Reduced Fluorescein Angiography and Fundus Photography Use in the Management of Neovascular Macular Degeneration and Macular Edema During the Past Decade

Eric W. Schneider,[1,2] Prithvi Mruthyunjaya,[1] Nidhi Talwar,[2] Kristen Harris Nwanyanwu,[2] Bin Nan,[3] and Joshua D. Stein[2]

[1]Duke University Eye Center, Department of Ophthalmology, Duke University, Durham, North Carolina
[2]W.K. Kellogg Eye Center, Department of Ophthalmology and Visual Sciences, University of Michigan, Ann Arbor, Michigan
[3]University of Michigan, Department of Biostatistics, Ann Arbor, Michigan

Correspondence: Joshua D. Stein, W.K. Kellogg Eye Center, University of Michigan, Department of Ophthalmology and Visual Sciences, 1000 Wall Street, Ann Arbor, MI 48105; jdstein@med.umich.edu.

Submitted: August 11, 2013
Accepted: December 8, 2013

Citation: Schneider EW, Mruthyunjaya P, Talwar N, Harris Nwanyanwu K, Nan B, Stein JD. Reduced fluorescein angiography and fundus photography use in the management of neovascular macular degeneration and macular edema during the past decade. *Invest Ophthalmol Vis Sci*. 2014;55:542–549. DOI:10.1167/iovs.13-13034

Purpose. We assessed recent trends in the use of diagnostic testing for neovascular age-related macular degeneration (NVAMD) and macular edema (ME).

Methods. Claims data from a managed-care network were analyzed on patients with NVAMD (n = 22,954) or ME (n = 31,810) to assess the use of fluorescein angiography (FA), fundus photography (FP), and optical coherence tomography (OCT) from 2001 to 2009. Repeated-measures logistic regression was performed to compare patients' odds of undergoing these procedures in 2001, 2005, and 2009. In addition, the proportions of patients with an incident NVAMD or ME diagnosis in 2003 or 2008 who underwent FA, FP, and OCT were compared.

Results. From 2001 to 2009, among patients with NVAMD, the odds of undergoing OCT increased 23-fold, whereas the odds of receiving FA and FP decreased by 68% and 79%, respectively. Similar trends were observed for ME. From 2003 to 2008, the proportion of patients undergoing OCT within 1 year of initial diagnosis increased by 315% for NVAMD and by 143% for ME; the proportion undergoing OCT without FA within 1 year increased by 463% for NVAMD and by 216% for ME.

Conclusions. Use of OCT increased dramatically during the past decade, whereas use of FA and FP declined considerably, suggesting that OCT may be replacing more traditional diagnostic testing in patients with NVAMD or ME. Future studies should evaluate whether this increased reliance on OCT instead of FA and FP affects patient outcomes.

Keywords: utilization, age-related macular degeneration, macular edema, optical coherence tomography, fluorescein angiography

With the release of the Zeiss OCT1 in 1996 (Carl Zeiss Meditec, Dublin, CA), optical coherence tomography (OCT) became commercially available to eye care providers. Capable of providing high-resolution, cross-sectional tomographic retinal images, OCT offered more rapid assessment of macular pathology compared to traditional methods, such as contact lens biomicroscopy and fluorescein angiography (FA). These attributes led to rapid adoption of OCT among the eye care community as reflected in Centers for Medicare and Medicaid Services reports detailing large increases in utilization.[1]

The rapid rise in OCT use has occurred largely without a systematic consideration of its impact on the use of established imaging modalities, such as FA and fundus photography (FP). In light of documented discrepancies between FA and OCT in the detection of macular edema (ME)[2,3] and exudation secondary to neovascular age-related macular degeneration (NVAMD),[4,5] accurately identifying "active" or "treatable" disease with a single imaging modality can be challenging. This issue is complicated further by decades of historic treatment trials, including landmark studies, such as the Early Treatment Diabetic Retinopathy Study (EDTRS),[6] Minimally Classic/Occult Trial of the Anti-VEGF Antibody Ranibizumab in the Treatment of Neovascular AMD (MARINA),[7] and the Branch/Central Vein Occlusion Studies (BVOS/CVOS),[8,9] in which FA and FP criteria were used exclusively to define treatment eligibility. More recent studies, including the Comparison of AMD Treatment Trial (CATT),[10] applied OCT as a major inclusion criterion, but only in conjunction with FA. Thus, it becomes important to ascertain whether the introduction of OCT has altered practice patterns to an extent whereby the definition of "treatable" disease, based on imaging characteristics, is substantially different from that established in these trials. If so, the applicability of treatment recommendations based on these historic studies may need to be reevaluated.

To assess the dynamic relationship between OCT and FA/FP use during the time period coinciding with the rise of OCT, we analyzed longitudinal healthcare claims data from a large managed care network from the period spanning 2001 to 2009. We assessed whether the emergence of OCT may have led to a change in the utilization of more traditional diagnostic tests for NVAMD and ME.

Methods

Data Source

The Clinformatics database (Ingenix, Eden Prairie, MN) contains detailed de-identified records of all beneficiaries in a large nationwide managed care network. We had access to data for all beneficiaries with any form of eye care from January 1, 2001 through December 31, 2009. This subset comprises beneficiaries who had one or more International Classification of Diseases, ninth revision (ICD-9-CM)[11] codes for any eye-related diagnosis (360–379.9) or Current Procedural Terminology (CPT-4)[12] code for any eye-related visits or procedures (65091–68899 or 92002–92499) during their time in the medical plan. We had access to all beneficiaries' medical claims for ocular and nonocular conditions, and sociodemographic information (age, sex, race, education, financial wealth). This database has been used previously to study enrollees with ocular diseases.[13]

Study Participants

We identified all persons $\geq$ 40 years old who were in the database for $\geq$1 year and had $\geq$1 eye care provider (ophthalmologist or optometrist) visit during their time in the plan. Persons in the plan for <365 days or with noncontinuous enrollment were excluded. The ICD-9-CM codes were used to identify patients with NVAMD (362.52) or ME, which includes diabetic macular edema (DME, 362.07), cystoid macular degeneration (362.53), or retinal edema (362.83).

Analyses

Statistical analyses were performed using SAS 9.3 (SAS Institute, Cary, NC) software. Participant characteristics were summarized using means and SDs for continuous variables, and frequencies and percentages for categorical variables.

Comparison of Ancillary Testing Among Enrollees With Newly-Diagnosed NVAMD and ME in 2003 Versus 2008. We identified two groups: enrollees with incident NVAMD diagnosed in 2003 and those first diagnosed in 2008. To be considered to have incident NVAMD, a patient must have received the first NVAMD diagnosis during 2003 and 2008, respectively, with no record of the condition during the patient's prior time in the plan. The years 2003 and 2008 were chosen to allow for a 2-year look back period for the 2003 group (e.g., 2001–2003) to assess for and exclude enrollees with prior NVAMD diagnoses, and a full 1-year follow-up period for the 2008 group (e.g., 2008–2009) to monitor utilization of the different diagnostic tests, within the overall period we had access to data (2001–2009). These two cohorts were followed from initial diagnosis to determine the proportions who underwent each of the following procedures for NVAMD in the subsequent 1, 3, 6, and 12 months: FA (CPT-4 codes 92230 and 92235), FP (92250), and OCT (92135). We calculated the proportions who underwent one, multiple, and none of these three types of diagnostic tests during the specified time intervals. Similar analyses were done for incident ME. Since FP and OCT may be used in the management of conditions besides age-related macular degeneration (AMD) and ME, this analysis was repeated after excluding patients with comorbid glaucoma and other conditions affecting the optic nerve (Supplementary Table S1) to ensure such coexisting conditions did not greatly impact results. No limits were set by the plan on the number of FA, FP, or OCT tests that could be performed on a given patient (personal communication, United Health Care, December 28, 2010) providing it was determined to be medically necessary per the treating provider.

Longitudinal Trends in Ancillary Testing for NVAMD and ME, 2001–2009. Repeated measures logistic regression was performed to compare the odds of undergoing each ancillary retinal procedure in each year from 2001 to 2009 for an enrollee with NVAMD or ME. The regression models were adjusted for age, sex, race, education level, household net worth, region of residence in the United States, insurance plan type, eye care provider type (ophthalmologist or optometrist only, or both provider types), time in the plan, hypertension, hyperlipidemia, obesity, and comorbid ocular conditions that could warrant the use of these diagnostic tests, specifically open-angle glaucoma (OAG), glaucoma suspect, other retinal conditions, and other optic neuropathies (Supplementary Table S1). Preliminary analysis showed a nonlinear trend in the use of these procedures; hence, the effect of time was modeled as nonlinear (quadratic) in the regression models. Furthermore, since this quadratic effect of time could differ with various comorbid ocular conditions, interactions were included between the effect of time and OAG, glaucoma suspect, ME, NVAMD, other retinal diseases, and optic nerve diseases for the OCT and FP models, and interactions between time and ME, NVAMD, and other retinal diseases for the FA models. Comparisons of the odds of receiving FA, FP, and OCT were performed for those with NVAMD and ME in the plan during 2001 versus 2005, 2005 versus 2009, and 2001 versus 2009. While performing these comparisons, all other ocular and nonocular conditions were assumed to be at average levels as computed from the data.

The estimated odds were converted to probabilities and trends in probabilities of receiving each test were analyzed for each year from 2001 to 2009. These probabilities were estimated assuming all other ocular and nonocular conditions to be at average levels as computed from the data, and assuming white race, male sex, age 60, preferred provider organization plan type, Northeastern residence, high school education, and $75,000 to $150,000 household net worth as was done previously.[13]

For all analyses, P values less than 0.05 were considered statistically significant. As the database was de-identified, the University of Michigan Institutional Review Board determined this study was exempt from requiring its approval.

Results

Of the 2,854,417 enrollees who met the study inclusion criteria, 22,954 (0.8%) had $\geq$1 NVAMD diagnosis and 31,810 (1.1%) had $\geq$1 ME diagnosis. The mean $\pm$ SD time in the plan for those with NVAMD was 4.5 $\pm$ 2.1 years and for those with ME was 4.5 $\pm$ 2.3 years. The mean age $\pm$ SD of those who were eligible for the study was 55.1 $\pm$ 10.3 years. Table 1 shows the sociodemographic characteristics of the groups.

Diagnostic Testing in First Year After Initial NVAMD Diagnosis: 2003 Versus 2008

The number of individuals with newly diagnosed NVAMD with $\geq$12 months of follow-up in 2003 and 2008 was 1023 and 1258, respectively. From 2003 to 2008, the proportions of beneficiaries undergoing FA and FP within 12 months of their initial NVAMD diagnosis decreased 13% and 18%, respectively, while the proportion undergoing OCT increased 315%. In the first year after diagnosis, the proportion undergoing same-day FA testing plus FP ($\pm$OCT) for NVAMD decreased from 55.5% in the 2003 cohort to 38.2% in the 2008 cohort ($P < 0.0001$).

Investigative Ophthalmology & Visual Science

Table 1. Sociodemographic Characteristics of Enrollees With NVAMD and ME

	Neovascular AMD, $n = 22{,}954$		Macular Edema, $n = 31{,}810$	
	n	%	*n*	%
Sex				
Male	10,062	43.8	15,405	48.4
Female	12,892	56.2	16,405	51.6
Race				
White	17,946	78.2	23,613	74.2
Black	674	2.9	1,595	5.0
Latino	916	4.0	1,702	5.4
Asian	332	1.5	711	2.2
Other race	144	0.6	273	0.9
Unspecified	2,942	12.8	3,916	12.3
Net worth				
<$25,000	1,551	6.8	2,275	7.2
$25–75,000	1,342	5.9	1,826	5.7
$75–150,000	2,508	10.9	3,416	10.7
$150–500,000	9,479	41.3	12,824	40.3
>$500,000	5,499	24.0	7,874	24.8
Unspecified	2,575	11.2	3,595	11.3
Region of residence				
NE	3,824	16.7	4,458	14.0
SE	8,712	38.0	13,408	42.2
MW	7,049	30.7	9,357	29.4
West	3,339	14.6	4,545	14.3
Other region	23	0.1	38	0.1
Unspecified	7	<0.1	4	<0.1
Ocular comorbidities				
NPDR	2,122	9.2	5,632	17.7
PDR	898	3.9	3,097	9.7
OAG	3,288	14.3	4,308	13.5
Glaucoma suspect	3,823	16.7	6,098	19.2

MW, Midwest; NE, Northeast; NPDR, nonproliferative diabetic retinopathy; PDR, proliferative diabetic retinopathy; SE, Southeast.

From 2003 to 2008, there were significant increases in the proportion undergoing same-day FP plus OCT (±FA, 1.5% vs. 12.0%), FA plus OCT (±FP, 7.6% vs. 28.5%), and all three tests (1.3% vs. 10.1%) within one year of diagnosis ($P < 0.0001$ for all comparisons). The percentage of patients undergoing FA only in 2008 was significantly decreased (0.5% vs. 3.6%, $P < 0.0001$), while it was not significantly changed for FP only (6.6% vs. 6.1%, $P = 0.61$), and was significantly increased for OCT only (18.7% vs. 3.8%, $P < 0.0001$) compared to 2003. From 2003 to 2008, the use of FA testing without any OCT decreased from 49.8% to 7.0% of enrollees, whereas use of OCT without FA testing increased 463% from 4.1% to 23.1% ($P < 0.0001$ for both comparisons). Figure 1 shows utilization of different tests, alone and in combination, within the first year of incident NVAMD diagnosis for the 2003 and 2008 cohorts. The proportion of patients undergoing none of the three ancillary procedures for NVAMD decreased from 27.1% in 2003 to 15.5% in 2008 ($P < 0.0001$). When the same analysis was repeated after excluding those individuals with comorbid OAG, glaucoma suspects, and other optic nerve conditions (analysis included $n = 667$ in 2003, $n = 798$ in 2008) the trends were very similar and statistical significance was preserved (Supplementary Fig. S1).

Diagnostic Testing in First Year After Initial ME Diagnosis: 2003 Versus 2008

The number of individuals with incident ME with ≥12 months of follow-up in 2003 and 2008 was 1090 and 2616, respectively. From 2003 to 2008, the proportions of patients undergoing FA and FP within 12 months of their initial ME diagnosis decreased 19% and 17%, respectively, while the proportion undergoing OCT increased 143%. In the first year after diagnosis, the proportion undergoing same-day FA testing plus FP (±OCT) for ME decreased from 42.9% of the 2003 cohort to 28.4% of the 2008 cohort ($P < 0.0001$). Between 2003 and 2008, there were significant increases in the proportion undergoing same-day FP plus OCT (±FA, 2.5% vs. 11.5%), FA plus OCT (±FP, 8.9% vs. 21.3%), and all three tests (1.7% vs. 7.7%) within one year of diagnosis ($P < 0.0001$ for all comparisons). The percentage of patients undergoing FA only was significantly decreased (0.5% vs. 3.2%, $P < 0.0001$), while it was not changed significantly for FP only (3.3% vs. 4.4%, $P = 0.14$), and was significantly increased for OCT only (33.7% vs. 11.5%, $P < 0.0001$) in 2008 compared to 2003. From 2003 to 2008, the use of FA testing without any OCT decreased from 34.4% of patients to 8.0%, whereas use of OCT without FA testing increased 216% from 12.9% to 40.8% ($P < 0.0001$ for both comparisons). Figure 2 shows utilization of the different tests, alone and in combination, within 1 year of incident ME diagnosis for the 2003 and 2008 cohorts. The proportion of patients undergoing none of the three tests decreased from 30.4% in 2003 to 13.5% in 2008 ($P < 0.0001$). Exclusion of individuals with comorbid OAG, glaucoma suspects, and other optic nerve conditions (included patients; $n = 641$ in 2003, $n = 1591$ in 2008) did not substantially impact the results (Supplementary Fig. S2).

Odds of Diagnostic Testing in 2001 Versus 2005 Versus 2009

In multivariable analysis, patients with NVAMD had a 68% and 79% reduced odds of undergoing FA and FP, respectively, in 2009 compared to 2001 (Table 2). In contrast, the odds of undergoing OCT were increased 23-fold in 2009 relative to 2001, with a greater increase noted during the first half of the study period (2001–2005, 8.3-fold increase) as compared to the latter half (2005–2009, 1.6-fold increase). Changes in the odds of undergoing FA, FP, and OCT were statistically significant for all comparisons at $P < 0.0001$ (2001 versus 2005, 2005 versus 2009, 2001 versus 2009).

In multivariable analysis, patients with ME had an 83% and 80% reduced odds of undergoing FA and FP, respectively, in 2009 compared to 2001 (Table 2). The odds of undergoing OCT were increased by 5.4-fold in 2009 relative to 2001, with nearly all of the increase occurring in the period from 2001 to 2005 (5.3-fold increase). There was no statistically significant difference in the odds of undergoing OCT in 2005 relative to 2009. Changes in the odds of undergoing FA, FP, and OCT were statistically significant at $P < 0.0001$ for all other comparisons.

Trends in the Use of Different Diagnostic Procedures for NVAMD and ME From 2001 to 2009

After adjusting for confounders, we observed a steady decline in the probability of a beneficiary with NVAMD undergoing FP from 48% in 2001 to 16% in 2009. Similarly, the probability of an enrollee undergoing FA for NVAMD dropped from 39% in 2001 to 17% by 2009. By comparison, the probability of undergoing OCT increased from 3% to 42% during the same time period. By 2006, OCT surpassed FP as the ancillary test performed with the greatest probability in enrollees with

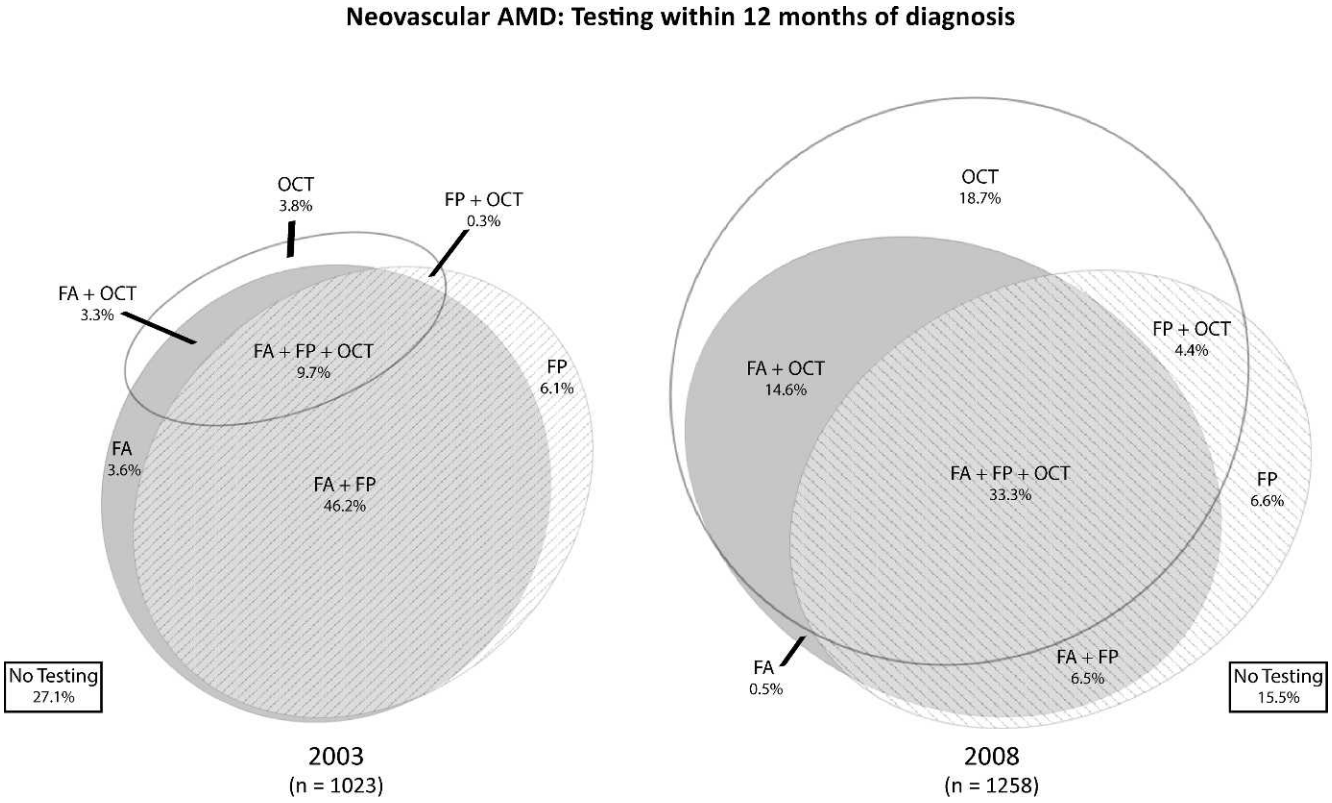

Figure 1. Percentage of enrollees undergoing specified diagnostic imaging test(s) within one year of incident diagnosis of NVAMD in 2003 compared to 2008. Figure drawn to scale.

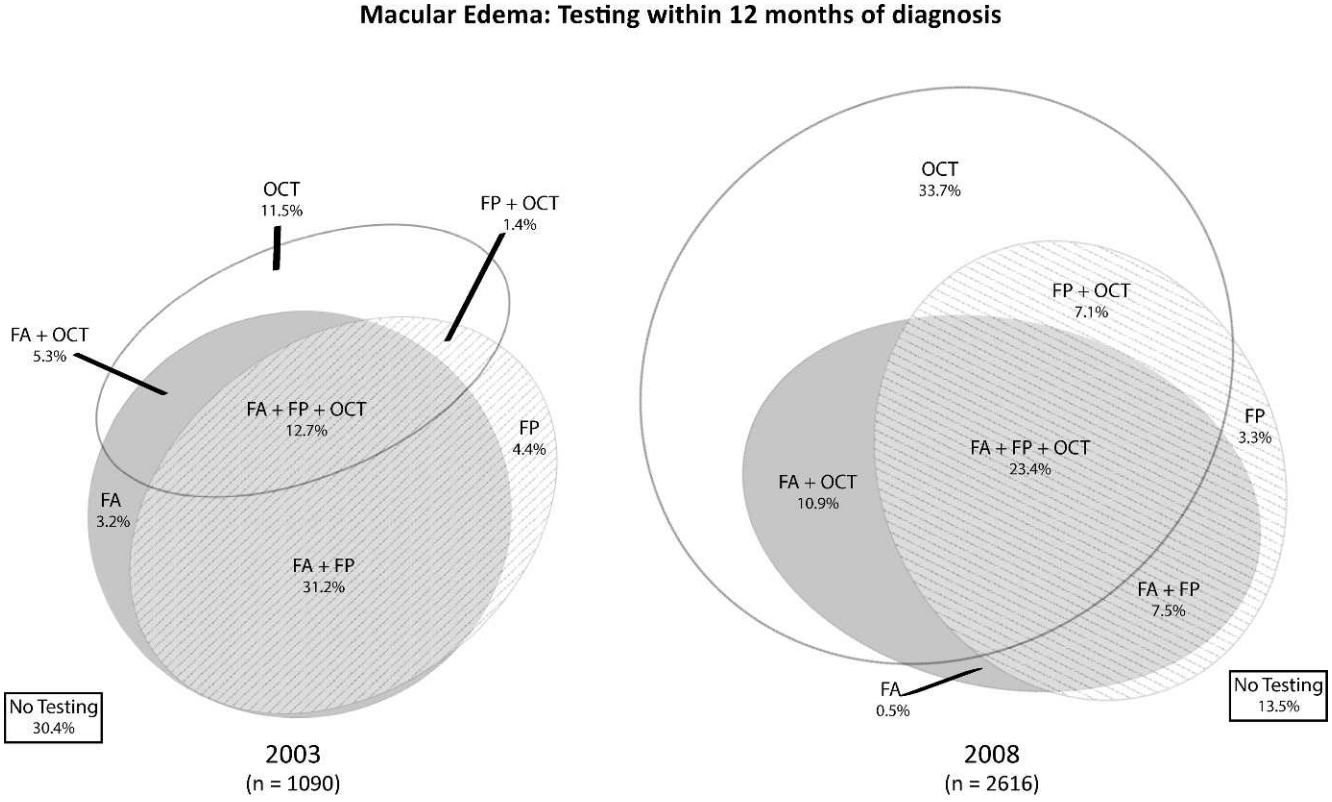

Figure 2. Percentage of enrollees undergoing specified diagnostic imaging test(s) within one year of incident diagnosis of ME in 2003 compared to 2008. Figure drawn to scale.

Investigative Ophthalmology & Visual Science

Table 2. Annual Odds of Undergoing Diagnostic Procedures for NVAMD and ME—Comparison of 2001, 2005, and 2009

	FP		FA		OCT	
	OR (CI)	*P* Value	OR (CI)	*P* Value	OR (CI)	*P* Value
Neovascular AMD						
2005 vs. 2001	0.40 (0.37–0.44)	<0.0001	0.48 (0.42–0.54)	<0.0001	9.26 (8.05–10.65)	<0.0001
2009 vs. 2005	0.53 (0.50–0.57)	<0.0001	0.67 (0.60–0.73)	<0.0001	2.60 (2.43–2.77)	<0.0001
2009 vs. 2001	0.21 (0.20–0.23)	<0.0001	0.32 (0.28–0.36)	<0.0001	24.03 (20.89–27.65)	<0.0001
Macular edema						
2005 vs. 2001	0.36 (0.32–0.39)	<0.0001	0.34 (0.30–0.38)	<0.0001	6.25 (5.56–7.01)	<0.0001
2009 vs. 2005	0.57 (0.54–0.60)	<0.0001	0.50 (0.46–0.54)	<0.0001	1.03 (0.98–1.09)	0.26
2009 vs. 2001	0.20 (0.19–0.22)	<0.0001	0.17 (0.15–0.19)	<0.0001	6.44 (5.74–7.23)	<0.0001

Regression models were adjusted for age, sex, race, education level, net worth, region of residence in the United States, insurance plan type, type of eye-care professional providing their care (ophthalmologist or optometrist only, or both), time in the plan (by year), hypertension, hyperlipidemia, obesity, and comorbid ocular conditions that could warrant the use of these diagnostic tests, specifically, OAG, glaucoma suspect status, nonproliferative and proliferative diabetic retinopathy, other retinal conditions, and other conditions that can affect the optic nerve (i.e., other glaucomas and optic neuropathies). OR, odds ratio; CI, 95% confidence interval.

NVAMD (Fig. 3). Similar patterns were observed for ME, with OCT surpassing FP as the most likely imaging modality in 2004 (Fig. 4). Of note, the probability of beneficiaries with ME undergoing OCT began to decline during the last two years of the study period whereas the probability of those with NVAMD undergoing OCT continued to climb, albeit at a slower rate, through the end of the study period.

Discussion

The introduction of OCT technology has altered substantially the way in which clinicians manage NVAMD and ME. From 2001 to 2009, a time period coinciding with rapid growth in commercially available OCT equipment, we see a dramatic increase in OCT use with a resultant decrease in the use of FP and FA. The odds of a beneficiary diagnosed with NVAMD undergoing FP and FA decreased 79% and 68%, respectively, from 2001 to 2009. A similar shift was seen for ME. Conversely, there were 5.4- and 23-fold increases in the odds of beneficiaries with ME and NVAMD, respectively, undergoing OCT during the same time period. Perhaps most importantly, there were large increases in the proportion of beneficiaries receiving OCT without accompanying FA up to one year following initial diagnosis.

To our knowledge, this is the first study to examine explicitly trends in the utilization of these three ancillary retinal imaging tests in the management of NVAMD or ME. Two studies estimated first-year payments for the care of incident DME[14] and NVAMD[15] using Medicare 5% sample files. As part of these cost analyses, both groups identified trends support-

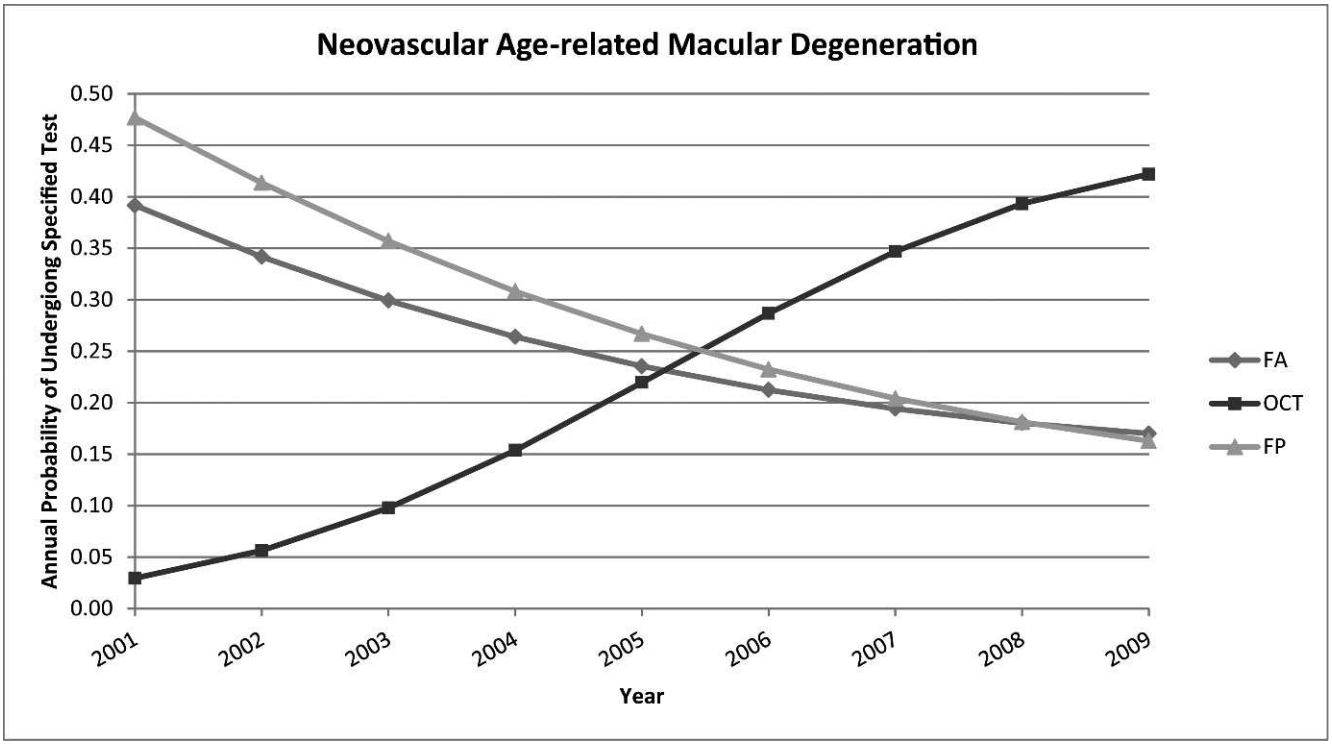

Figure 3. Annual probabilities of undergoing specified diagnostic imaging test from 2001 to 2009 among enrollees diagnosed with NVAMD in a large United States managed care network.

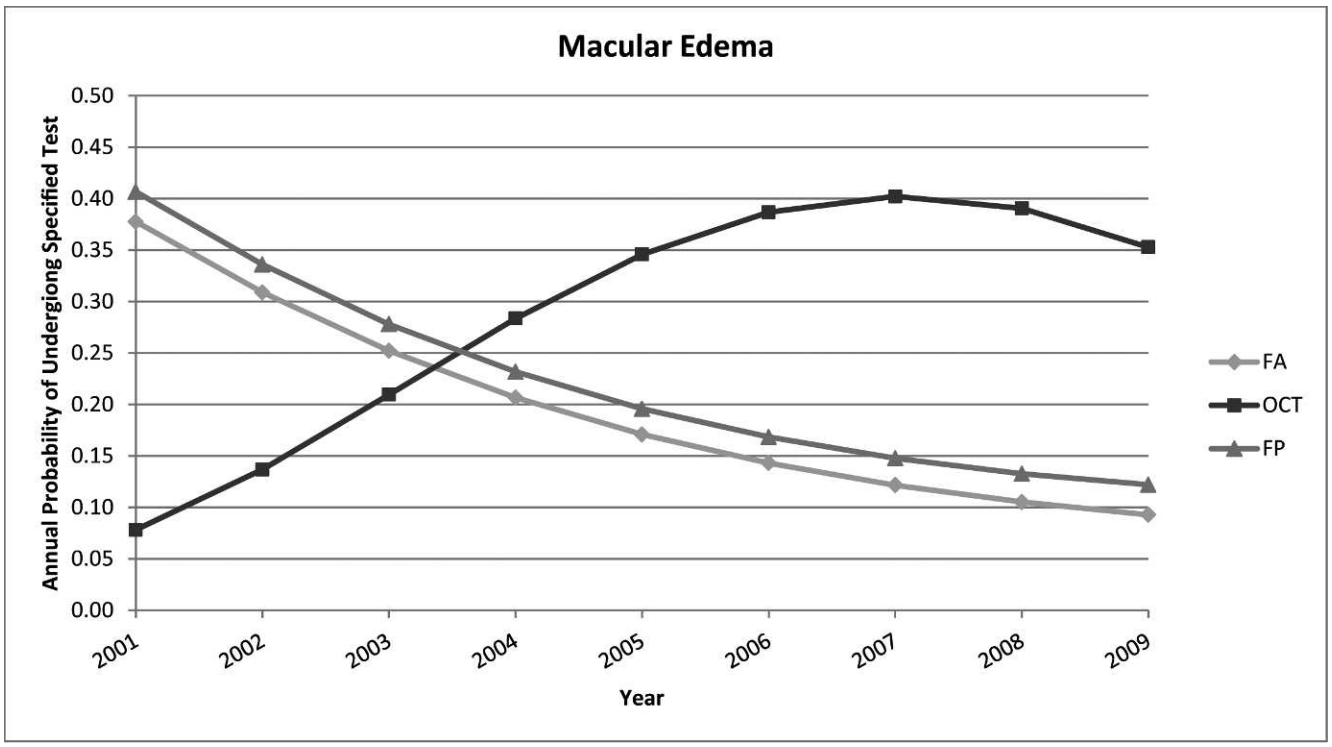

FIGURE 4. Annual probabilities of undergoing specified diagnostic imaging tests from 2001 to 2009 among enrollees diagnosed with ME in a large United States managed care network.

ing our data with respect to large increases in OCT use. Specifically, Shea et al.[14] reported a 16-fold increase in the proportion of incident DME cases undergoing OCT within one year of diagnosis in 2004 compared to 2000. Similarly, Day et al.[15] found significant increases in the mean number of OCT procedures performed for NVAMD during 2 time periods (1994 versus 2000 and 2000 versus 2006). Although direct comparison of our study to these earlier studies is difficult due to differences in study design, patient demographics, and insurance type, demonstration of increasing reliance on OCT in two distinct populations supports the notion that the trends seen here reflect patterns of care for insured patients with NVAMD and ME.

The increasing dependence on OCT is validated further by the large increase in the proportion of beneficiaries in our analysis who received only OCT imaging within one year following an initial NVAMD or ME diagnosis. From 2003 to 2008, the proportion of enrollees evaluated in this manner increased 392% and 193% following an incident diagnosis of NVAMD and ME, respectively. If these trends continue, further study is needed to determine whether outcomes differ among patients managed with OCT alone versus those managed with OCT plus supplemental FA or FP. This may be important particularly in light of the reliance on FA alone or FA in conjunction with OCT as key inclusion criteria in the historic treatment trials that form the basis for current NVAMD and ME treatment paradigms. Due to the absence of relevant clinical data (e.g., best corrected visual acuities) within the database, we are unable to assess the impact of this differential diagnostic test utilization on patient outcomes during the course of the study.

Indeed, there is little evidence in the literature to support a specific diagnostic approach to NVAMD or ME. Nonetheless, it is worthwhile to examine concerns relating to reliance on any single diagnostic modality in the management of these conditions. While results of OCT and FA testing are concordant in the vast majority of cases, there is a substantial minority in which results are discrepant. In several studies, OCT displayed only moderate specificity (37%–69%) for detecting active leakage as defined by gold standard FA.[4,5,16,17] In particular, OCT tended to overestimate the activity of lesions with significant degrees of fibrosis or pigment epithelial detachments.[18,19] On the other hand, FA appears to have demonstrably worse sensitivity for detecting leakage as defined by presence of intra- and subretinal fluid on OCT, and also may provide occasional false-positive results (specificity 61%–93%).[4,5,16,17] Such false-positive results may, in fact, represent mild active leakage in the presence of good retinal pigment epithelium function precluding the accumulation of fluid. Moreover, as OCT lacks the ability to depict vascular details, a relative strength of FA, the relative importance of this additional piece of information also may warrant investigation. In the absence of this information, certain NVAMD subtypes with characteristic vascular anatomy, including polypoidal choroidal vasculopathy and retinal angiomatous proliferation, may be missed. Similarly, the identification of macular ischemia complicating DME is an angiographic diagnosis, which would be missed on OCT.

Several factors likely contributed to the increased reliance on OCT observed during the study period. First, OCT has several practical advantages over traditional imaging modalities. The FA is time- and labor-intensive, requiring staff trained in venipuncture and anaphylaxis management.[20] Interpretation can be more time-consuming due to the lack of easily reviewed numeric results. By contrast, OCT involves a noncontact exam that can be performed by technicians with minimal training and generates quantifiable numerical results. Second, equipment availability and reimbursement concerns may factor in provider decision-making. With the growth in nonretinal applications of OCT (e.g., optic nerve head and anterior segment imaging),[21,22] wider availability of OCT would be expected as anterior segment surgeons, whose practices

frequently lack FA capabilities, increasingly adopt such equipment. Given the expense of such equipment, these providers may be incentivized also to use OCT for posterior segment evaluation as a means to recoup capital costs more quickly. Third, OCT can be useful in educating patients about their condition and the response, or lack thereof, to certain treatments, which allows for greater participation in management decisions. Moreover, patients appear to perceive the use of OCT technology as evidence that providers are employing cutting-edge medical practices.[23] Finally, the introduction of anti-VEGF therapy, which followed Food and Drug Administration (FDA) approval of pegaptanib (December 2004) and ranibizumab (June 2006), as well as reports of off-label bevacizumab use (June 2005), likely further encouraged OCT use due to the popularity of OCT-based dosing of these agents.[24,25] The rise in the use of intravitreal therapies corresponded to a sharp drop in the application of photodynamic therapy (PDT) for the treatment of NVAMD and focal laser for diabetic ME, which likely contributed the decline in FA use as safe application of these laser therapies is dependent on FA guidance.[26] Interestingly, the bulk of the shifting toward more OCT use occurred during the first half of the decade, before the introduction of anti-VEGF agents, indicating that this novel indication was likely only a small contributor to increased OCT use.

Coding-related reimbursement concerns also may have factored into these trends. The managed care company whose data were used for these analyses follows the National Correct Coding Initiative (NCCI) Guidelines set by the Center for Medicare and Medicaid Services. Under these guidelines, same-day FP and OCT are considered mutually exclusive, so that providers are reimbursed for only one of these procedures if both are done on the same day. Despite this financial disincentive, providers increasingly used same-day FP and OCT in the management of incident cases of NVAMD and ME with a significantly greater proportion of enrollees undergoing such testing in 2008 compared to 2003 (12% vs. 2%). This would seem to indicate that lack of reimbursement did not detract from use for some providers. Same-day FA-FP and FP-OCT are not mutually exclusive per NCCI guidelines.

Of interest, despite the trend toward decreased FA/FP utilization, overall use of diagnostic imaging of any kind rose sharply during the study period. The proportion of enrollees undergoing $\geq$1 imaging modality (FA, FP, and/or OCT) within 1 year of an initial diagnosis of NVAMD and ME increased 16% and 24%, respectively, from 2003 to 2008. Moreover, evaluation of individual enrollees with all three testing modalities (combined FA, FP, and OCT) also rose significantly from 2003 to 2008, with increases of 243% for NVAMD and 84% for ME. Given the drop in FA/FP use, this overall increase must be attributable directly to an increase in OCT use. Thus, the overall increase in OCT use in 2008 compared to 2003 could be viewed as the outcome of two related shifts in practice patterns: adoption of OCT in lieu of more traditional methods, which accounts for the drop in FA/FP use, and use of OCT as a supplemental modality in addition to FA and/or FP, or as the sole modality in enrollees who otherwise would have undergone no testing. With the anticipated shift toward a capitated reimbursement system in the coming years, providers may be incentivized to rely on a single diagnostic modality, likely OCT, or the clinical exam alone. However, if the new system also rewards quality of care and not simply lower cost care, future studies may be necessary to evaluate the relative value of these additional diagnostic tests in improving outcomes.

Our data indicated that a sizable proportion of these insured patients, 15.5% with incident NVAMD and 13.5% with incident ME in 2008, continue to receive no ancillary imaging of any kind up to one year following incident diagnosis. According to the 2003 and 2008 revisions of the American Academy of Ophthalmology's Preferred Practice Patterns (AAO PPP) for AMD, ancillary imaging tests (FA with or without OCT) constitute "components of quality care" for patients with evidence of new exudation.[27] Moreover, the 2006 Preferences and Trends survey, compiled annually by the American Society of Retinal Specialists to assess prevailing practice patterns, inquired about recommended diagnostic imaging for AMD and found nearly unanimous agreement among retina-trained providers as to the importance of FA.[28] Among respondents, 98% reported routine FA use at initial AMD diagnosis. Also, while clinical examination remains the current recommendation for routine diagnosis of DME according to the AAO PPP for diabetic retinopathy, ancillary testing is indicated for the evaluation of unexplained vision loss (to evaluate for macular ischemia) and before planned laser therapy.[20] Since our data are limited by lack of access to medical records, we can only speculate as to why some patients received potentially incomplete diagnostic evaluations. Possible explanations include patient-related factors (e.g., refusal, media opacity), provider-related factors (e.g., inadequate training), and lack of access to equipment. In certain cases, grossly obvious clinical findings may have rendered ancillary testing unnecessary, though a strong argument can be made for uniform baseline imaging to better evaluate response to future treatments.

A strength of this study is the large number of patients afforded by the use of a large claims database. This facilitated a rigorous analysis of usage patterns of various imaging modalities examined over nearly a decade and allowed for adjustment of numerous potential confounders. All patients had insurance coverage, thus insurance status should not have factored into the receipt of the services studied. Moreover, the data were acquired in a "real-world" environment at various types of clinical practices (e.g., academic versus private) and settings (e.g., rural versus urban versus suburban) throughout the country.

Several limitations must be acknowledged, many of which are inherent in analyses involving large healthcare claims datasets.[13,15] As we did not have access to medical records, we were unable to evaluate the appropriateness of medical decisions relating to the application of these tests for individual patients. Additionally, information was not available regarding the provider type (e.g., retina versus nonretina trained) or whether providers had access to specific diagnostic equipment. Finally, as is true of all claims data-based investigations, our data were subject to the idiosyncrasies of the individual providers who performed the examinations and diagnostic coding. Given that proper coding of these tests impacts provider reimbursement, we would expect that most encounters were coded correctly.

In summary, we present a longitudinal analysis of ancillary retinal imaging use in the management of NVAMD and ME using healthcare claims data. An important finding from this analysis is the identification of a corresponding decline in FA/FP utilization accompanying the anticipated increase in OCT use. Indeed, these trends appear to represent a shift in testing paradigms toward increasing reliance on OCT at the expense of more traditional modalities, best evidenced by the significant increase in the proportion of enrollees with newly diagnosed AMD and ME undergoing OCT without FA or FP in 2008 compared to 2003. As ancillary retinal imaging results have increasingly come to define "active disease" and have thereby become the primary indications for treatment, it will be important for future studies to reconcile definitions of "treatable disease," as established in historic treatment trials using FA and FP, across all imaging modalities to avoid over- or undertreatment.

Investigative Ophthalmology & Visual Science

Acknowledgments

Supported by a National Eye Institute K23 Mentored Clinician Scientist Award (1K23EY019511-01; JDS), Blue Cross Blue Shield of Michigan Foundation (JDS), and a Research to Prevent Blindness Physician Scientist Award (JDS). The authors alone are responsible for the content and writing of the paper.

Disclosure: **E.W. Schneider**, None; **P. Mruthyunjaya**, None; **N. Talwar**, None; **K. Harris Nwanyanwu**, None; **B. Nan**, None; **J.D. Stein**, None

References

1. Swanson E, Huang D. Ophthalmic OCT reaches $1 billion per year: but reimbursement clampdown clouds future innovation. *OCT News*. July 9 2011. Available at: http://www.octnews.org/articles/2844561/ophthalmic-oct-reaches-1-billion-per-year-but-reim/. Accessed June 29, 2012.
2. Brar M, Yuson R, Kozak I, et al. Correlation between morphologic features on spectral-domain optical coherence tomography and angiographic leakage patterns in macular edema. *Retina*. 2010;30:383–389.
3. Ossewaarde-Van Norel J, Camfferman LP, Rothova A. Discrepancies between fluorescein angiography and optical coherence tomography in macular edema in uveitis. *Am J Ophthalmol*. 2012;154:233–239.
4. Henschel A, Spital G, Lommatzsch A, Pauleikhoff D. Optical coherence tomography in neovascular age related macular degeneration compared to fluorescein angiography and visual acuity. *Eur J Ophthalmol*. 2009;19:831–835.
5. Khurana RN, Dupas B, Bressler NM. Agreement of time-domain and spectral-domain optical coherence tomography with fluorescein leakage from choroidal neovascularization. *Ophthalmology*. 2010;117:1376–1380.
6. Photocoagulation for diabetic macular edema. Early Treatment Diabetic Retinopathy Study report number 1. Early Treatment Diabetic Retinopathy Study research group. *Arch Ophthalmol*. 1985;103:1796–1806.
7. Rosenfeld PJ, Brown DM, Heier JS, et al. Ranibizumab for neovascular age-related macular degeneration. *N Eng J Med*. 2006;355:1419–1431.
8. Argon laser photocoagulation for macular edema in branch vein occlusion. The Branch Vein Occlusion Study Group. *Am J Ophthalmol*. 1984;98:271–282.
9. Evaluation of grid pattern photocoagulation for macular edema in central vein occlusion. The Central Vein Occlusion Study Group M report. *Ophthalmology*. 1995;102:1425–1433.
10. Martin DF, Maguire MG, Ying GS, Grunwald JE, Fine SL, Jaffe GJ. Ranibizumab and bevacizumab for neovascular age-related macular degeneration. *N Engl J Med*. 2011;364:1897–1908.
11. The American Medical Association: *Physician ICD-9-CM 2006. 9th Revision, Clinical Modification*. Chicago, IL: American Medical Association; 2006.
12. The American Medical Association: *CPT 2006. Current Procedural Terminology Professional Edition*. Chicago, IL: American Medical Association; 2006.
13. Stein JD, Talwar N, Laverne AM, Nan B, Lichter PR. Trends in use of ancillary glaucoma tests for patients with open-angle glaucoma from 2001 to 2009. *Ophthalmology*. 2012;119:748–758.
14. Shea AM, Curtis LH, Hammill BG, et al. Resource use and costs associated with diabetic macular edema in elderly persons. *Arch Ophthalmol*. 2008;126:1748–1754.
15. Day S, Acquah K, Lee PP, Mruthyunjaya P, Sloan FA. Medicare costs for neovascular age-related macular degeneration, 1994-2007. *Am J Ophthalmol*. 2011;152:1014–1020.
16. Salinas-Alaman A, Garcia-Layana A, Maldonado MJ, Sainz-Gomez C, Alvarez-Vidal A. Using optical coherence tomography to monitor photodynamic therapy in age related macular degeneration. *Am J Ophthalmol*. 2005;140:23–28.
17. Do DV, Gower EW, Cassard SD, et al. Detection of new-onset choroidal neovascularization using optical coherence tomography: the AMD DOC Study. *Ophthalmology*. 2012;119:771–778.
18. Cohen SY, Dubois L, Nghiem-Buffet S, et al. Retinal pseudocysts in age-related geographic atrophy. *Am J Ophthalmol*. 2010;150:211–217.
19. Krebs I, Hagen S, Brannath W, et al. Repeatability and reproducibility of retinal thickness measurements by optical coherence tomography in age-related macular degeneration. *Ophthalmology*. 2010;117:1577–1584.
20. American Academy of Ophthalmology Preferred Practice Patterns Committee Retina Panel. *Preferred Practice Patterns: Diabetic Retinopathy*. San Francisco, CA: American Academy of Ophthalmology; 2012.
21. Doors M, Berendschot TT, de Brabander J, Webers CA, Nuijts RM. Value of optical coherence tomography for anterior segment surgery. *J Cataract Refract Surg*. 2010;36:1213–1229.
22. Savini G, Carbonelli M, Barboni P. Spectral-domain optical coherence tomography for the diagnosis and follow-up of glaucoma. *Curr Opin Ophthalmol*. 2011;22:115–123.
23. Hillman B. Physicians' acquisition and use of new technology in an era of economic constraints. In: Gelijins A, ed. *Technology and Health Care in an Era of Limits*. Washington, DC: National Academy Press; 1992:133–149.
24. Lalwani GA, Rosenfeld PJ, Fung AE, et al. A variable-dosing regimen with intravitreal ranibizumab for neovascular age-related macular degeneration: year 2 of the PrONTO Study. *Am J Ophthalmol*. 2009;148:43–58.
25. Jumper JM, Mittra RA. Preferences and trends survey. *Am Soc Retinal Specialists*. 2011. Available at: http://www.asrs.org/asrs-community/pat-survey/pat-survey-archive. Accessed December 4, 2012.
26. Ramulu PY, Do DV, Corcoran KJ, Corcoran SL, Robin AL. Use of retinal procedures in medicare beneficiaries from 1997 to 2007. *Arch Ophthalmol*. 2010;128:1335–1340.
27. American Academy of Ophthalmology Preferred Practice Patterns Committee Retina Panel. *Preferred Practice Patterns: Age-Related Macular Degeneration*. San Francisco, CA: American Academy of Ophthalmology; 2003, 2008.
28. Pollack JS. Preferences and trends survey. *Am Soc Retinal Specialists*. 2006. Available at: http://www.asrs.org/asrs-community/pat-survey/pat-survey-archive. Accessed December 4, 2012.

Investigative Ophthalmology & Visual Science