Fully endoscopic microvascular decompression for hemifacial spasm

Tracy M. Flanders, MD,¹ Rachel Blue, MD,¹ Sanford Roberts, MD,¹ Brendan J. McShane, BA,¹ Bryan Wilent, PhD, DABNM,² Vijay Tambi, MS, DABNM,² Dmitriy Petrov, MD,¹ and John Y. K. Lee, MD, MSCE¹

¹Department of Neurosurgery, University of Pennsylvania, Philadelphia, Pennsylvania; and ²SpecialtyCare, Nashville, Tennessee

OBJECTIVE Hemifacial spasm (HFS) is characterized by involuntary tonic and/or clonic contractions of facial nerve muscles. Fully endoscopic microvascular decompression (E-MVD) for HFS has not been widely adopted. This paper aims to illustrate the safety and efficacy of the fully endoscopic technique for HFS treatment.

METHODS The authors conducted a single-center retrospective study of 27 patients (28 separate E-MVD cases; 1 patient had bilateral E-MVD) diagnosed with HFS who underwent fully E-MVD from January 2013 to October 2016. Intraoperative brainstem auditory evoked potentials and lateral spread resolution were reviewed. Outcome was based on the clinical status of the patient at the last contact point with the senior author. Complications were categorized as facial weakness, hearing loss, ataxia, dysphagia, or any adverse event able to be attributed to the surgical procedure.

RESULTS HFS was relieved either completely or partially in the majority of cases (24 of 28, 85.7%). Of the 28 separate procedures, 17 (60.7%) resulted in complete resolution of symptoms, 4 (14.3%) resulted in near-complete resolution, 2 (7.1%) resulted in 50% reduction of symptoms, 1 (3.6%) resulted in minimal reduction, and 4 (14.3%) resulted in no relief. Of the 27 patients, 26 (96%) had no permanent postoperative complications. In multivariate logistic regression, the best predictor of greater than 50% resolution of spasm was resolution of intraoperative lateral spread response.

CONCLUSIONS A fully E-MVD for HFS provides a safe and comprehensive view of the neurovascular conflict. Exclusive use of the endoscope in MVD is both safe and feasible in the treatment of HFS. Attention to lateral spread response monitoring remains an integral part of comprehensive neurosurgical management.

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KEYWORDS hemifacial spasm; endoscopic; microvascular decompression; lateral spread response; functional neurosurgery

HEMIFACIAL spasm (HFS) is the unilateral tonic and/or clonic contraction of facial muscles. Beginning in the orbicularis oculi muscle with subsequent eyelid closure and/or eyebrow elevation, the symptoms often progress to the frontalis, platysma, and orbicularis oris muscles.³⁹ In its most severe form, HFS can present as a disfiguring, sustained grimace of partial eye closure and mouth lifting, described as the “tonus phenomenon.”³⁴ The involuntary facial movements have various psychosocial consequences for patients and can be highly debilitating. Patients often report symptom exacerbation with fatigue, anxiety, and/or head movement.²

Focal compression of the facial nerve resulting in myelin breakdown and ephaptic transmission is the accepted pathophysiology for HFS.²⁶ The root exit zone is recognized as the myelination transition of oligodendrocyte to Schwann cells; this region of the facial nerve is thus only protected by the arachnoid mater and is highly vulnerable to vascular insults.³⁰ The anterior inferior cerebellar artery (AICA), posterior inferior cerebellar artery (PICA), and vertebral artery (VA) are the most frequently implicated vessels in HFS.³¹

In 1962, Gardner first described the treatment of HFS with elimination of the neurovascular conflict between

ABBREVIATIONS AICA = anterior inferior cerebellar artery; BAEP = brainstem auditory evoked potential; CPA = cerebellopontine angle; EA-MVD = endoscope-assisted MVD; E-MVD = endoscopic MVD; HFS = hemifacial spasm; IONM = intraoperative neuromonitoring; LSR = lateral spread response; MVD = microvascular decompression; PICA = posterior inferior cerebellar artery; VA = vertebral artery.

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compressive arterial vessels and the facial nerve.⁸ Janetta et al. revolutionized the treatment of HFS with microvascular decompression (MVD) via the suboccipital approach to the cerebellopontine angle (CPA). MVD has now become the standard and accepted surgical technique for HFS treatment with long-term success rates (within 10 years) of 83%–97%.^{5,14}

In recent years, endoscopy has entered the neurosurgical arena as an attractive alternative or adjunct for conventional microsurgery.^{1,7,15–17,20,27,28,33} The endoscope provides the advantage over the microscope of enhanced and safe visualization of the neurovascular anatomy.²³ The panoramic view afforded by the endoscope enlarges the surgical field of vision while eliminating cerebellar or brainstem retraction and the need for extensive dissection, which is necessary when using the microscope, to allow for an unobstructed view of the relevant neurovascular structures. Additionally, the use of angled lenses allows for visualization around corners, which would otherwise be visually obstructed. In cadaveric studies, quantitative analysis has demonstrated a nearly 2-fold increase in the view of the endoscope compared with the microscope.³⁵ This enhanced visualization has, in our experience and in commentary of other surgeons, allowed for a greater anatomical exposure that enables an increased ability to locate nerve-vessel conflicts that are limited with the microscope vantage point.⁴ While the endoscope has been adopted by neurosurgeons as an adjunct to microsurgery in the posterior fossa, there are limited data on fully endoscopic microvascular decompression (E-MVD) for HFS. The current study aimed to present one surgeon's case series of HFS patients undergoing fully E-MVD to illustrate the safety and efficacy of the fully endoscopic technique.

Methods

Study Participants

The University of Pennsylvania institutional review board approved this study, and a waiver of HIPAA Authorization was obtained as data were retrospectively analyzed. Between January 2013 and October 2016, 27 patients with a preoperative diagnosis of HFS underwent fully E-MVD by the senior author (J.Y.K.L.) in the Department of Neurosurgery at Pennsylvania Hospital. Patients were selected for elective treatment of their HFS based on clinical history and physical examination and radiological findings. Imaging studies were provided to note the presence of structural abnormalities and neurovascular conflicts. All patients underwent clinical evaluation preoperatively and postoperatively by the senior author or another healthcare provider at the same institution. The results in the present study represent only those patients who chose to undergo surgical treatment for HFS. Patients who underwent microscope only or combined microscope and endoscope-assisted MVD (EA-MVD) were excluded.

Operative Procedure

The surgeon performed 28 fully E-MVDs between 2013 and 2016. Prior to 2013, the surgeon had performed microscopic surgery exclusively and microscopic surgery with endoscopic assistance (EA-MVD), in which the mi-

croscope was used as the primary visualization tool and the endoscope as an adjunct. In the present study, the surgeon employed a fully endoscopic technique. Further details of the operative technique and early experiences with MVD for trigeminal neuralgia have been extensively described in prior publications.^{3,11,22,23} In particular, the position of the scope relative to the surgeon's hands has been extensively described as well.²³ In this fully endoscopic approach, the Mitaka Pneumatic Arm (Mitake Kohki Co.) was utilized with a 2.7-mm, 0° endoscope (Storz). The small diameter of the endoscope allows for maximization of the surgical working space to allow for entrée of other instruments (Fig. 1). The 30°-angled endoscope is employed to enhance further visualization of the CPA.

Intraoperative Neuromonitoring

The intraoperative neuromonitoring (IONM) plan for each patient included free-run and triggered cranial nerve electromyography, brainstem auditory evoked potentials (BAEPs), and lateral spread response (LSR) monitoring. IONM was performed using a Cascade (Cadwell) or NIM-Eclipse (Medtronic) system. Electromyography activity was recorded from needle electrodes inserted intradermally in the frontalis, orbicularis oculi, orbicularis

FIG. 1. Illustration of the operative technique employed by the senior author for the fully endoscopic approach. The position of the surgeon's hands in relation to the endoscope with the Mitaka Pneumatic Arm has been well described in prior publications.²³ Artist Eo Trueblood. Copyright Stream Studios at the Children's Hospital of Philadelphia. Published with permission. Figure is available in color online only.

oris, and mentalis muscles. LSR was evoked by stimulation of the zygomatic branch of the ipsilateral facial nerve from 6 to 12 mA. LSRs were recorded from the ipsilateral orbicularis oris and mentalis muscles. Short-acting depolarizing muscle relaxants were administered at induction and then maintained at minimal doses to preserve signals from the ulnar nerve, the median nerve, and the posterior tibial nerve. For BAEPs, alternating rarefaction and condensation clicks were delivered individually to each ear at 85- to 95-dB-SPL intensity at a rate of 11.1–17.5 Hz. While one ear was being stimulated, contralateral white noise masking 40–65 dB-SPL was applied. BAEPs were recorded via subdermal needles placed at A1, A2, and CPz with channels of A1-CPz and A2-CPz for the left and right ears, respectively. All BAEPs were bandpass filtered from 100 to 1000 Hz, and 200–500 trials were used for BAEP recording.

Clinical Follow-Up Review

Outcome was based on the clinical status of the patient at the last contact point with the senior author or with a clinician in the hospital system. The shortest follow-up time was less than 1 month. Outcome was determined by the effect of treatment on signs and symptoms. Complications were categorized as facial weakness, hearing loss, ataxia, dysphagia, or any adverse event that could be attributed to the surgical procedure.

Statistical Analysis

All patients were grouped into one of 2 groups based on clinical outcome: 1) resolution of symptoms or 2) presence of residual symptoms. Patients were also grouped based on intraoperative lateral spread findings: 1) complete resolution or 2) no resolution. Two-by-two contingency tables were created, and Fisher's exact test was used to compare groups due to low numbers, with α set at 0.05. Stata 10 (StataCorp) was used for analysis of contingency tables as well as of univariate and multivariate logistic regression.

Results

Patient Demographics

Patient demographics are summarized in Table 1. There were 9 men (33.3%) and 18 women (66.7%). The mean age was 54.6 years (range 28–73 years). Of the 27 patients, 26 (96.3%) had previously undergone failed treatment with Botox. There were 16 left-sided (57.1%) and 12 right-sided (42.9%) cases; of note, 1 patient had bilateral HFS and underwent staged (4 months later) bilateral E-MVD. Of the 27 patients, 2 patients (7.4%) had undergone prior ipsilateral MVD for HFS: one patient underwent 3 total ipsilateral MVDs prior to surgical treatment by the senior author (2 to treat HFS and 1 to treat trigeminal neuralgia), and the other patient underwent ipsilateral MVD by the senior author 2 years prior for HFS before implementation of the fully E-MVD. In addition, 1 patient had a stable, calcified meningioma posterior to the hypoglossal canal and above the foramen magnum in addition to HFS, and she underwent biopsy of this lesion during E-MVD. The mean duration of symptoms prior to surgical treatment was 6 years (range 1.5–17 years).

TABLE 1. Patient demographics

	Value
Sex	
Male	9 (33.3)
Female	18 (66.7)
Mean age, yrs (range)	54.6 (28–73)
Preop Botox	
Yes	26 (96.3)
No	1 (3.7)
Laterality*	
Lt	16 (57.1)
Rt	12 (42.9)
Prior ipsilateral HFS op	
Yes	2 (7.4)
No	25 (92.6)
Mean duration of Sx prior to op, yrs (range)	6.0 (1.5–17)

Sx = symptoms.

Values are presented as the number of patients (%) unless stated otherwise.

* Values are presented as the number of cases (%).

Intraoperative Findings: Operating Room Data and Offending Vessel

Intraoperative findings are summarized in Table 2. The mean operating room time, defined as from the start of skin incision to the end of skin closure, was 119.7 minutes with a range of 87 to 206 minutes.

Of the 28 E-MVDs, 19 (67.9%) were notable for BAEP changes, and 9 (32.1%) did not exhibit any BAEP changes. Of the 19 with BAEP changes, 5 (26.3%) returned to baseline, and 14 (73.7%) returned to near baseline at du-

TABLE 2. Intraoperative findings

	Value
Mean op room time, mins (range)	119.7 (87–206)
BAEP changes	
Yes	19 (67.9)
No	9 (32.1)
BAEP return to baseline prior to dural closure	
Yes	5 (26.3)
No	14 (73.7)
Resolution of LSR w/ decompression	
Yes	16 (57.1)
No	10 (35.7)
Unknown	2 (7.1)
Vessel	
AICA	19 (67.9)
AICA & other vessel	2 (7.1)
Other*	3 (10.7)
Unknown	4 (14.3)

Values are presented as the number of cases (%) unless stated otherwise.

* The VA and transverse pontine vein, among others.

ral closure. With regard to lateral spread, 16 (57.1%) cases exhibited complete resolution with decompression of the facial nerve and 10 (35.7%) did not have resolution of the LSR; 2 patients (7.1%) had unknown responses (one patient had no lateral spread that could be evoked at the time of surgery, and the other patient's IONM data were unable to be located).

The neurovascular conflict was attributed to the following vessels: 19 (67.9%) AICAs, 2 AICAs and another vessel (7.1%) (AICA and VA; and AICA and brainstem perforator), 3 (10.7%) other (transverse pontine vein or small arteriole; VA; and VA and PICA). The vessels were unknown in 4 (14.3%) cases (operative notes did not explicitly identify the offending vessel).

Postoperative Data and Complications

Postoperative information and complications are summarized in Table 3. The mean length of stay was 3 days (range 2–7 days). The mean follow-up with the senior author was 2.9 months (range 0.25–27 months, mode 1 month). Of the 27 patients, 26 (96%) patients had no permanent complications, and 20 (74%) had no postoperative complications at all. Only 1 patient had an objective permanent neurological complication, hearing loss, which was confirmed by specialist referral. This patient did not have BAEP changes at the time of surgery. One patient (3.7%) exhibited postoperative ataxia but refused vestibular rehabilitation or further treatment, and the symptoms resolved over time. One patient (3.7%) reported subjective dysphagia but did not require feeding tube placement or further workup, and the symptoms resolved over time. Three patients (11.1%) had transient facial weakness that resolved at the final clinic visit, and all 3 of these patients had previously been treated with Botox injections. One patient (3.7%) had significant transient pain from dried blood thought to be from an IONM needle resulting in otitis that resolved over time. CSF leak, cardiac events, stroke, and mortality did not occur in any of the patients postoperatively.

Clinical outcomes are summarized in Table 3. Of the 28 separate E-MVD cases (27 patients, 1 with bilateral E-MVD), 17 (60.7%) experienced complete resolution of symptoms, 4 (14.3%) had near-complete resolution, 2 (7.1%) had 50% reduction of symptoms, 1 (3.6%) had minimal reduction, and 4 (14.3%) had no relief.

IONM Findings and Correlation to Postoperative Outcomes

As summarized in Table 2, of the 28 E-MVDs, 19 (67.9%) had a > 1.0 msec shift in wave V of the BAEP, while 9 (32.1%) did not. Of the 19 cases, 5 (26.3%) returned to baseline, and 14 (73.7%) returned to near baseline at dural closure. Of the 19 cases with BAEP changes that had complete or near-complete return to baseline, none of the patients exhibited postoperative hearing loss. For the 9 cases that did not have > 1.0-msec shift in wave V, 1 patient did exhibit postoperative hearing loss, and this patient was noted to have a 0.7-msec shift in wave V on retrospective review. LSR data were available in 26 of 28 cases. Sixteen patients (61.5%) had complete resolution

TABLE 3. Postoperative findings

	Value
Mean LOS, days (range)	3.0 (2–7)
Follow-up w/ senior author, mos	
Mean (range)	2.9 (0.25–27)
Mode	1
Permanent complications	
Partial hearing loss	1 (3.7)
Cardiac event	0
Stroke	0
Death	0
Subjective/transient complications	
Transient facial palsy	3 (11.1)
Permanent facial palsy	0
Ataxia	1 (3.7)
Dysphagia	1 (3.7)
Otitis	1 (3.7)
CSF leak	0
Resolution of Sx*	
Complete resolution	17 (60.7)
Near-complete	4 (14.3)
50% reduction	2 (7.1)
Minimal reduction	1 (3.6)
No relief	4 (14.3)

LOS = length of stay.

Values are presented as the number of patients (%) unless stated otherwise.

* Values are presented as the number of cases (%).

with decompression of the facial nerve, and 10 (38.4%) did not. For one patient, an LSR could not be obtained at baseline, and for another, the IONM record was not retrievable.

As summarized in Tables 4 and 5, intraoperative resolution of lateral spread resulted in a 7-fold higher chance of achieving more than 50% spasm-free relief ($p = 0.036$). The following variables were tested in a stepwise logistic regression in multivariate analysis: sex, age (years), prior Botox injection, prior ipsilateral MVD, and duration of symptoms (years). In patients who experienced $\geq 50\%$ spasm relief, resolution of LSR was found to have an OR of 26.59 ($p = 0.020$).

Discussion

Since the late 1960s, MVD has been viewed as the standard of care for HFS treatment when medical manage-

TABLE 4. Prediction of spasm-free outcome with resolution of lateral spread

	Univariate Analysis p Value	Logistic Regression Analysis OR
100% spasm relief	0.15	3.3
$\geq 90\%$ spasm relief	0.074	4.5
$\geq 50\%$ spasm relief	0.036	7

TABLE 5. Multivariate analysis of spasm-free outcome

	Multivariate Analysis p Value	Logistic Regression Analysis OR
100% spasm relief	0.103	4.58
≥90% spasm relief	0.05	6
≥50% spasm relief	0.02	26.59

ment has failed.^{14,30} We propose that fully E-MVD confers superior visualization of the complex anatomy of the CPA. While many studies have examined fully endoscopic decompression of the trigeminal nerve, there are few reports of fully E-MVD for HFS. Cheng et al. reported 10 cases of fully E-MVD for HFS and stated that all of the patients experienced full resolution of symptoms postoperatively.⁴ They concluded that fully endoscopic approaches allow for identification of neurovascular conflicts that may not be clearly seen via the microscope.

Several studies have proven that IONM with BAEPs significantly reduces the risk of postoperative hearing loss.^{9,18,25,32} In the present study, 1 patient experienced ipsilateral postoperative hearing loss. This is comparable to reports of postoperative hearing deficits found in other studies.^{29,32} However, IONM during this particular patient's E-MVD in our series did not reveal a significant change in BAEPs during the decompression (i.e., greater than 1.0-msec shift in wave V). On retrospective review, the patient was noted to have a 0.7-msec shift in wave V, which suggests that more conservative alert criteria, such as 0.5 msec, may be warranted. The goal of IONM is near zero false negatives while limiting the false positives. The alert criteria of 1 msec is set to balance sensitivity and specificity.³⁶ In retrospect, a more prudent criterion may be a 0.5-msec shift from baseline set prior to dura opening. The patient's shift of 0.7 msec is more in line with these stricter criteria. Furthermore, the drilling, fluid deposition, or bone dust in the middle ear associated with a craniectomy can also produce hearing loss that may evolve in the postoperative period.⁴³ Further investigation of BAEPs in the context of fully endoscopic EVD is necessary to elucidate this mismatch between intraoperative BAEPs and postoperative hearing loss and, in this case, the cause of hearing loss is still not entirely clear.

LSR serves as an intraoperative surrogate to adequate facial nerve decompression.^{10,13,42} The phenomenon viewed on IONM presumes that resolution of lateral spread correlates with adequate decompression of the facial nerve (Fig. 2). However, the use of LSR as a prognostic indicator of HFS outcome is relatively controversial. Some studies have found that intraoperative LSR does not correlate with postdecompression outcome in HFS.^{6,24,38} Other studies have reported that intraoperative LSR accurately predicts clinical outcome.¹⁹ A meta-analysis showed that if the LSR is abolished intraoperatively, the success rate of achieving symptom relief will be 90.5% but will drop to 61% when the LSR cannot be abolished intraoperatively.³⁴ A study of 322 HFS patients showed a significant predictive value of LSR and a success rate of 94.7% when the LSR was abolished and only 67.3% when it is not.³⁷ The

FIG. 2. Resolution of lateral spread seen with IONM. Aqua indicates the baseline, and magenta indicates the most recent trace. Figure is available in color online only.

data here are consistent with those findings, as the success rate was 93.8% when the LSR was abolished but only 70% when the LSR was not abolished. We report that the LSR was abolished in 61.5% of cases, which is consistent with the report of patients with prior Botox treatment.⁴⁰

The fully endoscopic approach is limited in that the scope itself is prone to blood soiling and requires irrigation or antifogging. The scope also lacks 3D information feedback. At present, there is a lack of microinstruments specifically designed for endoscopic use in the subarachnoid space. These factors, along with the general lower frequency of use, contribute to the surgeon requiring a longer learning period to become proficient in the fully endoscopic technique to avoid complications. Identification of the neurovascular conflict in HFS is also surgeon dependent. The present study is limited in its generalizability due to the small sample size and lack of control groups. The retrospective nature further limits this study, given that not every single vessel was explicitly identified based on operative reports and that not all IONM information was readily available.

A study investigating outcomes among microsurgery,

endoscope-assisted microsurgery, and fully endoscopic surgery would further elucidate the safety and feasibility of fully endoscopic MVD and would also directly compare outcomes of various techniques and be of great value. The senior author previously published the results of his 2-year transition period from using the conventional microscope to endoscope-assisted to fully endoscopic MVDs; there was no statistically significant difference in outcomes for the endoscopic approach when compared with microscopic procedures.¹¹ In this 2-year transition period, all 5 patients with HFS had complete resolution of their preoperative symptoms. It is important to note that this transition period occurred only shortly after the endoscope was introduced into the senior author's routine practice. The purpose and outcome measures of this current study were designed to investigate the safety and feasibility, rather than the superiority, of fully E-MVD for HFS.

The present study found complete and near-complete resolution of symptoms in 60.7% and 14.3% of the cases, respectively. Patients in 7.1% of the cases experienced a 50% reduction in symptoms, and 3.6% had minimal reduction. No relief of symptoms was seen in 14.3% cases. This is lower than the reported success of 96.9% by Cheng et al. seen in endoscope-assisted and fully endoscopic MVD for HFS,⁴ but is comparable to the reported 70%–95% success from the general MVD literature regarding HFS.^{12,21,30,41} Long-term success rates (within 10 years) as high as 83%–97% have been reported.^{5,14} Of note, this follow-up is longer than that of our current cohort; in the cited studies, the proportion of spasm resolution increased with longer follow-up.

Visualization of the neurovascular conflict was seen in 100% of the cases in the present study. The endoscope allowed for complete visualization of the surgical region of interest. Video 1 shows a case in which the neurovascular conflict was only safely visualized with the 30° endoscope and not with the 0° scope alone.

VIDEO 1. Operative video showing a fully endoscopic approach for MVD for HFS. The lower cranial nerves are identified. The 30° endoscope was used to provide safe visualization of the deeper anatomical structures. The AICA is visualized and lifted from the nerve, and Teflon is easily placed between the root entry zone and the AICA. Copyright University of Pennsylvania. Published with permission. Click here to view.

In our experience, the angled 30° endoscope allows access to deeper structures that both the 0° endoscope and the microscope are unable to reach safely without significant brainstem retraction. We hypothesize that the smaller duralotomy required for the fully endoscopic technique may decrease postoperative headaches, which causes significant morbidity in this patient population. Future studies are needed to randomize patients into EA-MVD and E-MVD to determine if clinically significant benefit, such as decreased postoperative headaches, can be achieved from a fully endoscopic technique.

Conclusions

The present study reports our experience with fully endoscopic MVD for HFS treatment. The overall purpose of this paper is to add to the existing data on fully endoscopic MVD. The endoscope provides excellent visualization and

comprehensive evaluation of the neurovascular conflict in HFS patients. Exclusive use of the endoscope in MVD is a safe and feasible method of treating HFS. In the future, larger studies comparing arms of E-MVD, EA-MVD, and microscopic MVD will be of great value.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Flanders, Petrov, Lee. Acquisition of data: Flanders, McShane, Tambi, Lee. Analysis and interpretation of data: Flanders, Tambi, Lee. Drafting the article: Flanders, Wilent. Critically revising the article: Flanders, Blue, Wilent, Lee. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Flanders. Statistical analysis: Flanders, Wilent, Tambi, Lee. Administrative/technical/material support: Roberts, McShane, Wilent, Tambi, Petrov, Lee. Study supervision: Lee. Submission of IRB: McShane.

Supplemental Information

Videos

Video 1. <https://vimeo.com/274685949>.

Correspondence

Tracy M. Flanders: University of Pennsylvania, Philadelphia, PA. tracy.flanders@uphs.upenn.edu.