ORIGINAL ARTICLE

Impact of the COVID-19 Pandemic on Breast Imaging: An Analysis of the National Mammography Database

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Abstract

Purpose: The aim of this study was to quantify the initial decline and subsequent rebound in breast cancer screening metrics throughout the coronavirus disease 2019 (COVID-19) pandemic.

Methods: Screening and diagnostic mammographic examinations, biopsies performed, and cancer diagnoses were extracted from the ACR National Mammography Database from March 1, 2019, through May 31, 2021. Patient (race and age) and facility (regional location, community type, and facility type) demographics were collected. Three time periods were used for analysis: pre-COVID-19 (March 1, 2019, to May 31, 2019), peak COVID-19 (March 1, 2020, to May 31, 2020), and COVID-19 recovery (March 1, 2021, to May 31, 2021). Analysis was performed at the facility level and overall between time periods.

Results: In total, 5,633,783 screening mammographic studies, 1,282,374 diagnostic mammographic studies, 231,390 biopsies, and 69,657 cancer diagnoses were analyzed. All peak COVID-19 metrics were less than pre-COVID-19 volumes: 36.3% of pre-COVID-19 for screening mammography, 57.9% for diagnostic mammography, 47.3% for biopsies, and 48.7% for cancer diagnoses. There was some rebound during COVID-19 recovery as a percentage of pre-COVID-19 volumes: 85.3% of pre-COVID-19 for screening mammography, 97.8% for diagnostic mammography, 91.5% for biopsies, and 92.0% for cancer diagnoses. Across various metrics, there was a disproportionate negative impact on older women, Asian women, facilities in the Northeast, and facilities affiliated with academic medical centers.

Conclusions: COVID-19 had the greatest impact on screening mammography volumes, which have not returned to pre-COVID-19 levels. Cancer diagnoses declined significantly in the acute phase and have not fully rebounded, emphasizing the need to increase outreach efforts directed at specific patient population and facility types.

Key Words: COVID-19, screening mammography, diagnostic mammography, breast biopsies, breast cancer

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INTRODUCTION

The coronavirus disease 2019 (COVID-19) pandemic had a profound impact on health care delivery in the United States due to mandatary stay-at-home orders and patient fears about visiting health care facilities [1]. During the peak of the pandemic in early 2020, CMS recommended that individuals "consider postponing service" for "preventive care visit/screening" [2]. This led to the near complete cessation of many cancer screening services, including screening mammography [3-9]. As the public and health care organizations began to adapt, guidelines on a safe return to imaging were released by the Society of Breast Imaging in May 2020, followed by the ACR in July 2020 [10,11]. These guidelines advocated for strategies to shift the risk/benefit ratio for patients to facilitate a safe return to screening practices. In response, practices adopted a wide variety of strategies to encourage patients to return, including expanding hours, switching to electronic intake forms, improved cleaning and sanitation practices, and rearranging the workflows of clinics [12]. Several publications using regional and limited national data sets reported that in the months after the pandemic peak, screening mammography volumes began to rebound, but rates had not yet returned to prepandemic baseline [2,5,6]. However, the intermediate-term impact of COVID-19 on the use of screening and diagnostic mammography, demonstrated on a larger scale that is more representative of the national population and includes subgroup analysis across pertinent patient demographics and analysis at a facility level, has not been well studied.

The purpose of this study was to quantify the decrease and subsequent rebound in breast cancer screening and diagnostic metrics during the COVID-19 pandemic using the National Mammography Database (NMD).

METHODS

The NMD

The NMD was established by the ACR in 2008 to facilitate quality improvement and research efforts for screening mammography practices in the United States [13]. The NMD represents the broadest coverage of all national and regional breast imaging databases in the United States and allows subgroup analysis to assess for disproportionate impacts on specific patient and facility demographics. The NMD includes the results of more than 31 million mammographic examinations, representing 690 facilities in 45 states [14]. All NMD data are HIPAA compliant, anonymized, and deidentified before analysis by non-NMD investigators, who do not have access to any patient-, physician-, or facility-identifying information.

Study Population

The 377 distinct facilities that submitted data to the NMD from March 1, 2019, through May 31, 2021, were included for analysis. This duration was chosen to span 1 year before the peak of the COVID-19 pandemic in spring 2020 (March, April, and May) as well as 1 year after the peak. Patient demographics included age and race (Asian; black; Native American, Native Hawaiian, or Pacific Islander; white; or unknown). Facility demographics included regional location (Northeast, South, Midwest, or West), community type (metropolitan [>100,000 persons], suburban [50,000-100,000 persons], or rural [<50,000 persons]), and facility type (academic or university, community hospital, freestanding imaging center, or multispecialty clinic).

Outcomes Measures and Analysis

To assess for changes in the use of breast cancer screening services before, during, and after the height of the COVID-19 pandemic, we compared the number of occurrences per facility for screening mammography, diagnostic mammography, biopsies performed, and cancer diagnoses at all sites that contributed to the NMD across three time periods: pre-COVID-19 (March 1, 2019, to May 31, 2019), peak COVID-19 (March 1, 2020, to May 31, 2020), and COVID-19 recovery (March 1, 2021, to May 31, 2021). Because health care encounters tend to have "seasonality" (eg, patients often seek the bulk of their preventive care at the beginning or end of the year), we matched the date ranges in each of our three time periods [15]. Matched date ranges in each year help mitigate any skewness that would otherwise occur had we widened our ranges to entire calendar years for 2020 and portions of calendar years for 2019 and 2021.

Because the numbers of encounters per facility in each of the four encounter categories listed previously were not normally distributed, we assessed the median number of encounters and compared these medians between each possible pairing of time periods using nonparametric, one-sided Wilcoxon's rank-sum tests, resulting in three separate measures (ie, pre-COVID-19 vs peak COVID-19, peak COVID-19 vs COVID-19 recovery, and pre-COVID-19 vs COVID-19 recovery). We anticipated seeing significantly fewer encounters from pre-COVID-19 to peak COVID-19 and significantly more encounters from peak COVID-19 to COVID-19 recovery with no statistically significant difference from pre-COVID-19 to COVID-19 recovery. To avoid potentially "artificial" or overstated statistically significant findings with such large encounter numbers, any comparison with more than 10,000 total encounters for both groups used a more conservative α value of 0.01 for

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Table 1. Total volume of screening mammographic examinations, diagnostic mammographic examinations, breast biopsies, and cancer diagnoses by patient and facility demographics from March 1, 2019, through May 31, 2021

	Screening Mammography		Diagnostic Mammography		Biopsies		Cancer Diagnoses	
	n	%	n	%	n	%	n	%
Age								
<40 y	62,295	1.1	130,899	10.2	14,292	6.2	1,854	2.7
40-49 y	1,175,114	20.9	323,706	25.2	57,021	24.6	8,980	12.9
50-59 y	1,551,265	27.5	304,685	23.8	55,606	24.0	14,998	21.5
60-69 y	1,631,623	29.0	286,704	22.4	57,257	24.7	21,662	31.1
70-79 y	999,124	17.7	186,031	14.5	37,559	16.2	16,621	23.9
≥80 y	214,362	3.8	50,349	3.9	9,655	4.2	5,542	8.0
Race								
Asian	109,497	1.9	20,671	1.6	5,268	2.3	1,427	2.0
Black	246,026	4.4	43,924	3.4	8,856	3.8	2,472	3.5
Native American, Native Hawaiian, or Pacific Islander	38,932	0.7	6,046	0.5	1,260	0.5	363	0.5
White	1,923,641	34.1	367,601	28.7	75,510	32.6	24,027	34.5
Unknown	3,315,683	58.9	844,130	65.8	140,496	60.7	41,368	59.4
Community type								
Academic/university	599,772	11.0	169,674	13.5	33,856	15.0	10,251	15.0
Community hospital	2,301,231	42.1	514,308	40.9	95,234	42.1	28,676	41.9
Multispecialty clinic	391,185	7.2	52,402	4.2	12,306	5.4	3,793	5.5
Freestanding imaging center	2,178,651	39.8	522,098	41.5	84,699	37.5	25,660	37.5
Facility type								
Metropolitan (>100,000 persons)	3,268,582	58.0	828,716	64.6	142,980	61.8	44,231	63.5
Suburban/small (50,000-100,000 persons)	1,872,684	33.2	345,009	26.9	70,173	30.3	20,341	29.2
Rural (<50,000 persons)	492,521	8.7	108,650	8.5	18,237	7.9	5,085	7.3
Region								
Northeast	1,348,398	23.9	286,831	22.4	53,606	23.2	14,932	21.4
Midwest	1,391,629	24.7	257,868	20.1	51,927	22.4	17,816	25.6
South	1,404,760	24.9	328,844	25.6	56,220	24.3	15,850	22.8
West	1,489,000	26.4	408,832	31.9	69,637	30.1	21,059	30.2

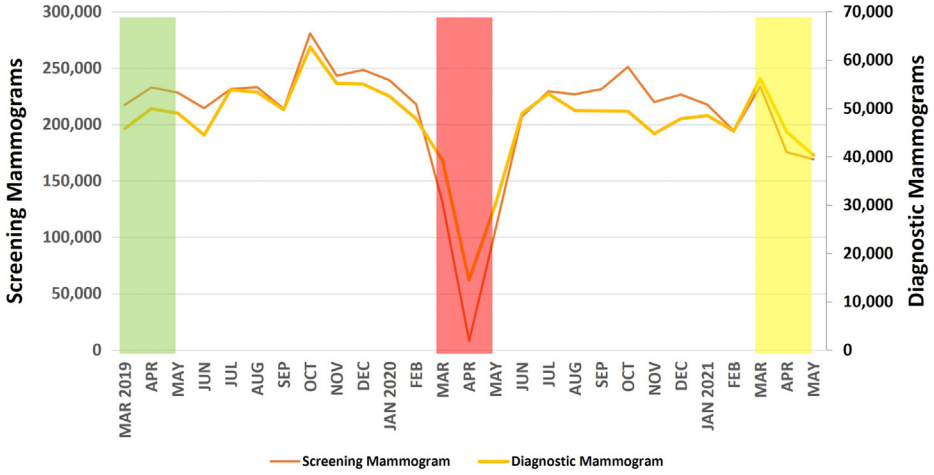

Fig. 1. Monthly volume of screening and diagnostic mammographic examinations from the National Mammography Database from March 1, 2019, through May 31, 2021. The green, red, and yellow boxes refer to the 3-month-long pre-COVID-19, peak COVID-19, and COVID-19 recovery periods, respectively, used for analysis. COVID-19 = coronavirus disease 2019.

statistical significance; comparisons with fewer than 10,000 encounters used an α value of 0.05. Alpha was not further adjusted to account for the number of comparisons. Results are presented as numbers, medians, and interquartile ranges.

RESULTS

Overall Study Population and Metrics

There were 5,633,783 screening mammographic studies, 1,282,374 diagnostic mammographic studies, 231,390 biopsies, and 69,657 cancer diagnoses reported from March 1, 2019, through May 31, 2021. A breakdown by patient and facility demographics over the entire study period is reported in Table 1. The greatest decrease in volume during the peak COVID-19 period was for screening mammography (36.3% of pre-COVID-19), and the smallest decrease in volumes was for diagnostic mammography (57.9% of pre-COVID-19), followed by biopsies (47.3% of pre-COVID-19) and cancer diagnoses (48.7% of pre-COVID-19). Similarly, the rebound during the COVID-19 recovery period was weakest for screening mammography (85.3% of pre-COVID-19) and greatest for diagnostic mammography (97.8% of pre-COVID-19), followed by biopsies (91.5% of pre-COVID-19) and cancer diagnoses (92.0% of pre-COVID-19). A graphical representation of the outcome metrics over time is shown in Figures 1 and 2.

Screening Mammography

The volume of screening mammographic examinations during the peak COVID-19 period (246,610 studies) was

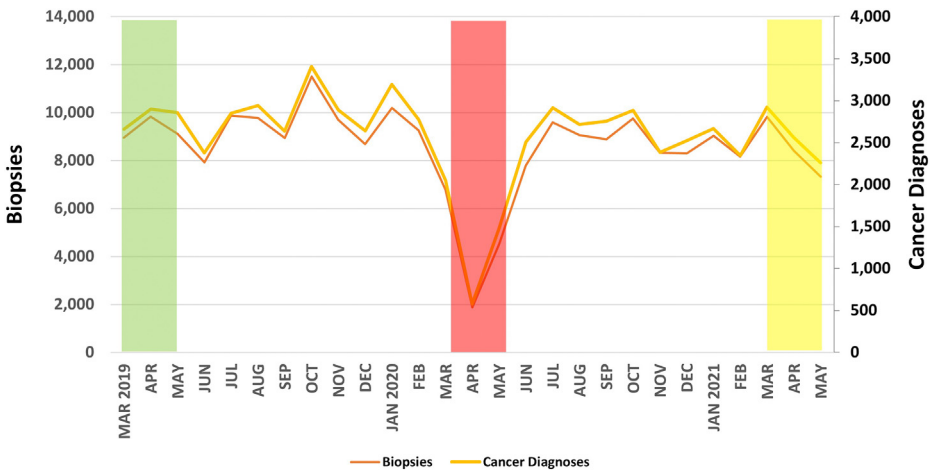

Fig. 2. Monthly volume of biopsies performed and cancer diagnoses from the National Mammography Database from March 1, 2019, through May 31, 2021. The green, red, and yellow boxes refer to the 3-month-long pre-COVID-19, peak COVID-19, and COVID-19 recovery periods, respectively, used for analysis. COVID-19 = coronavirus disease 2019.

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Table 2. Changes in screening mammography quarterly volumes in the pre-COVID-19, peak COVID-19, and COVID-19 recovery periods by patient and facility demographics

	Pre-COVID-19		Peak COVID-19		COVID-19 Recovery		Pre-COVID-19 vs Peak COVID-19		Peak COVID-19 vs COVID-19 Recovery		Pre-COVID-19 vs COVID-19 Recovery	
Dimension	Facility Median (IQR)	Total n	Facility Median (IQR)	Total n	Facility Median (IQR)	Total n	Facility *P* Value	Total Change %	Facility *P* Value	Total Change %	Facility *P* Value	Total Change %
Age group												
<40 y	14 (4-25)	7,922	5 (2-10)	2,936	11 (4-24)	7,055	**<0.001**	37.1	**<0.001**	240.3	0.172	89.1
40-49 y	247 (110-468)	142,207	88 (39-181)	52,377	242 (110-409)	128,369	**<0.001**	36.8	**<0.001**	245.1	0.131	90.3
50-59 y	329 (144-607)	189,226	119 (48-225)	68,741	272 (128-496)	158,123	**<0.001**	36.3	**<0.001**	230.0	0.017	83.6
60-69 y	334 (149-642)	194,679	109 (53-237)	70,686	279 (135-537)	163,760	**<0.001**	36.3	**<0.001**	231.7	0.017	84.1
70-79 y	192 (79-393)	117,886	67 (27-144)	43,181	164 (72-330)	101,003	**<0.001**	36.6	**<0.001**	233.9	0.021	85.7
≥80 y	43 (17-89)	26,969	11 (5-29)	8,689	30 (13-67)	20,526	**<0.001**	32.2	**<0.001**	236.2	**0.001**	76.1
Race												
Asian	0 (0-26)	14,705	0 (0-7)	4,181	0 (0-20)	10,664	**0.002**	28.4	**0.018**	255.1	0.2145	72.5
Black	2 (0-58)	32,163	0 (0-18)	10,627	1 (0-43)	24,717	**0.001**	33.0	**0.021**	232.6	0.157	76.8
Native American, Native Hawaiian or Pacific Islander	0 (0-4)	3,405	0 (0-1)	2,479	0 (0-4)	4,538	**<0.001**	72.8	**<0.001**	183.1	0.421	133.3
White	152 (0-862)	243,520	44 (0-262)	83,897	76 (0-663)	191,245	**<0.001**	34.5	**0.002**	228.0	0.123	78.5
Unknown	422 (84-1,209)	385,095	141 (23-478)	145,426	420 (71-1,079)	347,672	**<0.001**	37.8	**<0.001**	239.1	0.189	90.3
Community type												
Metropolitan (>100,000 persons)	1,839 (805-3,218)	397,037	646 (222-1,235)	144,170	1,539 (729-2,904)	347,318	**<0.001**	36.3	**<0.001**	240.9	0.124	87.5
Suburban/small (50,000-100,000 persons)	1,213 (766-1,905)	226,200	432 (234-694)	77,598	990 (589-1,544)	180,933	**<0.001**	34.3	**<0.001**	233.2	0.010	80.0
Rural (<50,000 persons)	391 (139-939)	55,653	167 (71-423)	24,842	323 (160-748)	50,585	**<0.001**	44.6	**<0.001**	203.6	0.454	90.9

(continued)

Table 2. Continued

Dimension	Pre-COVID-19		Peak COVID-19		COVID-19 Recovery		Pre-COVID-19 vs Peak COVID-19		Peak COVID-19 vs COVID-19 Recovery		Pre-COVID-19 vs COVID-19 Recovery	
	Facility Median (IQR)	Total n	Facility Median (IQR)	Total n	Facility Median (IQR)	Total n	Facility *P* Value	Total Change %	Facility *P* Value	Total Change %	Facility *P* Value	Total Change %
Facility type												
Academic/ university	1,475 (719-3,841)	73,164	510 (243-1,287)	22,231	1,221 (667-2,507)	58,027	**<0.001**	30.4	**0.002**	261.0	0.188	79.3
Community hospital	1,290 (402-2,227)	286,548	410 (133-796)	102,767	820 (239-1,881)	231,914	**<0.001**	35.9	**<0.001**	225.7	0.028	80.9
Multispecialty clinic	835 (450-2,022)	46,341	264 (135-657)	15,954	781 (492-1,504)	43,143	**<0.001**	34.4	**<0.001**	270.4	0.451	93.1
Freestanding imaging center	1,183 (627-2,093)	252,863	457 (213-778)	97,591	1,148 (677-1,794)	224,701	**<0.001**	38.6	**<0.001**	230.2	0.233	88.9
Region												
Northeast	1,209 (516-1,780)	162,705	378 (167-601)	50,486	955 (446-1,575)	138,814	**<0.001**	31.0	**<0.001**	275.0	0.076	85.3
Midwest	997 (584-2,185)	172,423	342 (175-691)	59,834	852 (465-1,769)	140,220	**<0.001**	34.7	**<0.001**	234.3	0.084	81.3
South	1,260 (563-2,379)	160,976	602 (221-987)	67,588	1,193 (602-2,009)	137,475	**<0.001**	42.0	**<0.001**	203.4	0.254	85.4
West	1,281 (462-2,888)	182,786	488 (151-1,192)	68,702	1,164 (324-2,271)	162,327	**<0.001**	37.6	**<0.001**	236.3	0.222	88.8

Note: Facility refers to the median and IQR for facilities. Total refers to the total reported at all facilities. Facility *P* value compares the metrics at the facility level. Statistical significance was defined as a *P* value of .01 for encounters greater than 10,000 and .05 for encounters less than 10,000. Statistically significant values are in boldface type. Total change refers to the second comparator group divided by the first comparator group as a percentage. COVID-19 = coronavirus disease 2019; IQR = interquartile range.

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Table 3. Changes in diagnostic mammography quarterly volumes in the pre-COVID-19, peak COVID-19, and COVID-19 recovery periods by patient and facility demographics

	Pre-COVID-19		Peak COVID-19		COVID-19 Recovery		Pre-COVID-19 vs Peak COVID-19		Peak COVID-19 vs COVID-19 Recovery		Pre-COVID-19 vs COVID-19 Recovery	
Dimension	Facility Median (IQR)	Total n	Facility Median (IQR)	Total n	Facility Median (IQR)	Total n	Facility *P* Value	Total Change %	Facility *P* Value	Total Change %	Facility *P* Value	Total Change %
Age group												
<40 y	7 (0-44)	15,062	6 (0-34)	9,952	11 (0-45)	15,056	0.107	66.1	0.019	151.3	0.236	100.0
40-49 y	30 (1-104)	35,981	20 (0-75)	21,434	35 (1-118)	37,240	0.023	59.6	**0.002**	173.7	0.214	103.5
50-59 y	30 (1-95)	34,765	19 (0-60)	19,772	35 (1-96)	33,087	**0.007**	56.9	**0.003**	167.3	0.411	95.2
60-69 y	28 (0-91)	32,216	17 (0-58)	18,145	32 (2-93)	30,647	**0.009**	56.3	**0.001**	168.9	0.296	95.1
70-79 y	17 (0-64)	20,964	10 (0-38)	11,624	18 (1-57)	20,042	**0.004**	55.4	**0.001**	172.4	0.409	95.6
≥80 y	4 (0-17)	5,866	2 (0-9)	2,988	5 (0-16)	5,615	**0.001**	50.9	**<0.001**	187.9	0.339	95.7
Race												
Asian	0 (0-0)	2,563	0 (0-0)	1,155	0 (0-0)	2,176	0.265	45.1	0.411	188.4	0.342	84.9
Black	0 (0-4)	5,241	0 (0-2)	2,848	0 (0-4)	4,496	0.202	54.3	0.141	157.9	0.406	85.8
Native American, Native Hawaiian, or Pacific Islander	0 (0-0)	598	0 (0-0)	518	0 (0-0)	653	**0.014**	86.6	0.180	126.1	0.105	109.2
White	0 (0-113)	43,546	0 (0-57)	24,621	0 (0-81)	36,543	0.125	56.5	0.325	148.4	0.246	83.9
Unknown	35 (0-197)	92,907	21 (0-156)	54,773	40 (0-245)	97,818	0.041	59.0	**0.008**	178.6	0.233	105.3
Community type												
Metropolitan (>100,000 persons)	276 (9-874)	99,039	178 (4-526)	52,650	303 (58-864)	94,817	**0.009**	53.2	**0.009**	180.1	0.483	95.7
Suburban/small (50,000-100,000 persons)	97 (0-256)	35,065	70 (0-180)	23,219	125 (0-285)	36,169	0.078	66.2	0.027	155.8	0.301	103.1
Rural (<50,000 persons)	40 (15-171)	10,751	36 (13-138)	8,046	54 (11-167)	10,701	0.258	74.8	0.156	133.0	0.352	99.5
Facility type												
Academic/ university	275 (0-1,267)	18,618	223 (0-660)	10,256	350 (0-988)	17,277	0.142	55.1	0.179	168.5	0.470	92.8

(continued)

Table 3. Continued

Dimension	Pre-COVID-19		Peak COVID-19		COVID-19 Recovery		Pre-COVID-19 vs Peak COVID-19		Peak COVID-19 vs COVID-19 Recovery		Pre-COVID-19 vs COVID-19 Recovery	
	Facility Median (IQR)	Total n	Facility Median (IQR)	Total n	Facility Median (IQR)	Total n	Facility *P* Value	Total Change %	Facility *P* Value	Total Change %	Facility *P* Value	Total Change %
Community hospital	150 (30-385)	56,929	97 (25-271)	34,632	155 (39-389)	57,305	0.049	60.8	**0.007**	165.5	0.248	100.7
Multispecialty clinic	1 (0-182)	5,098	1 (0-153)	4,193	0 (0-117)	5,832	0.365	82.2	0.377	139.1	0.251	114.4
Freestanding imaging center	155 (0-376)	60,146	90 (0-260)	33,950	176 (0-407)	59,554	0.050	56.4	0.024	175.4	0.389	99.0
Region												
Northeast	137 (0-368)	31,526	65 (0-181)	17,194	174 (20-399)	32,166	0.067	54.5	**0.003**	187.1	0.172	102.0
Midwest	86 (0-255)	26,799	48 (0-178)	17,579	72 (0-254)	25,637	0.118	65.6	0.183	145.8	0.402	95.7
South	172 (2-594)	38,841	157 (1-406)	23,280	213 (1-603)	34,729	0.122	59.9	0.108	149.2	0.472	89.4
West	157 (24-590)	47,689	111 (28-431)	25,862	218 (37-606)	49,155	0.185	54.2	0.108	190.1	0.381	103.1

Note: Facility refers to the median and IQR for facilities. Total refers to the total reported at all facilities. Facility *P* value compares the metrics at the facility level. Statistical significance was defined as a *P* value of .01 for encounters greater than 10,000 and .05 for encounters less than 10,000. Statistically significant values are in boldface type. Total change refers to the second comparator group divided by the first comparator group as a percentage. COVID-19 = coronavirus disease 2019; IQR = interquartile range.

36.3% of the pre-COVID-19 period (678,890 studies; Figure 1). During the nadir of the peak COVID-19 period in April 2020, screening mammography volume was 3.7% (8,403 studies) of the monthly average during the pre-COVID-19 period (226,297 studies). As shown in Table 2, the greatest decreases were seen for women aged 80 years or older (32.2% of pre-COVID-19), Asian women (28.4% of pre-COVID-19), and facilities in suburban communities (34.3% of pre-COVID-19), with academic or university affiliations (30.4% of pre-COVID-19), and in the Northeast (31.0% of pre-COVID-19). At the facility level, there were statistically significant decreases ($P < .01$) for all demographics studied.

During the COVID-19 recovery period, screening mammography volume (578,836 studies) rebounded to 85.3% of the pre-COVID-19 level (678,890 studies; Figure 1). The smallest rebounds were for women aged 80 years or older (76.1% of pre-COVID-19, $P = .001$), Asian women (72.5% of pre-COVID-19), and facilities in suburban communities (80.0% of pre-COVID-19), with academic or university affiliations (79.3% of pre-COVID-19), and in the Midwest (81.3% of pre-COVID-19).

Diagnostic Mammography

The volume of diagnostic mammographic examinations during the peak COVID-19 period (83,915 studies) was 57.9% of the pre-COVID-19 period (144,855 studies, Figure 1). During the nadir of the peak COVID-19 period in April 2020, diagnostic mammography volume was 30.2% (14,586 studies) of the monthly average in the pre-COVID-19 period (48,285 studies). As shown in Table 3, the greatest decreases were seen for women aged 80 years and older (50.9% of pre-COVID-19), Asian women (45.1% of pre-COVID-19), and facilities in metropolitan communities (53.2% of pre-COVID-19), with academic or university affiliations (55.1% of pre-COVID-19), and in the West (54.2% of pre-COVID-19). At the facility level, there were statistically significant decreases for all age groups 50 years and older ($P < .01$ for all); Native American, Native Hawaiian, or Pacific Islander women ($P = .014$); and facilities in metropolitan communities ($P = .009$), as shown in Table 2. There was a significant linear decrease in diagnostic mammographic examinations with increasing age decade ($R^2 = 0.88$, $P = .005$; Figure 3).

During the COVID-19 recovery, diagnostic mammography volume (141,687 studies) rebounded to 97.8% of the pre-COVID-19 level (144,855 studies; Figure 1). The smallest rebounds were for women aged 60 to 69 years (95.1% of pre-COVID-19), white women (83.9% of pre-COVID-19), and facilities in metropolitan communities (95.7% of pre-COVID-19), with academic or university affiliations (92.8% of pre-COVID-19), and in the South (89.4% of pre-COVID-19). There were no significant differences in the pre-COVID-19 versus COVID-19 recovery period diagnostic volumes for the demographics studied.

Biopsies

The volume of biopsies during the peak COVID-19 period (13,191 biopsies) was 47.3% of the pre-COVID-19 period (27,907 biopsies; Figure 2). During the nadir of the peak COVID-19 period in April 2020, the biopsy volume was 20.1% (1,876 biopsies) of the monthly average in the pre-COVID-19 period (9,302 biopsies). As shown in Table 4, the largest declines were seen for women aged 50 to 59 and 60 to 69 years (45.2% of pre-COVID-19 for both),

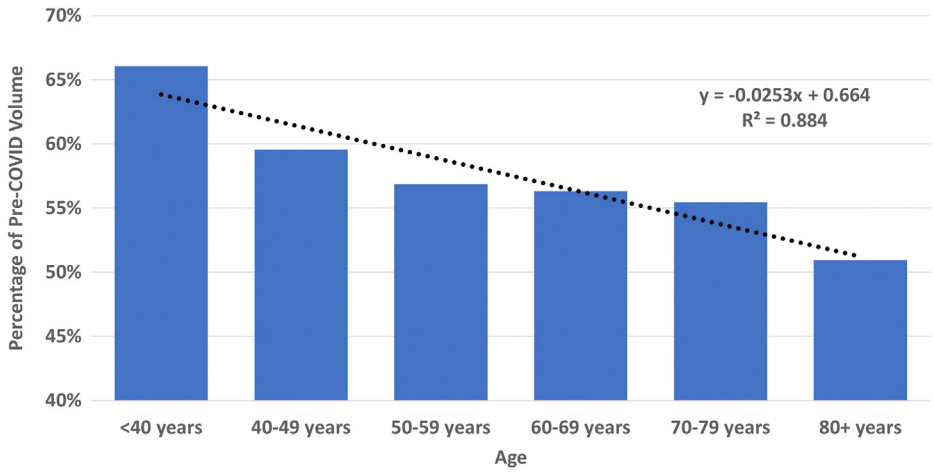

Fig. 3. Percentage of diagnostic mammographic examinations during the peak COVID-19 versus the pre-COVID-19 period by age decade with fitted trend line. COVID-19 = coronavirus disease 2019.

Table 4. Changes in biopsy quarterly volumes in the pre-COVID-19, peak COVID-19, and COVID-19 recovery periods by patient and facility demographics

	Pre-COVID-19		Peak COVID-19		COVID-19 Recovery		Pre-COVID-19 vs Peak COVID-19		Peak COVID-19 vs COVID-19 Recovery		Pre-COVID-19 vs COVID-19 Recovery	
Dimension	Facility Median (IQR)	Total n	Facility Median (IQR)	Total n	Facility Median (IQR)	Total n	Facility *P* Value	Total Change %	Facility *P* Value	Total Change %	Facility *P* Value	Total Change %
Age												
<40 y	1 (0-4)	1,676	0 (0-3)	1,148	1 (0-4)	1,611	**0.024**	68.5	**0.021**	140.3	0.469	96.1
40-49 y	6 (1-20)	6,715	3 (0-11)	3,198	7 (1-19)	6,527	**<0.001**	47.6	**<0.001**	204.1	0.477	97.2
50-59 y	6 (1-21)	6,950	3 (0-10)	3,143	6 (1-16)	6,061	**<0.001**	45.2	**<0.001**	192.8	0.158	87.2
60-69 y	7 (2-23)	6,936	3 (0-10)	3,133	7 (2-18)	6,245	**<0.001**	45.2	**<0.001**	199.3	0.279	90.0
70-79 y	4 (0-14)	4,462	2 (0-6)	2,021	4 (0-12)	4,056	**<0.001**	45.3	**<0.001**	200.7	0.143	90.9
≥80+ y	1 (0-4)	1,168	0 (0-2)	548	1 (0-3)	1,047	**<0.001**	46.9	**<0.001**	191.1	0.076	89.6
Race												
Asian	0 (0-0)	662	0 (0-0)	286	0 (0-0)	537	**0.006**	43.2	**0.011**	187.8	0.405	81.1
Black	0 (0-1)	1,078	0 (0-0)	573	0 (0-1)	930	**0.001**	53.2	**0.009**	162.3	0.261	86.3
Native American, Native Hawaiian, or Pacific Islander	0 (0-0)	122	0 (0-0)	84	0 (0-0)	143	**0.003**	68.9	**0.002**	170.2	0.439	117.2
White	2 (0-28)	9,736	0 (0-10)	4,247	2 (0-18)	7,350	**0.002**	43.6	**0.017**	173.1	0.208	75.5
Unknown	9 (1-37)	16,309	4 (0-20)	8,001	9 (0-41)	16,587	**<0.001**	49.1	**<0.001**	207.3	0.360	101.7
Community type												
Metropolitan (>100,000 persons)	54 (13-155)	17,393	24 (5-79)	8,262	48 (14-146)	16,382	**<0.001**	47.5	**<0.001**	198.3	0.362	94.2
Suburban/small (50,000-100,000 persons)	29 (7-60)	8,414	11 (2-30)	3,698	26 (9-58)	7,446	**<0.001**	44.0	**<0.001**	201.4	0.426	88.5
Rural (<50,000 persons)	5 (0-26)	2,100	4 (0-16)	1,231	6 (0-24)	1,719	0.122	58.6	0.218	139.6	0.340	81.9
Facility type												
Academic/ university	91 (17-260)	4,095	43 (5-111)	1,847	56 (9-205)	3,231	**0.012**	45.1	0.094	174.9	0.147	78.9

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Community hospital	30 (4-73)	11,248	15 (2-39)	5,564	24 (4-68)	10,348	**0.002**	49.5	0.015	186.0	0.226	92.0
Multispecialty clinic	10 (2-51)	1,344	1 (0-34)	676	10 (4-40)	1,554	**0.030**	50.3	**0.021**	229.9	0.356	115.6
Freestanding imaging center	26 (8-74)	10,396	11 (4-34)	4,853	26 (10-71)	9,830	**<0.001**	46.7	**<0.001**	202.6	0.375	94.6
Region												
Northeast	24 (4-76)	6,809	9 (1-30)	2,649	24 (9-59)	5,550	**0.003**	38.9	**<0.001**	209.5	0.495	81.5
Midwest	19 (7-71)	6,277	9 (1-27)	2,783	19 (6-51)	5,450	**<0.001**	44.3	**<0.001**	195.8	0.186	86.8
South	28 (8-107)	6,860	11 (3-63)	3,444	32 (8-96)	6,192	**0.008**	50.2	**0.014**	179.8	0.458	90.3
West	37 (8-116)	7,961	27 (7-66)	4,315	36 (7-118)	8,355	0.095	54.2	0.105	193.6	0.486	104.9

Note: Facility refers to the median and IQR for facilities. Total refers to the total reported at all facilities. Facility P value compares the metrics at the facility level. Statistical significance was defined as a P value of .01 for encounters greater than 10,000 and .05 for encounters less than 10,000. Statistically significant values are in boldface type. Total change refers to the second comparator group divided by the first comparator group as a percentage. COVID-19 = coronavirus disease 2019; IQR = interquartile range.

Asian women (43.2% of pre-COVID-19), and facilities in suburban communities (44.0% of pre-COVID-19), with academic or university affiliations (45.1% of pre-COVID-19), and in the Northeast (38.9% of pre-COVID-19). At the facility level, there were statistically significant decreases ($P < .01$) for all demographics except for facilities in rural communities ($P = .122$) and in the West ($P = .095$).

During the COVID-19 recovery, biopsy volume (25,547 biopsies) rebounded to 91.5% of the pre-COVID-19 level (27,907 biopsies; Figure 1). The smallest rebounds were for women aged 60 to 69 years (90.0% of pre-COVID-19), white women (75.5% of pre-COVID-19), and facilities in rural communities (81.9% of pre-COVID-19), with academic or university affiliations (78.9% of pre-COVID-19), and in the Northeast (81.5% of pre-COVID-19). There were no significant differences in the pre-COVID-19 versus COVID-19 recovery period diagnostic volumes for the demographics studied.

Cancer Diagnoses

The volume of cancer diagnoses during the peak COVID-19 period (4,101 cancers) was 48.7% of the pre-COVID-19 period (8,413 cancers; Figure 2). During the nadir of the peak COVID-19 period in April 2020, the cancer diagnosis volume was 20.5% (576 cancers) of the monthly average in the pre-COVID-19 period (2,804 cancers). As shown in Table 5, the greatest decreases were seen for women aged 60 to 69 years (46.3% of pre-COVID-19), Asian women (35.5% of pre-COVID-19), and facilities in suburban communities (45.2% of pre-COVID-19), with academic or university affiliations (45.4% of pre-COVID-19), and in the Northeast (39.7% of pre-COVID-19). At the facility level, there were statistically significant decreases ($P < .05$) for all demographics except age < 40 years ($P = .245$); Asian race ($P = .069$); Native American, Native Hawaiian, or Pacific Islander race ($P = .154$); rural location ($P = .054$); and location in the West ($P = .095$).

During the COVID-19 recovery, cancer diagnoses (7,740 cancers) rebounded to 92.0% of the pre-COVID-19 level (8,413 cancers; Figure 2). The smallest rebounds were for women aged 50 to 59 years (85.5% of pre-COVID-19), Asian women (72.0% of pre-COVID-19), and facilities in rural communities (79.1% of pre-COVID-19), with academic or university affiliations (82.4% of pre-COVID-19), and in the Northeast (76.9% of pre-COVID-19). There were no significant differences in the pre-COVID-19 versus COVID-19 recovery period diagnostic volumes for the demographics studied. The monthly average of breast cancers diagnosed from March 2019 to February 2020 was 2,843 cancers. The cumulative cancer deficit (ie, monthly average from preceding year minus cancer diagnoses per month

Table 5. Changes in cancer quarterly volumes in the pre-COVID-19, peak COVID-19, and COVID-19 recovery periods by patient and facility demographics

	Pre-COVID-19		Peak COVID-19		COVID-19 Recovery		Pre-COVID-19 vs Peak COVID-19		Peak COVID-19 vs COVID-19 Recovery		Pre-COVID-19 vs COVID-19 Recovery	
Dimension	Facility Median (IQR)	Total n	Facility Median (IQR)	Total n	Facility Median (IQR)	Total n	Facility *P* Value	Total Change %	Facility *P* Value	Total Change %	Facility *P* Value	Total Change %
Age												
<40 y	0 (0-0)	199	0 (0-0)	189	0 (0-0)	200	0.245	95.0	0.424	105.8	0.315	100.5
40-49 y	1 (0-3)	1,079	0 (0-2)	558	1 (0-3)	1,047	**<0.001**	51.7	**<0.001**	187.6	0.397	97.0
50-59 y	2 (0-5)	1,888	1 (0-3)	894	1 (0-5)	1,614	**<0.001**	47.4	**0.001**	180.5	0.103	85.5
60-69 y	3 (0-9)	2,633	1 (0-4)	1,219	2 (0-8)	2,428	**<0.001**	46.3	**<0.001**	199.2	0.193	92.2
70-79 y	2 (0-6)	1,958	1 (0-3)	929	1 (0-5)	1,868	**<0.001**	47.4	**<0.001**	201.1	0.126	95.4
≥80 y	0 (0-2)	656	0 (0-1)	312	0 (0-2)	583	**<0.001**	47.6	**0.001**	186.9	0.118	88.9
Race												
Asian	0 (0-0)	211	0 (0-0)	75	0 (0-0)	152	0.069	35.5	0.344	202.7	0.144	72.0
Black	0 (0-0)	303	0 (0-0)	176	0 (0-0)	257	**0.018**	58.1	0.098	146.0	0.211	84.8
Native American, Native Hawaiian, or Pacific Islander	0 (0-0)	34	0 (0-0)	20	0 (0-0)	34	0.154	58.8	**0.015**	170.0	0.121	100.0
White	0 (0-9)	3,103	0 (0-3)	1,354	0 (0-5)	2,496	**<0.001**	43.6	**0.011**	184.3	0.107	80.4
Unknown	3 (0-12)	4,762	1 (0-6)	2,476	2 (0-12)	4,801	**<0.001**	52.0	**<0.001**	193.9	0.277	100.8
Community type												
Metropolitan (>100,000 persons)	17 (5-48)	5,277	8 (1-27)	2,653	12 (4-48)	5,011	**<0.001**	50.3	**<0.001**	188.9	0.297	95.0
Suburban/small (50,000-100,000 persons)	9 (3-20)	2,503	3 (0-9)	1,131	9 (2-19)	2,228	**<0.001**	45.2	**<0.001**	197.0	0.270	89.0
Rural (<50,000 persons)	2 (0-11)	633	1 (0-4)	317	1 (0-8)	501	0.054	50.1	0.243	158.0	0.205	79.1
Facility type												
Academic/ university	22 (6-78)	1,256	13 (2-31)	570	16 (3-55)	1,035	**0.032**	45.4	0.147	181.6	0.248	82.4
Community hospital	10 (1-27)	3,422	4 (0-14)	1,681	8 (1-25)	3,101	**<0.001**	49.1	**0.019**	184.5	0.158	90.6

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Multispecialty clinic	3 (0-17)	420	0 (0-8)	212	4 (1-11)	533	**0.014**	50.5	**0.009**	251.4	0.402	126.9
Freestanding imaging center	8 (2-22)	3,110	3 (1-11)	1,565	9 (2-21)	2,970	**<0.001**	50.3	**<0.001**	189.8	0.334	95.5
Region												
Northeast	9 (1-20)	1,943	2 (0-9)	771	7 (1-16)	1,494	**<0.001**	39.7	**0.004**	193.8	0.228	76.9
Midwest	8 (2-26)	2,217	3 (0-10)	988	6 (2-23)	1,969	**<0.001**	44.6	**<0.001**	199.3	0.192	88.8
South	9 (2-25)	1,911	4 (1-20)	1,019	9 (1-35)	1,736	**0.013**	53.3	**0.025**	170.4	0.447	90.8
West	8 (2-41)	2,342	5 (1-23)	1,323	11 (0-42)	2,541	0.095	56.5	0.149	192.1	0.437	108.5

Note: Facility refers to the median and IQR for facilities. Total refers to the total reported at all facilities. Facility *P* value compares the metrics at the facility level. Statistical significance was defined as a *P* value of .01 for encounters greater than 10,000 and .05 for encounters less than 10,000. Statistically significant values are in boldface type. Total change refers to the second comparator group divided by the first comparator group as a percentage. COVID-19 = coronavirus disease 2019; IQR = interquartile range.

in current year) accumulated from the peak COVID-19 to the COVID-19 recovery period was 7,113 cancers, as shown in Figure 4.

DISCUSSION

These results from the NMD provide the broadest and largest analysis in the United States of the impact of the COVID-19 pandemic on breast cancer screening outcomes both during the peak of the pandemic and in the subsequent (rebound) year. The COVID-19 pandemic resulted in acute and pronounced declines for all breast imaging metrics studied during the peak COVID-19 period, but the effect was greatest for screening mammography (36.3% of pre-COVID-19). The decrease in screening mammography followed federal guidelines to postpone screening services, and similar results have been reported using regional and smaller national data sets [2,5,6]. However, there is a paucity of longer follow-up data to document changes in patient behaviors and the seasonality associated with health maintenance examinations [5,6,16]. Our data collected 1 year after the acute phase of the pandemic, during the COVID-19 recovery period, demonstrate that screening mammography volumes (85.3% of pre-COVID-19) continued to lag behind all other breast imaging metrics studied (range, 91.5%-97.8% of pre-COVID-19), and this was exaggerated for women aged 80 years and older (76.1% of pre-COVID-19). The persistent failure to return to regular screening intervals has also been reproduced in colon and cervical cancer screening [16]. If volumes do not normalize, screening mammography will remain underused among asymptomatic women. Strategies to facilitate safe breast imaging have been developed, but radiologists will need to develop outreach efforts, especially at the local level, directed toward patients and ordering providers on the importance of screening mammography in order to improve utilization rates [10,11].

As expected, there was an acute decrease in breast cancer diagnoses during the peak COVID-19 period. But although cancer diagnoses largely rebounded (92.0% of pre-COVID-19). This is especially worrying as cancer diagnoses have not reached pre-COVID-19 levels, and the cumulative breast cancer deficit since the start of the pandemic continues to grow (Fig. 4). This rebound represents a mix of cancers not diagnosed during the peak COVID-19 period as well as the normal cancers detected through routine practice. There are major concerns that in the near future, depending on the lead time of breast cancer, there will be an increase in cancer diagnoses and that a larger proportion of breast cancers will be diagnosed at a higher stage and thus have a worse prognosis. Analysis of Breast Cancer Surveillance Consortium data demonstrates that decreases in cancer diagnoses were due

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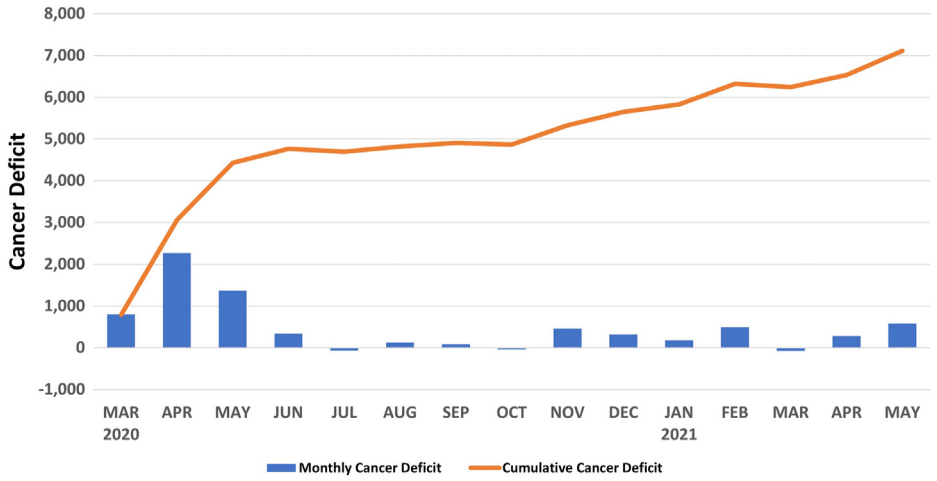

Fig. 4. Monthly and cumulative cancer deficits from March 2020 to May 2021 on the basis of the average monthly cancer diagnoses from March 2019 to February 2020.

largely to fewer screen-detected cancers [3]. The NMD unfortunately does not include tumor staging information to assess clinical outcomes and prognosis. To date, one study from Italy has demonstrated that a 2-month pause in mammographic screening resulted in an 11% increase in node-positive breast cancer and a 10% increase in stage III breast cancer [17]. Similarly, an increase in stage III breast cancer (8.4% pre-COVID-19 vs 23.8% post-COVID-19) and systemic first-line chemotherapy (23.0% pre-COVID-19 vs 36.5% post-COVID-19) have been reported in South Korea [18]. Longer term modeling studies all report an increase in poor outcomes, including life years lost, excess breast cancer deaths, and treatment morbidity [4,19,20]. Although there are differences in the modeling estimates on the basis of assumptions around screening practices (ie, annual vs biennial, screening utilization rates), a key unknown is how quickly screening practices will normalize. Our results indicate that screening practices may take much longer to normalize than previously hypothesized and that models will need to be adjusted for the persistent decline. Given the latency of breast cancer diagnosis and mortality as well as the persistent reduction in breast cancer screening practices currently, it may be several years before these results are fully realized.

There were notable differences in the reported breast cancer metrics on the basis of patient demographics. Compared with all other racial groups, Asian women had the largest decrease in screening mammography, diagnostic mammography, and cancer diagnoses during peak COVID-19 and experienced the smallest rebound in screening mammography and cancer diagnoses during COVID-19 recovery. Published literature examining the impact of the pandemic on breast cancer screening for different racial and ethnic groups is very mixed; however, there are examples of the disproportionate impact on Asian women, with studies demonstrating large decreases in screening mammography volumes [5,7,21] and fewer breast cancer diagnoses, similar to our findings [3]. Similar patterns for Asian women have been noted for other screening services, including cervical cancer [7]. Much of the focus on race/ethnicity in breast cancer screening outreach efforts unrelated to the pandemic has been directed toward black women because of their high rates of breast cancer and generally worse outcomes [22]. But our results suggest that outreach efforts directed toward the Asian community are important as well. These efforts could include engaging with local community organizations, disaggregating the impact of COVID-19 on specific Asian populations, especially immigrant groups, and identifying any underlying cultural barriers to returning for routine care [23]. Finally, there were greater decreases and more limited recovery across most breast cancer metrics for elderly women. COVID-19 had a disproportionate impact on elderly patients, especially minority elderly patients, with higher rates of death and severe infection from COVID-19 as well as an increased risk for neglect, loss of social support networks, and economic hardships [24-26]. Outreach efforts and reestablishing support networks are critical to meet the needs of this patient population, who are at the highest risk for developing breast cancer.

The early phase of the COVID-19 pandemic had an unequal geographic distribution, which is reflected in the outcome differences by facility demographics [27]. Facilities in the Northeast had the largest decrease in all metrics during the peak COVID-19 period and continued to have the smallest rebound in breast biopsies and cancer diagnoses during the COVID-19 recovery period. This may reflect the very large numbers of COVID-19 cases in metropolitan areas

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such as New York City [27]. The impact of breast imaging metrics on community type is mixed. Suburban and metropolitan facilities had larger decreases across all metrics during the peak COVID-19 period, which likely reflects the initial spread of disease in denser population centers. However, there were notably smaller rebounds in biopsies and cancer diagnoses in rural facilities during the COVID-19 recovery period, which likely reflects shifts in the spread of disease from urban to rural facilities [28,29]. Facilities affiliated with academic practices had the largest declines during peak COVID-19 and the smallest rebound during the COVID-19 recovery period for every breast cancer metric in our database. This may be due to a fear that academic centers were also treating many patients with COVID-19 and may be confounded by the higher concentration of academic facilities in metropolitan and suburban locations.

There were limitations to this study. Although the number of breast care encounters in the NMD is very large, which facilitates many subgroup analyses, some subgroups were still small. For example, measurements for women younger than 40 years and for Native American, Native Hawaiian, or Pacific Islander women have much wider confidence intervals. We compensated for this by adjusting our threshold for statistical significance on the basis of sample sizes. Additionally, a majority of patients have their race documented as "unknown" (58.9%), which is a limitation of NMD data entry. Data from the NMD are exported in aggregate, precluding multivariate analysis at the patient level, which would facilitate testing of confounding factors, especially for demographic subgroup analysis. Facilities have several months to report their metrics to the NMD, so data from late 2021 were not available for analysis. The NMD is also not linked with a tumor registry to allow assessment of tumor outcomes.

TAKE-HOME POINTS

- There were major decreases in screening mammography, diagnostic mammography, breast biopsies, and cancer diagnoses during the peak COVID-19 period, with a rapid rebound during the COVID-19 recovery period.
- COVID-19 had the greatest impact on screening mammography, and utilization rates have not returned to baseline, which may have long-term implications for breast cancer staging and outcomes.
- The acute deficits in breast cancer diagnoses during the peak COVID-19 period continued to increase in the following year.
- COVID-19 had a disproportionate effect on older women and Asian women for multiple breast cancer screening metrics during the peak COVID-19 and COVID-19 recovery periods.
- The impact of COVID-19 on facility demographics likely reflects differences in the temporal and geographic distribution of disease.

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