surgery	% reduction
Seizure Frequency/day (mean)	3.6	0.36	90.2%
Functional Limitations (mean)	1.5	0.5	67.5%
Any functional limitation (n)	43	22	48.8%
Academic (n)	39	11	71.8%
Behavioural (n)	22	8	63.6%
Gross Motor (n)	11	6	45.5%
Fine Motor (n)	12	1	91.7%

5.0 DISCUSSION

The evaluation of infants, children and adolescents with medically refractory epilepsy for the determination of the surgical candidacy is a complex step-wise process requiring multiple diagnostic tests and the expertise of a multidisciplinary team.[3;4] This study examined the utilization of diagnostic services and captured information regarding the time between the various stages of surgical candidacy assessment. This project was initiated to examine the use of MEG at the request of OHTAC.[6] In order to accomplish this request it was considered necessary to take a broader perspective to understand where MEG "fit-in" amongst all other diagnostic tests. Therefore, secondary to this request the study identified several issues related to the evaluation of surgical candidacy children with drug refractory epilepsy in Ontario.

As SickKids is the primary institution in Ontario that provides epilepsy surgery to children in the province, the referral pattern to the EMU and time to initiate the diagnostic evaluation was examined. On a per capita basis by LHIN, referrals to SickKids EMU occurred at a similar rate in the Greater Toronto Area and in Central and North Eastern Ontario. The similar referral rates may be partially explained by the absence of an EMU in Central and Northern Ontario, requiring children to travel to Toronto for assessment. During the two year period of enrolment into the study, there were 463 referrals to the EMU as SickKids. Of these referrals 349 (75.4%) received a prolonged overnight vEEG lasting at least 8 hours primarily at the request of a neurologist for diagnosis or pre-surgical assessment. On average, from the time since a child's first seizure, it took 4.7 years for this referral with a maximum time from first seizure of 16.2 years in an adolescent. At the time of EMU admission the mean number of seizures experienced by the children was 4.3 per day. In their lifetime the children had been prescribed at least 3 different medications on average to try to control seizures. Also, the majority of children exhibited at least one functional limitation (79%).

Along with a delay in referral for surgical candidacy assessment, there is an apparent low overall rate of referral. If it is assumed, based on prevalence data, that there are 3,300 children in the province with medically intractable epilepsy, the average annual referral rate to the EMU at SickKids for prolonged vEEG of 175 children per year (349

referrals over 2 years) would represent an estimated 6% annual referral rate. Reasons that have been suggested for a low rate and/or delayed referral for epilepsy surgical assessment include a lack of awareness and education among family practitioners and neurologists about the potential benefit of epilepsy surgery and that some clinicians may consider it to be a "last ditch effort"[8-11]

The potential for reduced surgical assessment decision time is possible provided there is timely access to diagnostic evaluation. From the EMU assessment, 160/349 (45.8%) children's cases were reviewed through the multidisciplinary seizure conference. Diagnostic evaluations are ordered prior to seizure conferences and each diagnostic test requested (i.e. MRI, MEG, NPA, fMRI) had an associated mean wait-time of between 100 and 180 days. Each incremental diagnostic evaluation thus contributed to the total time to surgical candidacy decision depending on the number of seizure conferences required. For those individuals that were surgical candidates the mean total time to surgery was 437 days from their index referral. A recent publication by Wright et al. examined paediatric surgical wait times and for neurosurgery reported that in 2009 that 23% of surgeries were completed past their target. However, surgical interventions in other subspecialties such as dentistry, ophthalmology, plastic surgery and oncology had a greater proportion of surgeries completed beyond their target time.[12]

It appears from this study that the utilization of MEG may reduce this wait-time to surgical decision depending on the timing of the diagnostic evaluation relative to the first seizure conference. In the surgical candidates, MEG was used as a part of the diagnostic evaluation in the majority of children (91%). More importantly, the use of MEG also contributed to the ability to avert the need for invasive monitoring prior to surgery in 32 (54.2%) of cases. In non-surgical candidates, MEG supported the decision to not to proceed to surgery in under half of the children (41.7%). The utility of MEG in the assessment of surgical candidacy at SickKids has been previously reported in the literature.[13-15] Details regarding outcomes for children that either had surgery or were assessed between April 2004 and August 2005, in this retrospective review, may have been included in these publications. In order to determine further incremental utility of MEG, more complex alternative study designs could be employed (e.g. blinded,

mock-adjudication of surgical candidacy with or without MEG diagnostic results), however these studies are challenging to implement without the risk of bias. Specifically, the ability to analyze MEG data and to integrate the MEG findings is limited to a few experts in the province.

In addition to the potential to reduce wait times for surgical assessment, there is also a potential to reduce the overall cost for diagnostic evaluations. The estimated average cost of surgical candidacy determination ranged from $4,454 for children having only an overnight vEEG to an average of $89,945 for children determined to be surgical candidates. A large proportion of the average cost per surgical candidate is attributed to the utilization of MEG (36%). With only 19 children requiring a repeated MEG, the majority of this costs is associated with a single evaluation.(Table 19) Multiple diagnostic evaluations were required for the determination of surgical candidacy with 88% of surgical candidates requiring repeated evaluation, primarily multiple MRIs.(Table 18) Factors that may contribute to the need for repeat evaluation include changes in seizure characteristics over time, re-evaluation based on results from other diagnostic tests, requirement for specific diagnostic test protocols for epilepsy and overall wait-times for other evaluations and assessments. It may be possible to reduce the need for repeat diagnostic evaluation, in some cases, through wait-time reductions and coordination of test protocols between diagnostic centres across the province.

In addition to the potential to reduce overall costs, there is external evidence that surgery may be cost effective relative to medical management. The cost effectiveness of surgery has been evaluated in adults and in children. In adults, Wiebe et al. have demonstrated that surgery was cost effective in temporal lobe epilepsy.[16] Recently, the cost-effectiveness of paediatric epilepsy surgery compared to medical treatment in children was examined at SickKids using a subset of data from children undergoing surgery (n=15) and medical-management (n=15) included in this field evaluation. In this cost-effectiveness evaluation, the base-case analysis yielded an incremental cost-effectiveness ratio of $36,900 for seizure freedom at 1 year follow-up relative to medical treatment.[17] The authors of this analysis state that further evaluation of cost-effectiveness is warranted that incorporates quality adjusted life years to further examine the impact on long-term quality of life in children with medically refractory

epilepsy.[17] In adults, quality of life in patients undergoing epilepsy surgery has been measured using disease-specific scales and generic quality of life measures are less frequently employed.[18] The impact of medically intractable epilepsy on the quality of life of children and adolescents has been evaluated using qualitative research methods and the impact on physical, emotional/behavioural, social, and cognitive/academic aspects of life described.[19] The overarching theme identified this study was that "seizures are a barrier to normalcy".[19] Changes in quality of life following epilepsy surgery however may take time to occur and longer-term evaluation is warranted.[20-23]

In our analysis, epilepsy surgery improved the quality of life for children at least over the short term. For those children that had a surgical resection (n=52), the overall percentage of that were seizure free at 1 year was 73% with 94% of experiencing a reduction in seizure frequency following surgery. Overall there was a 90.2% reduction in seizure frequency and in those children with baseline functional limitations, a 48.8% reduction in those reporting any limitation. These clinical outcomes similar if not better than other centres conducting paediatric epilepsy surgery.[24-28]

This field evaluation has examined issues related to epilepsy surgery in Ontario, specifically referral patterns and delays, diagnostic test wait-times, utilization of diagnostic tests, healthcare resource utilization and costs as well as surgical outcomes. The primary findings of this evaluation are that in Ontario there are geographic imbalances related to access to vEEG and specialized epilepsy care. Referral rates for surgical assessment are low with only a small proportion of potentially eligible children being seen at SickKids. Few children are being assessed for surgical candidacy and thus are not being provided the potential opportunity to be seizure free and to be without functional limitations following surgical intervention. There are also opportunities to reduce wait-times and costs, by avoiding the duplication of diagnostic evaluations through coordinated care between centres in the province.

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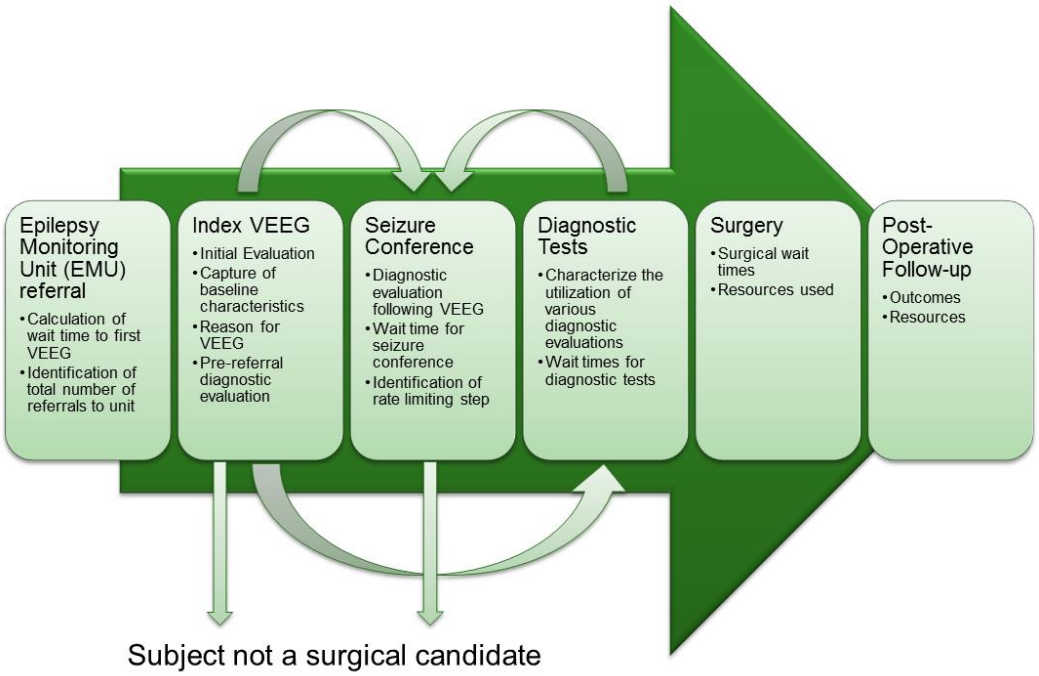
Appendix I. Overview of Study Design



Appendix 2. Population of Local Health Integration Networks in Ontario in 2006.

LHIN number	Location	Population in 2006
	Ontario	12364500
1	Erie St.Clair	645200
2	South West	924100
3	Waterloo Wellington	685400
4	Hamilton Niagara Haldimand Brant	1352500
5	Central West	720300
6	Mississauga Halton	1040800
7	Toronto Central	1146800
8	Central	1542900
9	Central East	1459800
10	South East	442800
11	Champlain	1176600
12	North Simcoe Muskoka	416900
13	North East	567900
14	North West	242500

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