Patient Harm due to Diagnostic Error of Neuro-Ophthalmologic Conditions

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Running head: Diagnostic Error of Neuro-Ophthalmologic Conditions

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Abstract

Objective: To prospectively examine diagnostic error of neuro-ophthalmic conditions and resultant harm at multiple sites.

Design: Prospective cross-sectional study.


Methods: Collected data regarding demographics, prior care, referral diagnosis, final diagnosis, diagnostic testing, treatment, patient disposition, and impact of the neuro-ophthalmologic encounter. For misdiagnosed patients, we identified the cause of error using the Diagnosis Error Evaluation and Research (DEER) taxonomy tool, and whether the patient suffered harm due to the misdiagnosis.

Main Outcome Measures: The primary outcome was whether patients who were misdiagnosed prior to neuro-ophthalmology referral suffered harm as a result of the misdiagnosis. Secondary outcomes included appropriateness of referrals, misdiagnosis rate, interventions undergone prior to referral, and the primary type of diagnostic error.

Results: Referral diagnosis was incorrect in 49% of cases. Misdiagnosed patients suffered harm in 26%, which could have been prevented by earlier referral to neuro-ophthalmology in 97%. Patients experienced inappropriate laboratory testing, diagnostic imaging, or treatment prior to referral in 23%, with higher rates for patients misdiagnosed prior to referral (34% of patients compared to 13% with a correct referral diagnosis, p<0.0001). Seventy-six percent of inappropriate referrals were misdiagnosed, compared to 45% of appropriate referrals (p<0.0001). The most common reasons for referral were optic neuritis or optic neuropathy (21%), papilledema (18%), diplopia or
cranial nerve palsies (16%), and unspecified vision loss (11%). The most common sources of diagnostic error were the physical examination (36%), generation of a complete differential diagnosis (24%), history taking (24%), and utilization or interpretation of diagnostic testing (13%). In 489/496 (99%) patients, neuro-ophtalmologic consultation impacted patient care. In 2% of cases, neuro-ophtalmology directly saved the patient’s life or vision, in an additional 10% harmful treatment was avoided or appropriate urgent referral was provided, and in an additional 48% neuro-ophtalmology provided a diagnosis and direction to the patient’s care. **Conclusions:** Misdiagnosis of neuro-ophtalmic conditions, mismanagement prior to referral, and preventable harm are common. Early appropriate referral to neuro-ophtalmology may prevent patient harm.
Diagnostic error is common\textsuperscript{1-3} and can lead to serious harm, including death.\textsuperscript{4} A large proportion of malpractice claims are related to diagnostic error,\textsuperscript{5} and the rate is highest in fields that require complex, analytic diagnostic reasoning.\textsuperscript{6}

Neuro-ophthalmologists are trained to approach diagnosis using a systematic, time-intensive, analytic lens,\textsuperscript{7,8} and commonly encounter high rates of diagnostic error in the patients referred to their practices.\textsuperscript{9-19} When patients are incorrectly diagnosed, providers are likely to order unnecessary or even inappropriate tests and treatments,\textsuperscript{9-16,20,21} which may be costly or even harmful.

Prior studies of diagnostic error of neuro-ophthalmic conditions have typically been retrospective.\textsuperscript{9,10,12-15,19} Most have focused on a single neuro-ophthalmologic condition, such as third nerve palsy,\textsuperscript{10,15} idiopathic intracranial hypertension,\textsuperscript{12} optic neuritis,\textsuperscript{13} optic nerve sheath meningioma,\textsuperscript{14} and papilledema.\textsuperscript{16} While some have evaluated the amount of unnecessary or inappropriate diagnostic testing and treatments resulting from these misdiagnoses, such as neuro-imaging studies,\textsuperscript{9,11-15,20,21} intravenous steroids,\textsuperscript{13,14} lumbar punctures,\textsuperscript{12-14} and neurosurgical procedures,\textsuperscript{12} they have typically stopped short of measuring direct patient harms. Direct measurement of diagnostic error-related harms,\textsuperscript{22} which has been performed in studies of diagnostic error of dizziness due to stroke,\textsuperscript{23-31} may sidestep the inherent subjectivity and methodologic limitations that have limited prior research into diagnostic error.\textsuperscript{2,32}

Our goal was to prospectively evaluate diagnostic error of neuro-ophthalmologic conditions prior to referral to neuro-ophthalmology at multiple neuro-ophthalmologic services, and to directly evaluate actual patient harms resulting from the diagnostic errors that existed before the time of neuro-ophthalmologic consultation (NOC).
Methods

Institutional Review Board (IRB)/Ethics Committee approval was obtained at Emory University, Washington University in St. Louis, and Indiana University. Informed consent was waived because data were deidentified. The project adhered to the tenets of the Declaration of Helsinki.

We performed a prospective observational study of 496 new patient encounters seen at 3 academic tertiary care neuro-ophthalmology clinics by 5 neuro-ophthalmology attending providers (VB, NJN, LS, GVS, and DDM). Each site individually collected data for consecutive new patient encounters. These collection periods were not simultaneous, but each site’s collection period captured all consecutive new adult patients seen within the collection period. Indiana University collected all new adult patients who presented from 9/10/2019 to 10/11/2019; Washington University in St. Louis from 10/7/2019 to 11/8/2019; and Emory University from 1/2/2020 to 3/16/2020. Patients under age 18 were excluded. Referral materials were systematically reviewed by each provider, and further information was obtained from patient histories, as a standard aspect of the NOC in order to determine referral patterns. Each patient underwent a full neuro-ophthalmic assessment as a standard aspect of their clinical care. Final diagnosis was determined by a fellowship-trained neuro-ophthalmologist (VB, NJN, LS, GVS, or DDM) using history, a structured neuro-ophthalmic examination, and any appropriate ancillary diagnostic testing. In some cases, clear diagnosis required following up on results or following the course of the patient over time.

Data collected included: patient demographics (age, gender, body mass index, race/ ethnicity), duration of symptoms, time from referral to NOC, appropriateness of
referral (defined a priori as whether the referral question was a neuro-ophthalmologic
question as determined by the consulting neuro-ophthalmologist; examples of
inappropriate referrals included monocular diplopia or chronic eye pain from known dry
eye syndrome), number and specialties of providers seen before NOC, referral
diagnosis (based on detailed review of referral and medical records), tests and
treatments preceding NOC, whether those tests and treatments were appropriate, tests
and treatments ordered at NOC, final diagnosis, disposition from NOC, and the impact
of NOC on patient outcome. Impact on patient outcome was classified into 5 categories:
no impact; provided reassurance, avoiding further visits and tests; provided a diagnosis
and direction to treatment; avoided harmful treatment or provided urgent referral to an
appropriate provider; or directly saved vision or life.

For cases in which the referral diagnosis was incorrect (or absent), the Diagnosis
Error Evaluation and Research (DEER) taxonomy tool\textsuperscript{33,34} was applied, in keeping with
prior studies of diagnostic error of neuro-ophthalmic conditions,\textsuperscript{12-15} to identify the type
of diagnostic error and to locate the point in the diagnostic process at which the problem
occurred. If multiple types of error contributed, the most proximal cause of error was
assigned. This convention was chosen based on reasoning that the most proximal error
likely had downstream effects that influenced any other errors (for example, if the
examination was performed incorrectly and the generation of the differential diagnosis
was also incorrect, 2B was assigned rather than 5A, as the incorrect differential
diagnosis was highly likely to have been influenced by or directly caused by the
incorrect interpretation of the examination).
Data were collected on whether the patient suffered harm as the result of the diagnostic error, and whether quicker access to NOC could have prevented the harm, based on the clinical judgment of the attending neuro-ophthalmologist. Harm was defined by physical injury or adverse effect, including adverse effects of inappropriate medications. We did not capture unnecessary financial expenditures or potential stress or psychological harm.

Data were analyzed using SAS 9.4, SAS Inc., Cary, North Carolina. Proportions were compared using a chi-square test. Means were compared using a t-test. Data Availability Statement: anonymized data will be shared by request from any qualified investigator.

Results

We included 496 patients (223 from Emory, 162 from Washington University in St. Louis, and 111 from Indiana University). Sixty-six percent were female. Ages ranged from 18 to 97, with median age 50. Races and ethnicities represented were: 72% white, 23% black, 3% Asian, and 2% Hispanic. BMI was collected on 96% of patients, and ranged from 15-69, with mean BMI 32 ±9.

Two hundred forty-two (49%) patients were misdiagnosed, defined as a referral diagnosis that was different than the final diagnosis given at the NOC, or no diagnosis given by the referring doctor. The misdiagnosis rate did not differ based on gender (49% in females, 48% in males). BMI did not significantly differ in the misdiagnosed patients (p=0.79).
Symptom duration was collected for 98% of patients (in some cases, findings were noted incidentally, or symptoms had insidious onset): median estimated time from symptom onset to NOC was 200 days (IQR 71-730 days, range 0-16790 days). Time from referral request to NOC was collected for all patients: median number of days from referral to appointment was 30 days (IQR 10-65, range 0-476 days). Number of providers seen before NOC ranged from 0-22, with median 2 (IQR 2-3). There was no significant difference (p=0.85) in the number of providers seen before NOC for misdiagnosed patients. Patients had most commonly seen either an eye care provider (ophthalmologist or optometrist) or neurologist prior to NOC (Table 1). There was no meaningful difference between rates of misdiagnosis or rates of harm based on the specialty of the providers seen prior to referral.

Referral to neuro-ophthalmology was appropriate in 434 (88%) patients, with appropriateness defined by whether the referral was for a neuro-ophthalmic question. Inappropriate referrals were more likely to be misdiagnosed (76% of inappropriate referrals were misdiagnosed, versus 45% of appropriate referrals, p=<0.0001). Patients were referred for a wide range of complaints, including papilledema, optic neuropathies, anisocoria, diplopia or abnormal eye movements, headaches or sensory disturbances, sellar masses, unexplained vision loss, or other complaints (Table 2). There were no clinically or statistically significant differences in misdiagnosis rates or appropriate rates between afferent versus efferent disorders (p=0.6). Misdiagnoses were more common in referrals for diplopia (56% misdiagnosed), headache or sensory disturbance (56% misdiagnosed), and vision or visual field loss
(56% misdiagnosed), and relatively less common in referrals for papilledema (39%
misdiagnosed) and sellar masses (27% misdiagnosed) (p=0.04).

Disposition from NOC was most frequently to return to the referring provider
(59%), but in rare cases the patient required evaluation in the emergency department
(ED) or direct admission (6 patients, 1.2%) (Table 3). Four of the 6 patients sent to the
ED or directly admitted had been misdiagnosed by the referring provider (representing
2% of the misdiagnosed patients). Twenty percent of patients required referral to an
alternative subspecialty, including neurosurgery, neurology (including multiple sclerosis
and stroke specialists), otolaryngology (including neuro-otology), ophthalmology
(including cornea, retina, uveitis, glaucoma, comprehensive including cataract surgery),
optometry and orthoptists for prism, Low Vision services, and psychology (for cognitive
behavioral therapy).

In 489 (99%) patients, the NOC had a direct impact on the patient’s care (Figure
1). Eight (2%) had their vision or life directly saved—these patients had severe
papilledema, angle closure glaucoma, orbital apex syndrome, giant cell arteritis, and
choroidal neovascular membrane. Misdiagnosis and inappropriate referrals were both
correlated with increased impact of the NOC (p<0.0001 for correlation of misdiagnosis
and p<0.0001 for inappropriate referrals with impact of NOC) (Figure 2). For example,
avoiding harmful treatment or providing urgent referral was more common in
misdiagnosed patients (17% versus 4% of correctly diagnosed patients). Avoiding
unnecessary tests was a more common outcome for inappropriate referrals, occurring in
61% of inappropriate referrals versus 35% of appropriate referrals.
The most common sources of diagnostic error were the physical examination (36%) (inaccurate funduscopic or motility examinations, and underweighing normal examination findings); generation of a differential diagnosis (24%); history taking (24%); and utilization or interpretation of diagnostic testing (13%) (failure to obtain appropriate neuroimaging or poor interpretation of or failure to obtain visual fields) (Table 4).

One hundred sixteen (23%) patients had undergone inappropriate management (laboratory studies, imaging, or treatment) prior to referral. Thirty-four percent of misdiagnosed patients had undergone inappropriate management, versus 13% of correctly diagnosed patients \((p<0.0001)\). Sixty-two (26%) patients who were misdiagnosed were directly harmed, with harms including: death due to delay in diagnosis of a diffuse leptomeningeal glioneuronal tumor, stroke that occurred after failure to recognize a TIA with visual symptoms, progression of permanent vision loss due to a treatable cause of optic neuropathy, recurrence of spontaneous CSF leak after failure to recognize underlying IIH, development of irreversible strabismus due to delay in diagnosis of ocular myasthenia gravis, radiation optic neuropathy that was treated with further radiation, and delays in diagnosis and treatment of demyelinating optic neuritis, glaucoma, sellar masses, multiple sclerosis, and glioblastoma multiforme, as well as adverse effects from unnecessary treatments with steroids and acetazolamide.

In 60 (97%) patients, earlier access to neuro-ophthalmology could potentially have prevented the harm.

Discussion
This is the first prospective, multisite study of diagnostic error to include all neuro-ophthalmic conditions, and the first to directly measure harm due to diagnostic error.

In this sample, approximately half (49%) of all new patients referred to neuro-ophthalmology were misdiagnosed. This reaffirms that neuro-ophthalmologists confront high rates of diagnostic error in referrals to our clinics, consistent with prior studies, and shows that this high rate of misdiagnosis is not limited to a specific diagnosis. Neuro-ophthalmic conditions were more likely to be misdiagnosed-in-excess, while non-neuro-ophthalmic diagnoses were more likely to have been missed. This is expected in the biased sample of patients referred for NOC—these patients were referred due to suspicion for a neuro-ophthalmic condition. The vast majority of referrals were appropriate (asked a neuro-ophthalmic question), and the inappropriate ones were more likely to be misdiagnosed.

Similar to our prior retrospective study, access to NOC was limited by wait times, and most patients had seen an eye care provider (ophthalmologist or optometrist) or neurologist prior to neuro-ophthalmology referral. In almost every case (99%), the NOC had a direct impact on care, including saving vision or life in 2%, with misdiagnosis at the time of referral correlating with a higher impact of the NOC. Notably, even for patients who were inappropriately referred for NOC, the NOC had a high impact.

Over one-quarter of misdiagnosed patients suffered harm due to the misdiagnosis, and in almost all cases this could potentially have been prevented with earlier access to NOC. Harms ranged from adverse effects of inappropriate medications to death due to delay in diagnosis of a brain tumor. Similar to prior studies
misdiagnosed patients were more likely to be exposed to inappropriate management
(laboratory testing, imaging, or treatment) prior to referral. This study is the first to
confirm a statistically-significant relationship between misdiagnosis and exposure to the
risk, time, and cost of unnecessary diagnostic testing and treatments.

The most common pitfalls leading to diagnostic errors of neuro-ophthalmic
conditions occurred in the physical examination, history, and the generation and
consideration of the differential diagnosis. Neuro-ophthalmology subspeciality training
and real-world experience provides an expertise in the detailed neuro-ophthalmic
history and examination, and the differential diagnosis of conditions that affect the visual
pathways. These results emphasize the value of subspecialty-trained neuro-
ophthalmologists in diagnosing and managing these potentially devastating
conditions.\textsuperscript{35-39}

This study was inherently limited by the accuracy of referral records, although
this limitation was mitigated by the prospective nature of this study, allowing us to verify
information with the patient at the time of NOC. Our evaluation had subjective
components (e.g., whether referral was appropriate, whether harm occurred due to
diagnostic error, whether harm was preventable). In our study, there were 5 different
neuro-ophthalmologists from 3 institutions, and there may have been some differences
in how the survey questions were applied; however, it is important to emphasize that all
participating neuro-ophthalmologists had experience working together on similar
projects, ensuring relative homogeneity of data documentation and collection. There is
also subjectivity to the definition of misdiagnosis. We chose to define misdiagnosis as a
referral diagnosis that was different than the final neuro-ophthalmic diagnosis or a
referral diagnosis that was missing. Of course, many patients are referred for NOC as a request for help with the diagnosis, but it is not benign for a misdiagnosis or lack of diagnosis to perpetuate while waiting for NOC, especially in light of the known limitations of access to NOC.\textsuperscript{8,19,35-40} The DEER taxonomy is inherently subjective. We chose to assign the most proximal error as causative with the reasoning that it influenced or caused more distal errors, but this assumption may not have been true in every case, and may have biased our assessment toward more proximal DEER elements (such as history and physical examination elements). Future directions could include a detailed analysis of the costs incurred in unnecessary diagnostic testing and treatments due to diagnostic errors before NOC. Psychologic harms or stress that patients suffer due to misdiagnosis was not captured by this study, and this also would be interesting to investigate. Finally, we did not capture harms that occurred due to delay in neuro-ophthalmic evaluation for patients who had a correct referral diagnosis, which could also be an avenue for future study.

In this study, misdiagnosis of neuro-ophthalmic conditions and preventable harms due to misdiagnosis were common. In misdiagnosed patients, mismanagement prior to referral was common, and more than one-quarter of misdiagnosed patients were directly harmed due to the misdiagnosis. In almost all cases, these harms could potentially have been avoided with earlier access to NOC. Diagnostic errors could often be traced to history, physical examination, or interpretation of the differential diagnosis, all aspects of the unique skill set honed by neuro-ophthalmology subspeciality training.

Improving access to neuro-ophthalmologists has the potential to prevent patient harm, which is made challenging by the current shortage of neuro-ophthalmologists.
Improving incentives to attract trainees to subspecialize in neuro-ophthalmology will allow expanded access to patients who need care for these complex conditions.
References


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Elimination of Consultation Codes on Neuro-Ophthalmology in the United States.

**Figure Legends**

Figure 1:
Title: Impact of neuro-ophthalmology consultation on the outcome of 496 patients.
Legend: Impact of neuro-ophthalmology consultation was classified into 5 categories: 1) no impact; 2) provided reassurance, avoiding further visits and tests; 3) provided a diagnosis and direction to treatment; 4) avoided harmful treatment or provided urgent referral to appropriate provider; or 5) directly saved vision or life.

Figure 2:
Title: Misdiagnosis rates and inappropriate referral rates stratified by impact of neuro-ophthalmology consultation.
Legend: Impact of neuro-ophthalmology consultation was classified into 5 categories: 1) no impact; 2) provided reassurance, avoiding further visits and tests; 3) provided a diagnosis and direction to treatment; 4) avoided harmful treatment or provided urgent referral to appropriate provider; or 5) directly saved vision or life.
Table 2:
Title: Final neuro-ophthalmologic diagnoses compared with referral diagnoses.

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Referral Diagnosis</th>
<th>Final Diagnosis</th>
<th>Δ</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Optic neuropathies</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optic atrophy, any cause (chronic)</td>
<td>48 (10%)</td>
<td>38 (8%)</td>
<td>↓^a</td>
</tr>
<tr>
<td>Other optic neuropathy, any type (acute)</td>
<td>38 (8%)</td>
<td>23 (5%)</td>
<td>↓</td>
</tr>
<tr>
<td>Optic neuritis</td>
<td>16 (3%)</td>
<td>11 (2%)</td>
<td>↓</td>
</tr>
<tr>
<td>Glaucoma</td>
<td>4 (&lt;1%)</td>
<td>12 (2%)</td>
<td>↑</td>
</tr>
<tr>
<td><strong>Papilledema or Abnormal Optic Disc Appearance</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suspected due to IIH</td>
<td>89 (18%)</td>
<td>71 (14%)</td>
<td>↓</td>
</tr>
<tr>
<td>Suspected due to secondary intracranial hypertension</td>
<td>5 (1%)</td>
<td>6 (1%)</td>
<td>=</td>
</tr>
<tr>
<td>Pseudopapilledema or congenital disc abnormality</td>
<td>8 (2%)</td>
<td>23 (5%)</td>
<td>↑</td>
</tr>
<tr>
<td><strong>Diplopia and Nystagmus</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diplopia or acute CN 3, 4 or 6 palsy</td>
<td>79 (16%)</td>
<td>49 (10%)</td>
<td>↓</td>
</tr>
<tr>
<td>Nystagmus</td>
<td>17 (3%)</td>
<td>11 (2%)</td>
<td>↓</td>
</tr>
<tr>
<td>Childhood strabismus/decompensated phoria</td>
<td>5 (1%)</td>
<td>19 (4%)</td>
<td>↑</td>
</tr>
<tr>
<td>Skew deviation</td>
<td>0 (0%)</td>
<td>5 (1%)</td>
<td>↑</td>
</tr>
<tr>
<td><strong>Vision Loss</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vision loss/ Visual field defect</td>
<td>55 (11%)</td>
<td>9 (2%)</td>
<td>↓</td>
</tr>
<tr>
<td>Non-organic vision loss</td>
<td>4 (&lt;1%)</td>
<td>19 (4%)</td>
<td>↑</td>
</tr>
<tr>
<td>Amblyopia</td>
<td>1 (&lt;1%)</td>
<td>2 (&lt;1%)</td>
<td>↑</td>
</tr>
<tr>
<td>Sellar mass</td>
<td>25 (5%)</td>
<td>24 (5%)</td>
<td>↓</td>
</tr>
<tr>
<td><strong>Vascular</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condition</td>
<td>Referral</td>
<td>Final</td>
<td>↓/↑</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>----------</td>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>Stroke/ Transient ischemic attack</td>
<td>16 (3%)</td>
<td>16 (3%)</td>
<td>=</td>
</tr>
<tr>
<td>Transient vision loss, unspecified</td>
<td>10 (2%)</td>
<td>3 (&lt;1%)</td>
<td>↓</td>
</tr>
<tr>
<td>Retinal ischemia/infarction (RAO)</td>
<td>2 (&lt;1%)</td>
<td>6 (1%)</td>
<td>↑</td>
</tr>
<tr>
<td><strong>Headaches and related symptoms</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cerebrospinal fluid Leak</td>
<td>10 (2%)</td>
<td>7 (1%)</td>
<td>↓</td>
</tr>
<tr>
<td>Primary headache disorder</td>
<td>7 (1%)</td>
<td>23 (5%)</td>
<td>↑</td>
</tr>
<tr>
<td>Concussion related visual symptoms</td>
<td>3 (&lt;1%)</td>
<td>1 (&lt;1%)</td>
<td>↓</td>
</tr>
<tr>
<td>Pupillary abnormality (Horner, Adie)</td>
<td>12 (2%)</td>
<td>10 (2%)</td>
<td>↓</td>
</tr>
<tr>
<td>Other cranial neuropathy, any type</td>
<td>11 (2%)</td>
<td>3 (&lt;1%)</td>
<td>↓</td>
</tr>
<tr>
<td>Giant cell arteritis</td>
<td>9 (2%)</td>
<td>3 (&lt;1%)</td>
<td>↓</td>
</tr>
<tr>
<td>Myasthenia gravis</td>
<td>9 (2%)</td>
<td>9 (2%)</td>
<td>=</td>
</tr>
<tr>
<td>Other orbital process (unspecified)</td>
<td>4 (&lt;1%)</td>
<td>3 (&lt;1%)</td>
<td>↓</td>
</tr>
<tr>
<td>Ocular surface disease or cataract</td>
<td>3 (&lt;1%)</td>
<td>24 (5%)</td>
<td>↑</td>
</tr>
<tr>
<td>Retinal disease or uveitis</td>
<td>3 (&lt;1%)</td>
<td>24 (5%)</td>
<td>↑</td>
</tr>
<tr>
<td>Thyroid eye disease</td>
<td>0 (0%)</td>
<td>2 (&lt;1%)</td>
<td>↑</td>
</tr>
<tr>
<td>Uncorrected refractive error</td>
<td>0 (0%)</td>
<td>4 (&lt;1%)</td>
<td>↑</td>
</tr>
<tr>
<td>Other</td>
<td>2 (&lt;1%)</td>
<td>33 (7%)</td>
<td>↑</td>
</tr>
<tr>
<td>No referral diagnosis</td>
<td>1 (&lt;1%)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Normal examination</td>
<td>N/A</td>
<td>3 (&lt;1%)</td>
<td>↑</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>496 (100%)</td>
<td>496 (100%)</td>
<td>=</td>
</tr>
</tbody>
</table>

- **↑** Conditions with higher frequency of final diagnoses than referral diagnoses, meaning that referring providers missed the diagnosis, are indicated with an upward arrow (↑).
- **↓** Conditions with lower frequency of final diagnoses than referral diagnoses, meaning that referring providers misdiagnosed-in-excess, are indicated with a downward arrow (↓).

P values were not calculated for comparisons because of small group sizes.
Table 3:

Title: Disposition of patients after neuro-ophthalmology consultation.

<table>
<thead>
<tr>
<th>Disposition</th>
<th># (% ) of patients^a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Admitted or sent directly to the emergency room</td>
<td>6 (1.2%)</td>
</tr>
<tr>
<td>Return to referring provider</td>
<td>291 (59%)</td>
</tr>
<tr>
<td>Referral to another provider</td>
<td>100 (20%)</td>
</tr>
<tr>
<td>Follow up in neuro-ophthalmology clinic</td>
<td>175 (35%)</td>
</tr>
</tbody>
</table>

^a. Total will exceed 496 and total percentages will exceed 100% because patients may have had multiple dispositions (for example, a patient may have both been sent to the emergency department and seen in neuro-ophthalmology follow-up).
Table 4: Diagnosis Error Research and Evaluation (DEER) Taxonomy.

<table>
<thead>
<tr>
<th>Diagnosis Error Research and Evaluation (DEER) Taxonomy</th>
<th># (%) of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A – Failure/ delay in presentation</td>
<td>1 (0.4%)</td>
</tr>
<tr>
<td>2A – Failure/ delay in eliciting critical piece of history</td>
<td>22 (9%)</td>
</tr>
<tr>
<td>2B – Inaccurate/ misinterpreted history</td>
<td>21 (9%)</td>
</tr>
<tr>
<td>2C – Failure in weighing history</td>
<td>15 (6%)</td>
</tr>
<tr>
<td>3A – Failure/ delay in eliciting critical examination findings</td>
<td>36 (15%)</td>
</tr>
<tr>
<td>3B – Inaccurate/ misinterpreted examination</td>
<td>38 (15%)</td>
</tr>
<tr>
<td>3C – Failure in weighing examination</td>
<td>13 (5%)</td>
</tr>
<tr>
<td>4A – Failure/ delay in ordering needed test(s)</td>
<td>12 (5%)</td>
</tr>
<tr>
<td>4B – Failure/ delay in performing needed test(s)</td>
<td>1 (0.4%)</td>
</tr>
<tr>
<td>4D – Ordering wrong test(s)</td>
<td>2 (1%)</td>
</tr>
<tr>
<td>4I – Failure/ delay in reported of result to clinician</td>
<td>1 (0.4%)</td>
</tr>
<tr>
<td>4K – Error in clinician interpretation of test</td>
<td>16 (7%)</td>
</tr>
<tr>
<td>5A – Failure/ delay in considering the diagnosis</td>
<td>26 (11%)</td>
</tr>
<tr>
<td>5B – Too little consideration/ weight given to the diagnosis</td>
<td>7 (3%)</td>
</tr>
<tr>
<td>5C – Too much weight on competing or coexisting diagnosis</td>
<td>26 (11%)</td>
</tr>
<tr>
<td>5D – Failure to recognize/ weigh urgency</td>
<td>3 (1%)</td>
</tr>
<tr>
<td>6D – Failure/ delayed communication/ follow-up of consultation</td>
<td>2 (1%)</td>
</tr>
<tr>
<td>Total Misdiagnosed</td>
<td>242 (100%)</td>
</tr>
</tbody>
</table>
Table 1:
Title: Specialties of all providers seen before neuro-ophthalmology consultation.
Brief Description: Misdiagnosis and harm rate broken down by specialties patients had contact with prior to neuro-ophthalmology consultation.

<table>
<thead>
<tr>
<th>Specialty:</th>
<th># (%) of patients seen by a provider of this specialty prior to neuro-ophthalmology consultation</th>
<th>Misdiagnosis Rate</th>
<th>Harm due to Misdiagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ophthalmology</td>
<td>296 (60%)</td>
<td>157 (53%)</td>
<td>40 (14%)</td>
</tr>
<tr>
<td>Neurology</td>
<td>184 (42%)</td>
<td>97 (53%)</td>
<td>28 (15%)</td>
</tr>
<tr>
<td>Optometry</td>
<td>176 (35%)</td>
<td>117 (66%)</td>
<td>24 (14%)</td>
</tr>
<tr>
<td>Neurosurgery</td>
<td>80 (16%)</td>
<td>26 (33%)</td>
<td>10 (13%)</td>
</tr>
<tr>
<td>Primary Care/Internal Medicine</td>
<td>105 (21%)</td>
<td>45 (43%)</td>
<td>12 (11%)</td>
</tr>
<tr>
<td>Emergency Medicine</td>
<td>95 (19%)</td>
<td>39 (41%)</td>
<td>14 (15%)</td>
</tr>
<tr>
<td>Other specialties</td>
<td>76 (15%)</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

a. Total patients will exceed 496, total misdiagnosed patients will exceed 242, total harmed will exceed 62, and percentages will exceed 100% because patients may have seen providers of multiple specialties prior to neuro-ophthalmology consultation.
Impact of neuro-ophthalmology consultation on patient outcome (n=496)

1) No impact 1.4%
2) Provided reassurance/avoided unnecessary treatment or tests 38%
3) Provided diagnosis and direction to treatment 48%
4) Avoided harmful treatment or provided urgent referral to appropriate provider 10%
5) Directly saved life or vision 2%
Précis

This multisite, prospective, study of neuro-ophthalmic conditions prior to neuro-ophthalmology consultation shows that almost half are misdiagnosed prior to referral, and 26% of those experience harm that could have been prevented by earlier referral.