APPENDIX E1

In this Appendix, we will present supporting text, tables, and figures. The document is structured into five sections as follows: Section A consists of Table E1, which shows the demographic and experience characteristics of the 107 radiologists included in the analysis sample. Section B consists of Tables E2 and E3, which show distribution of characteristics by radiologist-specific average annual diagnostic volume for mammography performed for additional imaging and for mammography performed to assess a breast concern or problem. Section C includes a boxplot of each volume measure, prior to range restrictions imposed when modeling the relationship between volume and diagnostic performance. Section D provides a detailed description of how to interpret graphical results based on natural cubic spline modeling. Section E offers graphical representation of primary results based on natural cubic spline modeling for each volume measure and performance measure combination stratified by type of diagnostic mammogram (additional imaging vs breast concern or problem mammography). Section F contains tabular results for analyses of screening and total volume. Section G pertains to tumor characteristics.

Section A

Table E1. **Demographic and Experience Characteristics of 107 Radiologists included in the Analysis Sample Compared with Original Sample of 214 Survey Respondents**

Characteristic	All Eligible Radiologists (*n* = 214)	Radiologists in Analysis (*n* = 107)*
Demographics		
Age at survey		
<45 y	62 (29)	26 (24)
45—54 y	70 (33)	31 (29)
≥55 y	82 (38)	50 (47)
Gender		
Male	150 (70)	71 (66)
Female	64 (30)	36 (34)
Work full time (≥40 hrs/week)		
No	47 (22)	26 (25)
Yes	164 (78)	79 (75)
Unknown	3 (1)	2 (2)
Affiliation with academic medical center		
No affiliation	168 (80)	77 (73)
Adjunct	21 (10)	9 (8)
Primary	22 (10)	20 (19)
Unknown	3 (1)	1 (1)
Experience		
Combined variable of fellowship training and duration of mammogram interpretation		
No fellowship, <10 y	42 (20)	17 (16)
No fellowship, 10—19 y	69 (32)	33 (31)
No fellowship, ≥20 y	86 (40)	49 (46)
Fellowship, <10 y	8 (4)	3 (3)
Fellowship, ≥10 y	9 (4)	5 (5)
Time working in breast imaging		
<20%	56 (27)	27 (26)
20%—39%	58 (28)	26 (25)
40%—79%	29 (14)	15 (15)
80%—100%	64 (31)	35 (34)
Unknown	7 (3)	4 (4)

Note.—Data are numbers of radiologists, and data in parentheses are percentages. Unknown percentages are based on all 214 or 107 radiologists; remaining percentages are based on the number of with the characteristic known.

* Subset of 214 eligible radiologists.

Table E2. **Distribution of Characteristics for Additional Imaging Diagnostic Mammograms by Radiologist-specific Average Annual Diagnostic Volume**

Characteristic	Total No. of Mammograms (*n* = 46|369)	Total Percentage of Mammograms	Average Annual Diagnostic Volume (%)					
			<100 Mammograms (*n* = 853)	100–199 Mammograms (*n* =1219)	200—299 Mammograms (*n* = 6645)	300–499 Mammograms (*n* = 14|398)	500—999 Mammograms (*n* = 8028)	≥1000 Mammograms (15|226))
Age								
<40 y	1694	4	4	3	3	3	3	5
40—49 y	16|132	35	34	33	33	30	33	41
50—59 y	14|243	31	29	33	31	31	31	30
60—69 y	7994	17	17	18	18	19	18	14
70—79 y	4578	10	11	8	10	12	10	8
≥80 y	1728	4	4	3	4	5	4	2
Breast density								
Almost entirely fat	1783	5	8	3	3	3	4	7
Scattered fibroglandular tissue	15|534	40	45	49	47	41	35	37
Heterogeneously dense	19|063	49	41	43	44	48	52	52
Extremely dense	2403	6	7	4	6	7	9	4
Unknown	7586	16	26	9	2	12	9	31
First-degree family history								
No	33|892	82	85	85	84	82	82	82
Yes	7217	18	15	15	16	18	18	18
Unknown	5260	11	21	8	10	14	15	8
SRL								
No	41|555	98	97	98	99	98	98	97
Yes	971	2	3	2	1	2	2	3
Unknown	3843	8	18	5	10	12	11	2
Time since last mammography								
No previous mammography	3706	8	9	6	8	8	8	10
<12 mo	1918	4	4	4	5	4	5	4
12—35 mo	33|201	75	71	77	75	76	76	75
35—59 mo	3022	7	10	7	7	7	7	7
≥60 mo	2176	5	6	5	5	5	5	5
Unknown	2346	5	9	4	4	6	6	4
Average annual total volume								
<480 mammograms	17	0	2	0	0	0	0	0
480—1000 mammograms	1890	4	59	55	11	0	0	0
1000—1499 mammograms	6326	14	29	38	43	19	0	0
1500—1999 mammograms	5018	11	0	0	20	25	0	0
2000—2999 mammograms	10|962	24	0	0	26	47	31	0
3000—4999 mammograms	9976	22	10	6	0	7	50	31
≥5000	12|180	26	0	0	0	1	19	69

mammograms

	Total No. of Mammograms							
Average annual screening volume								
<480 mammograms	122	0	14	0	0	0	0	0
480—1000 mammograms	5073	11	56	59	37	10	0	0
1000—1499 mammograms	5361	12	20	35	22	23	0	0
1500—1999 mammograms	9153	20	0	0	36	39	14	0
2000—2999 mammograms	8257	18	10	0	6	25	36	8
≥3000 mammograms	18|403	40	0	6	0	3	50	92
Average annual diagnostic focus								
≤10%	2287	5	66	41	14	2	0	0
11%--15%	6350	14	21	14	38	16	8	4
16%--20%	18|307	39	12	25	32	53	74	14
21%--25%	11|947	26	0	20	10	22	10	46
>25%	7478	16	0	0	7	6	7	36

Note.---Unless otherwise indicated, data are percentages. Unknown percentages are based on all mammograms; remaining percentages are based on mammograms with the characteristic known. SRL = self-reported lump.

Table E3. **Distribution of Characteristics for Breast Concern or Problem Diagnostic Mammograms by Radiologist-specific Average Annual Diagnostic Volume**

Characteristic			Average Annual Diagnostic Volume					
	Total No. of Mammograms (n = 70|767)	Total Percentage of Mammograms	<100 Mammograms (n = 1044)	100—199 Mammograms (n = 1340)	200—299 Mammograms (n = 4814)	300—499 Mammograms (n = 13|984)	500—999 Mammograms (n = 9230)	≥1000 Mammograms (n = 40|355)
Age								
<40 y	11|973	17	21	18	21	16	14	17
40–49 y	20|219	29	34	33	30	29	28	28
50–59 y	17|913	25	21	24	22	24	28	26
60–69 y	10|749	15	11	14	13	15	16	15
70–79 y	6769	10	9	7	9	10	9	9
≥80 y	3144	4	4	3	5	5	5	4
Breast density								
Almost entirely fat	4250	9	17	5	6	6	10	11
Scattered fibroglandular tissue	18|064	37	37	41	41	37	38	36
Heterogeneously dense	20|706	43	35	43	43	45	39	43
Extremely dense	5466	11	11	10	11	12	13	11
Unknown	22|281	31	35	30	3	13	13	45
First-degree family history								
No	51|605	82	85	84	83	83	81	82
Yes	11|247	18	15	16	17	17	19	18
Unknown	7915	11	17	10	7	14	15	10
SRL								

No	43|788	67	56	55	43	61	70	71
Yes	21|903	33	44	45	57	39	30	29
Unknown	5076	7	10	9	7	8	8	7
Time since last mammography								
No previous mammography	6307	10	15	14	16	12	9	8
<12 mo	20|283	32	37	29	29	32	38	31
12–35 mo	31|112	49	34	46	41	47	45	52
35–59 mo	3519	5	8	6	8	6	5	5
≥60 mo	2785	4	6	5	6	4	4	4
Unknown	6761	10	12	7	7	9	6	11
Average annual total volume								
<480 mammograms	6	0	1	0	0	0	0	0
480–1000 mammograms	1494	2	67	43	5	0	0	0
1000–1499 mammograms	4259	6	31	31	40	12	0	0
1500–1999 mammograms	4135	6	2	0	25	21	0	0
2000–2999 mammograms	11|241	16	0	0	31	49	32	0
3000–4999 mammograms	12|141	17	0	26	0	13	47	14
≥5000 mammograms	37|491	53	0	0	0	6	22	86
Average annual screening volume								
<480 mammograms	105	0	10	0	0	0	0	0
480–1000 mammograms	3111	4	67	45	28	3	0	0
1000–1499 mammograms	4154	6	22	28	19	19	0	0
1500–1999 mammograms	9429	13	2	0	41	38	24	0
2000—2999 mammograms	15|447	22	0	0	12	28	29	21
≥3000 mammograms	38|521	54	0	26	0	13	47	79
Average annual diagnostic focus								
≤10%	3694	5	54	55	19	11	0	0
11%—15%	6862	10	33	13	48	15	6	3
16%—20%	15|960	23	13	16	26	59	54	3
21%—25%	10|497	15	0	16	3	14	2	20
>25%	33|754	48	0	0	4	2	38	74

Note.---Unless otherwise indicated, data are percentages. Unknown percentages are based on all mammograms; remaining percentages are based on mammograms with the characteristic known.
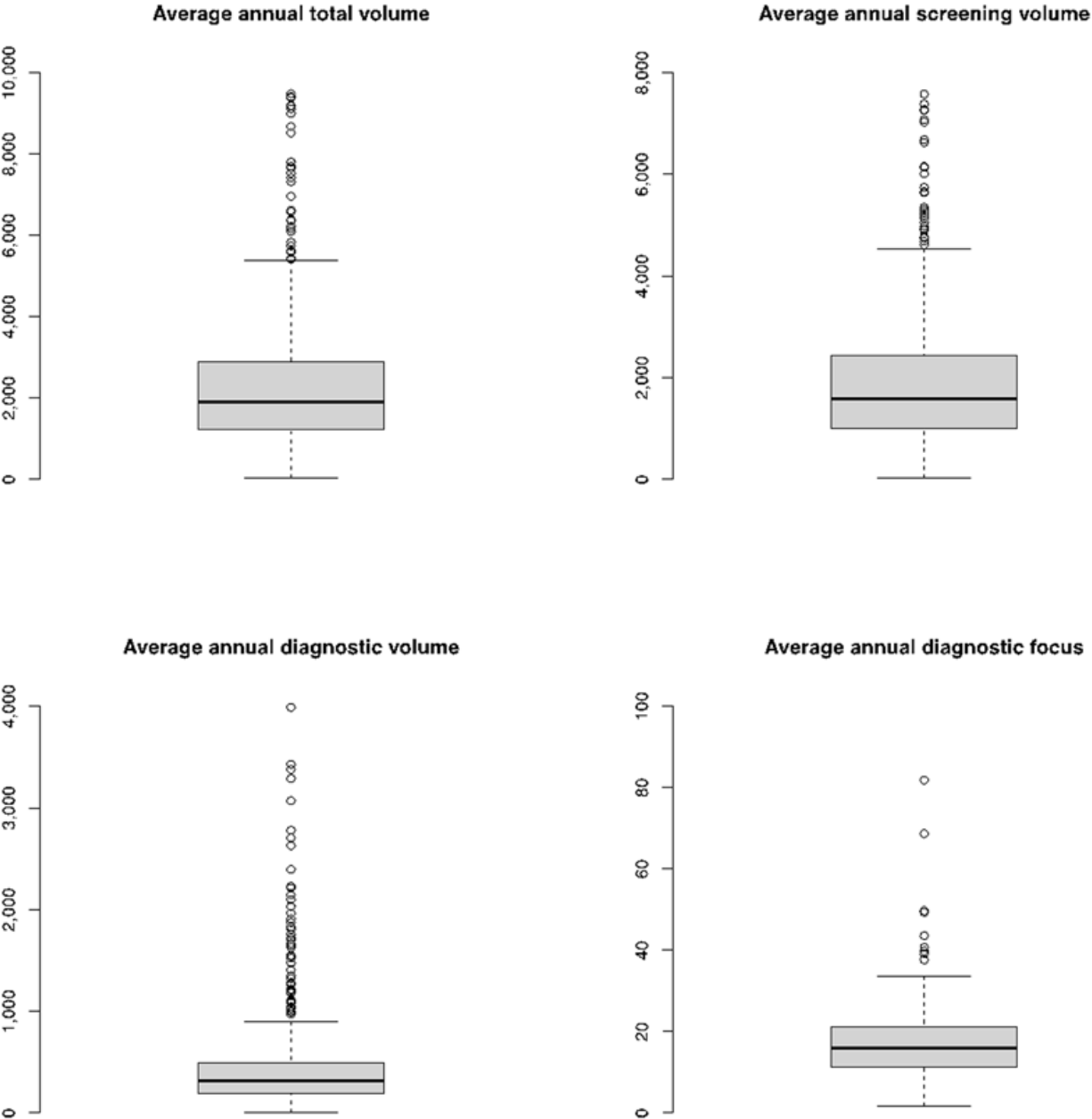
Section C

Figure E1: Boxplots of each volume measure, prior to range restrictions imposed when modeling the relationship between volume and diagnostic performance.

Section D

Results from primary analyses, in which we examined the association between interpretive volume and diagnostic mammography performance, are presented in Figures E4 through E7. Each subfigure uses a natural cubic spline to provide a flexible specification of the odds ratio (OR) association (22).

Here we provide a detailed description of how to interpret the graphic representation of the results corresponding to the association between diagnostic volume and sensitivity for additional imaging diagnostic mammography. This relationship is given by the upper left image in Figure E4.

Interpretation of a Standard Analysis

When modeling the association between a continuous exposure and some outcome, consideration should be given to whether or not the association is linear. One common strategy to relax the linearity assumption is to categorize the continuous exposure and model the association via a series of dummy variables. Table E2 presents estimated ORs and 95% confidence intervals (CIs) from a logistic regression analysis of sensitivity for additional imaging diagnostic mammography with the continuous exposure (diagnostic volume) categorized into six groups: 0—250 mammograms, 250—499 mammograms, 500–999 mammograms, 1000–1499 mammograms,1500–1999 mammograms, and 2000–2500 mammograms. As in the article, the model was adjusted for study registry, patient-level characteristics (age, family history, self-reported presence of a lump (SRL), and time since last mammography) and radiologist-level characteristics (years of mammogram interpretation and percentage of time working in breast imaging).

Table E2 indicates that there are five OR parameters that summarize the effect of diagnostic volume; one for each volume category being compared with the reference 1000–1499-mammogram group. Consider the results for the 500–999-mammogram group (OR = 0.55; 95% CI: 0.28, 1.09). To obtain a precise interpretation of this estimate, consider two mammograms read by two radiologists: Mammogram 1 was interpreted by a radiologist who read 600 diagnostic mammograms in the previous year. Mammogram 2 was interpreted by a radiologist who read 1000 diagnostic mammograms in the previous year. Otherwise, the mammograms are assumed to be the same in terms of the other characteristics included in the model. In Table E2, we see that the adjusted odds of a true-positive result for mammogram are estimated to be 0.55 times the adjusted odds of a true-positive result for mammography. Similarly, for a third mammogram (Mammogram 3) interpreted by a radiologist who read 200 diagnostic mammograms in the prior year, the relative odds of a true-positive finding would be 0.42 (95% CI: 0.22, 0.82).

Note, if Mammogram 1 had been interpreted by a radiologist with a diagnostic volume of 850 mammograms in the previous year, the estimated relative odds would be the same as if he or she had interpreted 500 mammograms (0.55). This is a consequence of the categorization of diagnostic volume and the choice of referent category and can be seen explicitly in the graphic representation of Table E2 (Fig E2); the black lines represent the OR estimates, and the grey lines are the 95% CIs. Finally, since the OR scale is not symmetric around 1.0, we used the log-scale for the y-axis, although the labels are based on the OR scale (in their appropriate locations).

Interpretation of the Natural Cubic Spline Analysis

The choice of the six categories in Table E2 and Figure E2, as well as the cutoffs, is somewhat arbitrary and may be restrictive. One could easily increase flexibility by performing a similar analysis with a greater number of diagnostic volume categories. A trade-off, however, is that

additional parameters (corresponding to the new groups) would need to be estimated. Since the sample size would not change, this would lead to greater uncertainty; standard errors would increase, CIs would widen, and power to detect an association would be reduced. Natural cubic splines provide an alternative modeling strategy that is extremely flexible in its specification of the model while being parsimonious in the number of parameters. For example, the analyses we present in the article use a natural cubic spline with a single knot located at the midpoint of the prespecified volume ranges; such a model requires only two parameters. Hastie et al (22) provide an excellent summary of technical details regarding splines and related techniques.

One drawback of the use of splines is that the model parameters are difficult to interpret directly. As such, a common approach to presenting the estimated ORs and 95% CIs is to do so graphically. Figure E3 provides such a representation for the analysis of the association between diagnostic volume and sensitivity for additional imaging diagnostic mammography. Note, this is the same as the upper left figure of Figure E4. Similar to Figure E2, the black line represents the estimated OR and the grey lines represent 95% CIs, both of which are interpreted in exactly the same way as in Figure E2. Specifically, consider two mammograms interpreted by two radiologists, one who interpreted 2000 diagnostic mammograms in the previous year and one who interpreted 1000 diagnostic mammograms in the previous year. The vertical dashed lines indicate the two mammograms in Figure E3. The height of the right-most dashed line is 0.43 (95% CI: 0.29, 0.64). One could interpret the height of the curve at any point along the x-axis in the same way.

Note that while the 1000–1499 mammogram group is taken to be the reference category in Table E2 and Figure E2, the reference group in Figure E3 is the single value of 1000. For both sets of analyses (Figs E2, E3), the choice of reference group does not affect the relative differences across the groups (the shape of the association), nor does it impact significance.

Table E4. **Estimated Adjusted OR Associations between Diagnostic Volume and Sensitivity for Additional Imaging Diagnostic Mammography Based on a Categorization of the Volume Measure with 6 Groups**

Diagnostic Volume Category	Sensitivity
0–250 mammograms	0.42 (0.22, 0.82)
250–499 mammograms	0.38 (0.18, 0.83)
500–999 mammograms	0.55 (0.28, 1.09)
1000–1499 mammograms	1.00 (NA)
1500–1999 mammograms	0.19 (0.11, 0.34)
2000–2500 mammograms	0.22 (0.12, 0.40)

Note.---Data are odds ratios, and data in parentheses are 95% CIs. NA = not applicable.
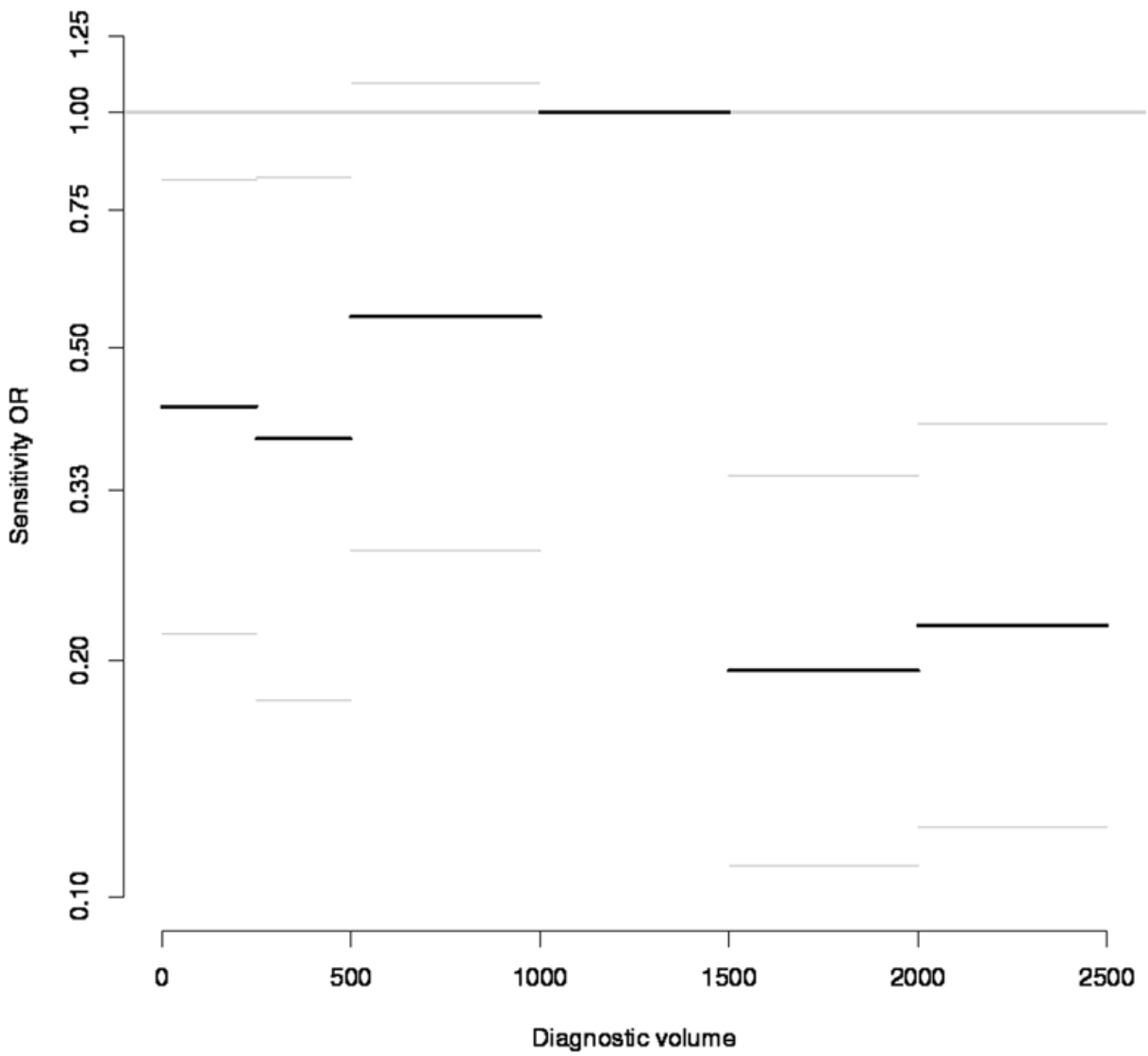
Figure E2: Graph shows estimated adjusted OR associations between diagnostic volume and sensitivity for additional imaging diagnostic mammography based on a categorization of the volume measure with six groups. Gray lines are pointwise 95% confidence intervals.
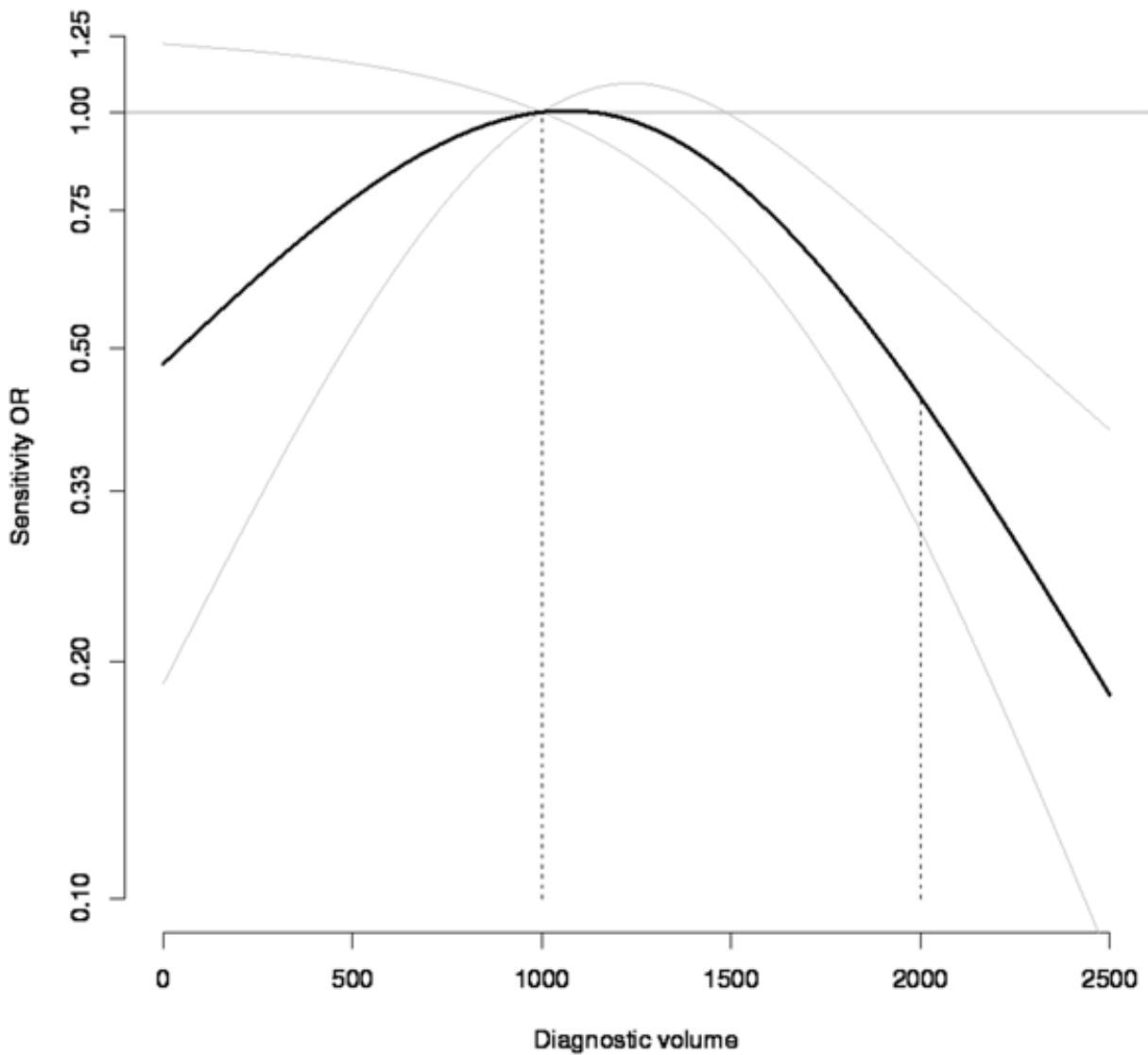
Figure E3: Estimated adjusted OR associations between diagnostic volume and sensitivity for additional imaging diagnostic mammography based on a natural cubic spline representation for the volume effect. Gray lines are pointwise 95% CIs. Dashed lines indicate two mammograms read by radiologists, one with a diagnostic volume of 1000 mammograms and the other with a diagnostic volume of 2000 mammograms.

Section E

The following graphs show the primary results based on natural cubic spline modeling for each

volume measure and performance measure combination, stratified by type of diagnostic

mammogram (additional imaging vs breast concern or problem mammography). Figures E4 and

E5 correspond to Tables 4 and 5, respectively. Figures E6 and E7 correspond to Tables E5 and
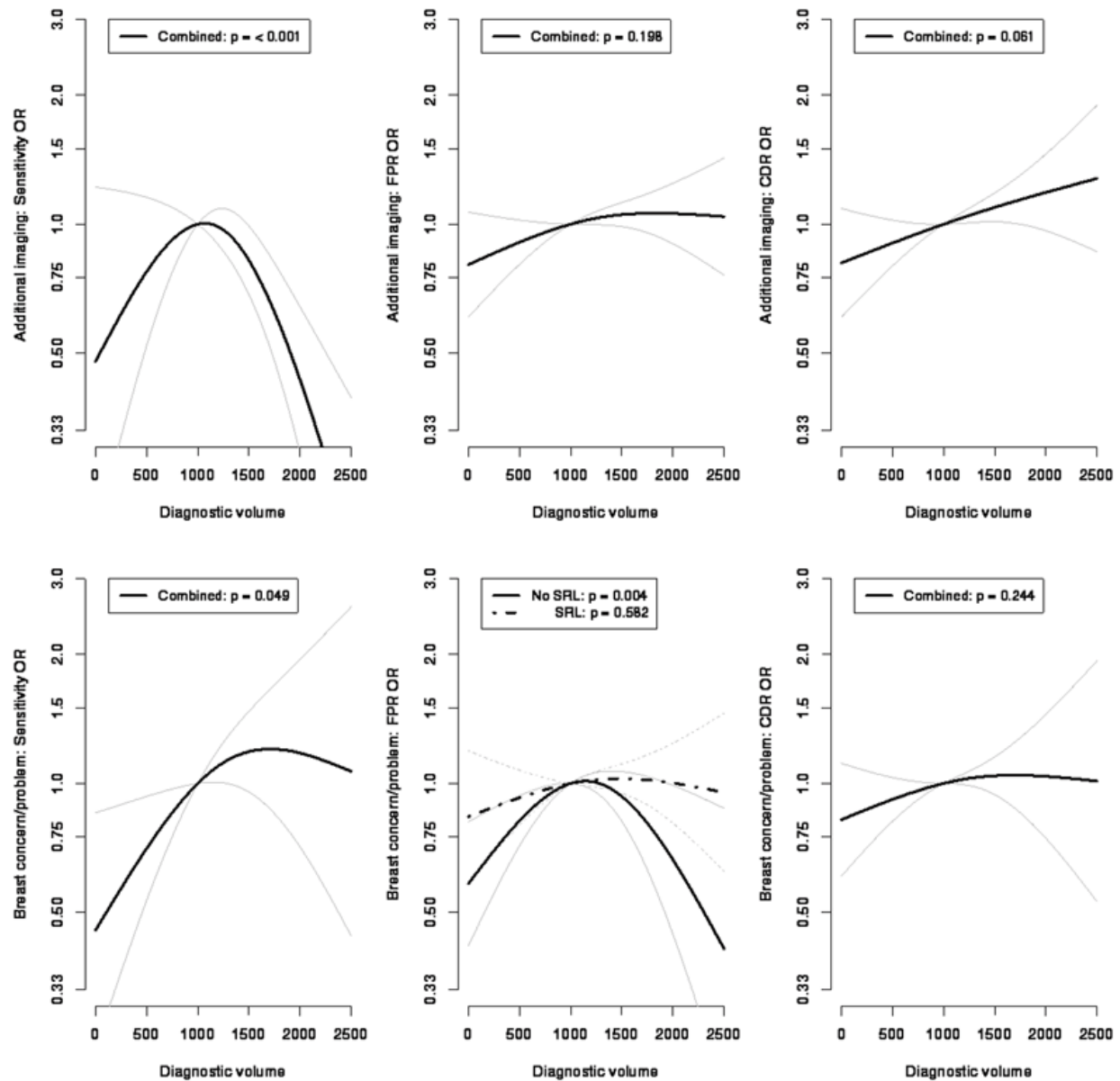
E6 in section E.

Figure E4: Graphs show adjusted OR associations between diagnostic volume and sensitivity, FPR, and CDR. The upper row is for additional imaging diagnostic mammography; the lower row is for breast concern or problem diagnostic mammography. Results for breast concern or problem diagnostic mammography models where an interaction with SRL is significant are stratified by SRL. Gray lines are pointwise 95% CIs; *P* values represent tests of whether or not there is an association based on the combined sample or within SRL strata.

Figure E5: Graphs show adjusted OR associations between diagnostic focus and sensitivity, FPR, and CDR. The upper row is for additional imaging diagnostic mammography; the lower row is for breast concern or problem diagnostic mammography. Results for breast concern or problem diagnostic mammography models where an interaction with SRL is significant are stratified by SRL. Gray lines are pointwise 95% CIs; *P* values represent tests of whether or not there is an association based on the combined sample or within SRL strata.
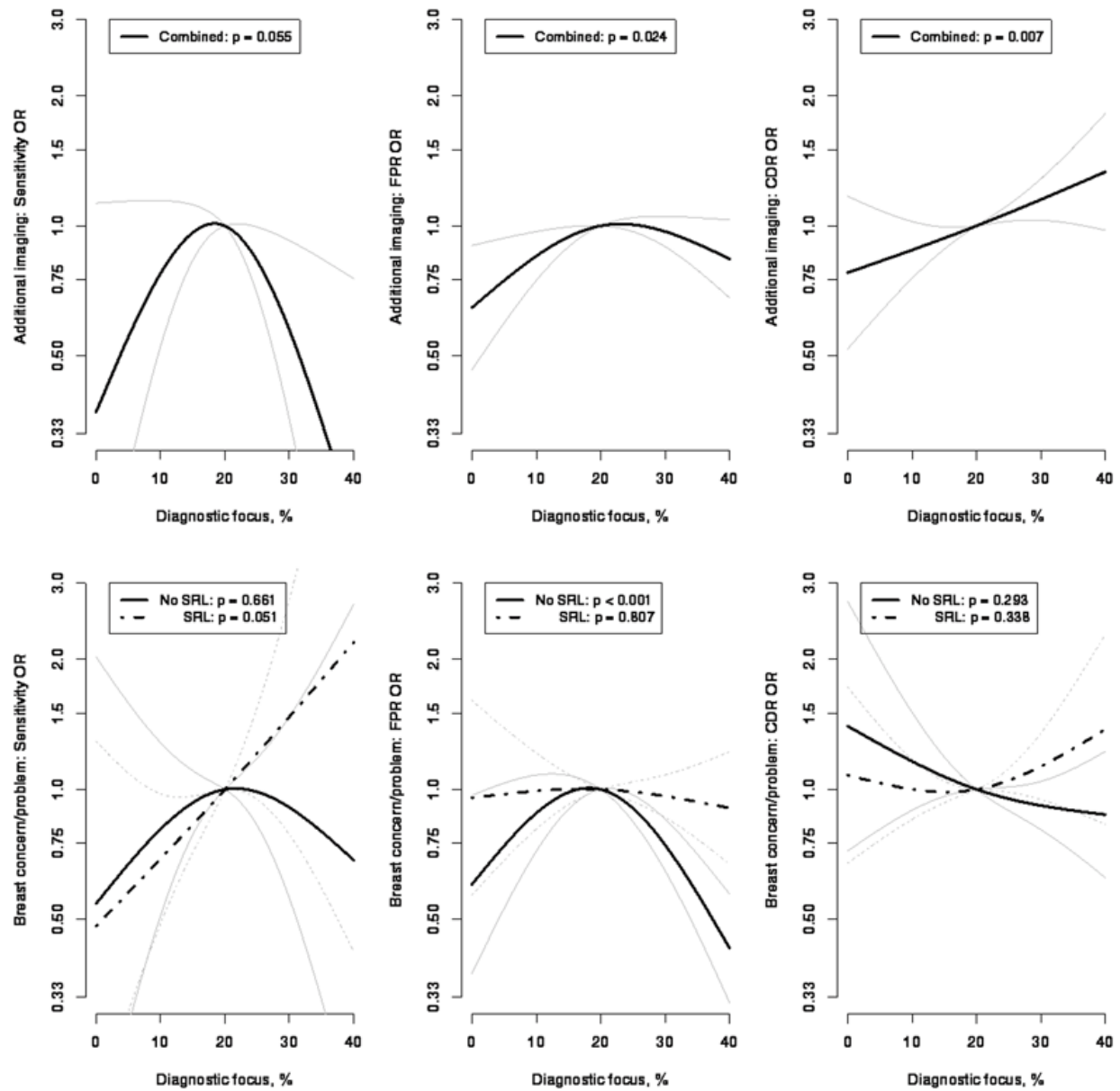
Figure E6: Adjusted OR associations between screening volume and sensitivity, FPR, and CDR. The upper row is for additional imaging diagnostic mammography; the lower row is for breast concern or problem diagnostic mammography. Results for breast concern or problem diagnostic mammography models where an interaction with SRL is significant are stratified by SRL. Gray lines are pointwise 95% confidence intervals; *P* values represent tests of whether or not there is an association based on the combined sample or within SRL strata.
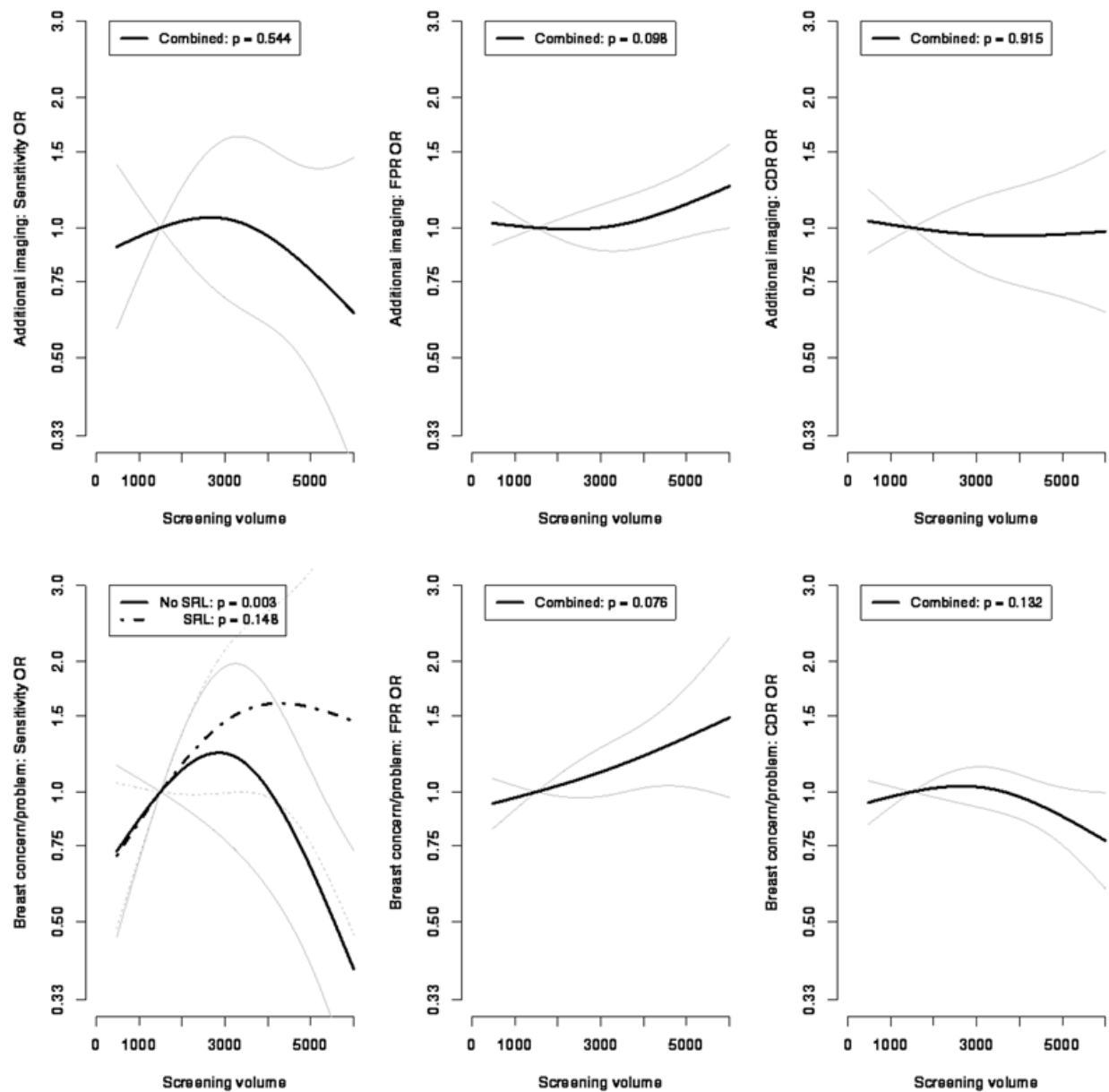
Figure E7: Adjusted OR associations between total volume and sensitivity, FPR, and CDR. The upper row is for additional imaging diagnostic mammography; the lower row is for breast concern or problem diagnostic mammography. Results for breast concern or problem diagnostic mammography models where an interaction with SRL is significant are stratified by SRL. Gray lines are pointwise 95% confidence intervals; *P* values represent tests of whether or not there is an association based on the combined sample or within SRL strata.
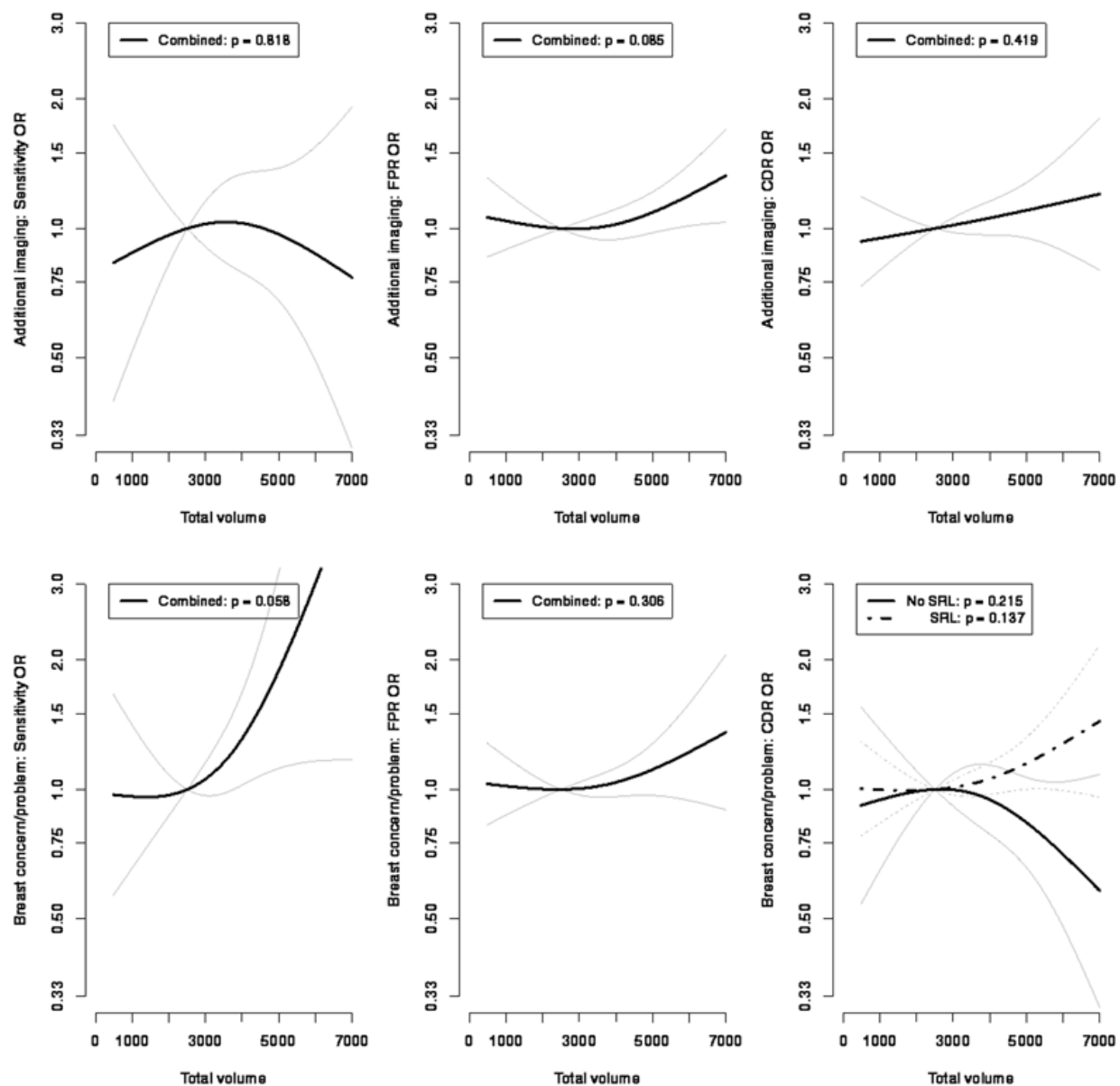
Section F

Table E5. **Estimated Adjusted OR Associations and 95% CIs between Screening Volume and Sensitivity, FPR, and CDR**

Group and Screening Volume	Sensitivity			FPR			CDR		
	OR	95% CI	P Value*	OR	95% CI	P Value*	OR	95% CI	P Value*
Additional imaging	…	…	.544			.098	…	…	.915
500 mammograms	0.95	0.75, 1.20	…	1.01	0.95, 1.08	…	1.02	0.93, 1.12	…
1000 mammograms	0.99	0.95, 1.03	…	1.00	0.99, 1.01	…	1.00	0.99, 1.02	…
2000 mammograms	1.05	0.79, 1.39	…	0.99	0.92, 1.07	…	0.98	0.87, 1.10	…
3000 mammograms	1.04	0.66, 1.63	…	1.01	0.88, 1.15	…	0.96	0.78, 1.19	…
4000 mammograms	0.93	0.58, 1.50	…	1.06	0.91, 1.24	…	0.96	0.73, 1.26	…
5000 mammograms	0.78	0.45, 1.37		1.14	0.96, 1.36		0.97	0.69, 1.36	
6000 mammograms	0.64	0.28, 1.45		1.25	1.00, 1.56		0.98	0.64, 1.51	
Breast concern or problem: no lump	…	…	.003	…	…	.076[†]	…	…	.132[†]
500 mammograms	0.85	0.66, 1.08	…	0.97	0.90, 1.04	…	0.97	0.91, 1.03	…
1000 mammograms	0.97	0.93, 1.01	…	0.99	0.98, 1.01	…	1.00	0.99, 1.01	…
2000 mammograms	1.19	0.88, 1.60	…	1.06	0.97, 1.15	…	1.03	0.96, 1.10	…
3000 mammograms	1.21	0.74, 1.98	…	1.13	0.98, 1.30	…	1.02	0.91, 1.14	…
4000 mammograms	0.96	0.57, 1.63	…	1.23	1.03, 1.47	…	0.96	0.85, 1.08	…
5000 mammograms	0.64	0.38, 1.08	…	1.35	1.02, 1.78	…	0.87	0.74, 1.02	…
6000 mammograms	0.39	0.21, 0.73	…	1.49	0.97, 2.27	…	0.77	0.60, 1.00	…
Breast concern or problem: lump	…	…	.148	…	…	NA	…	…	NA
500	0.83	0.68, 1.02	…	NA[‡]	NA[‡]	…	NA[‡]	NA[‡]	…
1000 mammograms	0.97	0.94, 1.00	…	NA[‡]	NA[‡]	…	NA[‡]	NA[‡]	…
2000 mammograms	1.26	0.99, 1.62	…	NA[‡]	NA[‡]	…	NA[‡]	NA[‡]	…
3000 mammograms	1.51	1.00, 2.27	…	NA[‡]	NA[‡]	…	NA[‡]	NA[‡]	…
4000 mammograms	1.60	0.95, 2.69	…	NA[‡]	NA[‡]	…	NA[‡]	NA[‡]	…
5000 mammograms	1.56	0.74, 3.31	…	NA[‡]	NA[‡]	…	NA[‡]	NA[‡]	…
6000 mammograms	1.46	0.47, 4.54	…	NA[‡]	NA[‡]	…	NA[‡]	NA[‡]	…

Note.---For breast concern or problem mammography, an interaction with SRL was evaluated. When the interaction was not significant, a main effects--only model was fit, and no lump or lump stratum-specific estimates were the same. When the interaction was significant, no lump or lump stratum-specific estimates differed. FPR is rate per 100 mammograms; CDR is rate per 1000 mammograms. NA = not applicable.

* Two-sided omnibus P value for overall association based on natural cubic spline model.

[†] P value for main effects--only model when an interaction between volume and presence of lump was not significant.

Table E6. **Estimated Adjusted OR Associations and 95% CIs between Total Volume and Sensitivity, FPR, and CDR**

Group and Screening Volume	Sensitivity			FPR			CDR	
	OR	95% CI	P Value[*]	OR	95% CI	P Value[*]	OR	95% CI
Additional imaging	…	…	.818	…	…	.085	…	…
500 mammograms	0.87	0.50, 1.52	…	1.04	0.89, 1.22	…	0.95	0.79, 1.13
1000 mammograms	0.92	0.64, 1.32	…	1.03	0.92, 1.14	…	0.96	0.86, 1.08
2000 mammograms	0.99	0.95, 1.04	…	1.00	0.99, 1.02	…	0.99	0.98, 1.01
3000 mammograms	1.03	0.87, 1.23	…	1.00	0.95, 1.05	…	1.03	0.97, 1.09
4000 mammograms	1.02	0.77, 1.35	…	1.03	0.95, 1.13	…	1.07	0.97, 1.18
5000 mammograms	0.96	0.66, 1.39	…	1.10	0.98, 1.24	…	1.11	0.94, 1.30
6000 mammograms	0.87	0.48, 1.57	…	1.20	1.02, 1.42	…	1.15	0.88, 1.51
7000 mammograms	0.77	0.31, 1.92	…	1.33	1.03, 1.70	…	1.20	0.80, 1.81
Breast concern or problem: no lump	…	…	.058[†]	…	…	.305[†]	…	…
500 mammograms	0.96	0.65, 1.43	…	1.02	0.87, 1.20	…	0.94	0.64, 1.40
1000 mammograms	0.96	0.74, 1.25	…	1.01	0.91, 1.12	…	0.97	0.75, 1.25
2000 mammograms	0.99	0.96, 1.02	…	1.00	0.99, 1.01	…	1.00	0.97, 1.03
3000 mammograms	1.11	0.97, 1.26	…	1.01	0.96, 1.06	…	0.99	0.88, 1.12
4000 mammograms	1.40	1.05, 1.88	…	1.05	0.96, 1.14	…	0.93	0.76, 1.13
5000 mammograms	2.01	1.13, 3.57	…	1.13	0.97, 1.31	…	0.82	0.64, 1.06
6000 mammograms	3.12	1.17, 8.36	…	1.23	0.94, 1.61	…	0.70	0.47, 1.04
7000 mammograms	5.07	1.17, 21.97	…	1.36	0.90, 2.06	…	0.58	0.31, 1.08
Breast concern or problem: lump	…	…	NA	…	…	NA	…	…
500 mammograms	NA[‡]	NA[‡]	…	NA[‡]	NA[‡]	…	1.00	0.83, 1.20
1000 mammograms	NA[‡]	NA[‡]	…	NA[‡]	NA[‡]	…	1.00	0.88, 1.13
2000 mammograms	NA[‡]	NA[‡]	…	NA[‡]	NA[‡]	…	1.00	0.98, 1.01
3000 mammograms	NA[‡]	NA[‡]	…	NA[‡]	NA[‡]	…	1.02	0.96, 1.08
4000 mammograms	NA[‡]	NA[‡]	…	NA[‡]	NA[‡]	…	1.07	0.98, 1.18
5000 mammograms	NA[‡]	NA[‡]	…	NA[‡]	NA[‡]	…	1.17	1.00, 1.36
6000 mammograms	NA[‡]	NA[‡]	…	NA[‡]	NA[‡]	…	1.29	0.99, 1.68
7000 mammograms	NA[‡]	NA[‡]	…	NA[‡]	NA[‡]	…	1.44	0.96, 2.17

Note.---For breast concern or problem mammography, an interaction with SRL was evaluated. When the interaction was not significant, a main effects--only model was fit, and no lump or lump stratum-specific estimates were the same. When the interaction was significant, no lump or lump stratum-specific estimates differed. FPR is rate per 100 mammograms; CDR is rate per 1000 mammograms. NA = not applicable.

* Two-sided omnibus P value for overall association based on natural cubic spline model.

† *P* value for main effects—only model when an interaction between volume and presence of lump was not significant.

‡ Interaction with lump was not significant. See results for no lump.

Section G

Tumor characteristics were collected from tumor registries and pathology databases. We investigated the prevalence of early stage cancer by considering three definitions of early: *(a)* ductal carcinoma in situ (DCIS) or invasive cancer, with tumors 10 mm in diameter or smaller; *(b)* DCIS or invasive cancer, with tumors 10 mm in diameter or smaller and node negative; or *(c)* DCIS or invasive cancer, with tumors smaller than 15 mm in diameter and node negative (18).

Tables E7 and E8 show tumor characteristics for additional imaging and breast concern or problem mammography stratified by the average annual diagnostic focus for the radiologist who interpreted the most recent mammogram linked to the cancer. A total of 4861 cancers were detected: a total of 2156 for additional work-up mammography and 2705 for breast concern or problem mammography. We found 72% of additional imaging cancers were invasive; the percentage was greater among breast concern or problem cancers (89%). For additional imaging, the percentage of invasive cancers decreased with increasing average annual diagnostic focus (from 80% to 72%). Among invasive breast concern or problem cancers, the median tumor size decreased from 24.5 mm to 21.0 mm across increasing the average annual diagnostic focus categories; no such pattern was found among invasive additional imaging cancers. The percentage of cancers detected at early stages generally increased and then decreased across the range of average annual diagnostic focus for all three definitions and for each type of mammography. For example, by using the first definition (DCIS or invasive cancer, with tumors 10 mm in diameter or smaller and node negative), the proportion of early cancers among additional imaging mammograms increased from 54% to 63% between average annual

diagnostic focus of 10% or less to 16%--20% and then decreased to 55% among mammograms

with average annual diagnostic focus of more than 30%.

Table E7. **Distribution of Tumor Characteristics for Additional Imaging Diagnostic Mammography by Radiologist-specific Average Annual Diagnostic Focus**

Tumor Characteristic	Overall (n = 2156)	Average Annual Diagnostic Focus (%)					
		≤10% (n = 87)	11%--15% (n = 248)	16%--20% (n = 841)	21%--25% (n = 469)	26%--30% (n = 149)	>30% (n = 362)
Histologic type							
DCIS	28	20	22	30	29	29	28
All invasive	72	80	78	70	71	71	72
Stage							
0	29	21	24	31	30	30	28
I	49	54	52	47	50	50	48
II	18	20	17	18	17	19	21
III or IV	4	5	7	4	3	2	2
Unknown	3	7	8	3	2	3	1
Cancer size*							
≤5 mm	14	15	13	16	14	12	13
6—10 mm	28	28	27	30	30	27	24
11--15 mm	27	25	25	24	28	36	33
16--20 mm	12	15	13	12	11	8	12
>20 mm	18	18	22	18	16	17	18
Unknown	4	3	8	3	5	4	2
Median cancer size* (mm)	NA	12	13	12	12	12	12
Early stage at diagnosis (definition 1)							
DCIS or invasive cancer ≤10 mm	59	54	54	63	61	57	55
Invasive cancer >10 mm	41	46	46	37	39	43	45
Unknown	3	2	6	2	3	3	1
Early stage at diagnosis (definition 2)							
DCIS or invasive cancer ≤10 mm and node negative	67	64	64	69	68	68	65
Other	33	36	36	31	32	32	35
Unknown	3	3	8	3	3	2	2
Early stage at diagnosis (definition 3)							
DCIS or invasive cancer <15 mm and node negative	56	50	52	59	59	52	53
Other	44	50	48	41	41	48	47
Unknown	3	3	8	3	3	2	2
Auxiliary lymph node status*							
Negative	81	84	83	79	81	82	79
Positive	19	16	17	21	19	18	21
Unknown	3	3	7	3	3	2	1
Grade*							
1, well differentiated	28	25	34	29	23	31	28
2, moderately well differentiated	49	45	46	47	50	50	51
3/4, poorly differentiated/undifferentiated	24	30	20	24	27	19	21
Unknown	8	14	16	9	6	5	3
Estrogen receptor status†							
Negative	14	26	9	17	12	13	13
Positive	86	74	91	83	88	87	87

Unknown	10	19	16	12	5	6	6

Note.---Unless otherwise indicated, data are percentages. Unknown percentages are based on all tumors; remaining percentages are based on tumors with the characteristic known. NA = not applicable.

* Invasive cancers only.

Table E8. **Distribution of Tumor Characteristics for Breast Concern or Problem Diagnostic Mammography by Radiologist-specific Average Annual Diagnostic Focus**

Tumor Characteristic	Overall (n = 2705)	Average Annual Diagnostic Focus (%)					
		≤10 (n = 163)	11—15 (n = 305)	16—20 (n = 746)	21—25 (n = 421)	26—30 (n = 228)	>30 (n = 842)
Cancer histologic type							
DCIS	11	6	10	11	10	19	12
All invasive	89	94	90	89	90	81	88
Stage							
0	12	6	12	12	10	19	12
I	33	30	29	34	34	39	33
II	39	45	34	39	37	34	42
III/IV	16	18	25	16	18	8	13
Unknown	5	8	12	4	3	2	6
Cancer size*							
≤5 mm	6	3	6	6	7	8	6
6—10 mm	12	8	10	10	15	15	12
11—15 mm	19	18	17	20	18	22	18
16--20 mm	16	17	16	20	12	16	16
>20 mm	47	54	51	45	48	39	49
Unknown	6	6	12	4	5	4	5
Median cancer size (mm)*	NA	24.5	23	20	21	17	21
Early stage at diagnosis (definition 1)							
DCIS or invasive cancer ≤10 mm	27	16	26	25	30	38	28
Invasive cancer >10 mm	73	84	74	75	70	62	72
Unknown	5	6	10	4	5	3	5
Early stage at diagnosis (definition 2)							
DCIS or invasive cancer ≤10 mm and node negative	32	24	28	31	35	45	30
Other	68	76	72	69	65	55	70
Unknown	5	5	9	3	4	3	5
Early stage at diagnosis (definition 3)							
DCIS or invasive cancer <15 mm and node negative	23	13	22	22	25	34	23
Other	77	87	78	78	75	66	77
Unknown	5	5	9	3	4	3	5
Auxiliary lymph node status*							
Negative	60	55	61	58	60	68	60
Positive	40	45	39	42	40	32	40
Unknown	3	3	5	2	4	1	4
Grade*							
1, well differentiated	18	12	22	20	17	27	15
2, moderately well differentiated	40	46	38	39	45	40	38
3/4, poorly differentiated/undifferentiated	42	43	41	41	37	34	47
Unknown	10	12	20	8	11	8	6
Estrogen receptor status*							

Negative	25	31	25	27	22	21	26
Positive	75	69	75	73	78	79	74
Unknown	12	24	24	13	8	7	9

Note.---Unless otherwise indicated, data are percentages. Unknown percentages are based on all tumors; remaining percentages are based on tumors with the characteristic known. NA = not applicable.

* Invasive cancers only.