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Prioritizing breast imaging services during the COVID pandemic: A survey of breast imaging facilities within the Breast Cancer Surveillance Consortium

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ABSTRACT

The COVID-19 pandemic disrupted breast cancer screening and diagnostic imaging in the United States. We sought to evaluate how medical facilities prioritized breast imaging services during periods of reduced capacity or upon re-opening after closures. In fall 2020, we surveyed 77 breast imaging facilities within the Breast Cancer Surveillance Consortium in the United States. The survey ascertained the pandemic's impact on clinical practices during March–September 2020. Nearly all facilities (97%) reported closing or operating at reduced capacity at some point during this period. All facilities were open by August 2020, though 14% were still operating at reduced capacity in September 2020. During periods of re-opening or reduced capacity, 93% of facilities reported prioritizing diagnostic breast imaging over breast cancer screening. For diagnostic imaging, facilities prioritized based on rescheduling canceled appointments (89%), specific indication for diagnostic imaging (89%), patient demand (84%), individual characteristics and risk factors (77%), and time since last imaging examination (72%). For screening mammography, facilities prioritized based on rescheduled cancellations (96%), patient demand (83%), individual characteristics and risk factors (73%), and time since last mammogram (71%). For biopsy services, more than 90% of facilities reported prioritization based on rescheduling of canceled exams, patient demand, patient characteristics and risk factors and level of suspicion on imaging. The observed patterns from this large and geographically diverse sample of facilities in the United States indicate that multiple factors were commonly used to prioritize breast imaging services during periods of reduced capacity.

1. Introduction

Breast cancer screening and diagnostic imaging services were widely interrupted in the United States at the onset of the COVID-19 pandemic.

Nearly all states issued emergency executive orders barring elective medical procedures by April 2020 (Strategies, 2020). Mammography screening plummeted by more than 90% during April 2020 (EPIC Health Research Network, 2020b; Whaley et al., 2020; Yin et al., 2020), with

Abbreviations: BCSC, Breast Cancer Surveillance Consortium; CI, Confidence interval; MRI, Magnetic resonance imaging.

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diagnostic mammography down by as much as 80% (Norbash et al., 2020; Song et al., 2021). These impacts raised widespread concerns about delays in breast cancer diagnosis and adverse impacts on breast cancer mortality (Patt et al., 2020; Sharpless, 2020), underscoring the importance of resuming services as quickly as could be safely accomplished.

Breast imaging facilities faced significant challenges to resuming services, including the need to ensure patient, staff, and provider safety by developing new protocols to minimize exposures to and spread of COVID-19. Radiology professional societies published expert opinion best practice guidelines for resuming breast imaging services, including recommendations for personal protective equipment, social distancing, and COVID-19 screening (Davenport et al., 2020; RSNA COVID Task Force, 2020; Society of Breast Imaging, 2020; The COVID-19 Pandemic Breast Cancer Consortium, 2020). Given the concern that these initiatives would likely be associated with a reduced capacity to accommodate the usual volume of breast imaging services, the Society of Breast Imaging recommendations included guidelines for prioritizing breast imaging services. These ranged in order from most to least urgent, from treatment and biopsy related imaging, to diagnostic workup following prior abnormal imaging findings or patient-reported symptoms, to routine breast cancer screening (Society of Breast Imaging, 2020).

While various reports demonstrated that screening and diagnostic imaging use in the United States remained reduced throughout summer 2020 (EPIC Health Research Network, 2020a; Norbash et al., 2020; Song et al., 2021), direct evidence on breast imaging facility capacity and facility response to the pandemic is limited. We sought to evaluate how breast imaging facilities modified their breast imaging services during the pandemic, and particularly how facilities prioritized women for different types of breast imaging examinations during periods of limited capacity or upon re-opening after closures.

2. Methods

2.1. Study setting

The Breast Cancer Surveillance Consortium (BCSC) includes a network of breast imaging facilities in the United States that pool data for breast cancer research purposes via regional registries (Ballard-Barbash et al., 1997; Breast Cancer Surveillance Consortium, 2021; Sprague et al., 2020). Participating facilities are linked by their agreements to contribute data to the registries and to a central Statistical Coordinating Center; there are no efforts to coordinate clinical operations or policy through the BCSC. Seven BCSC registries were included in this study: Carolina Mammography Registry, Kaiser Permanente Washington, New Hampshire Mammography Network, Metropolitan Chicago Breast Cancer Registry, Sacramento Area Breast Imaging Registry, San Francisco Mammography Registry, and Vermont Breast Cancer Surveillance System. This study was approved by human subjects institutional review boards at each registry and the Statistical Coordinating Center, with a waiver of consent to collect and analyze facility-level information.

2.2. Data collection

Each registry invited their participating breast imaging facilities to complete a single electronic survey regarding their breast imaging practice during the pandemic to date. A total of 80 facilities were invited to participate, and 77 facilities completed the survey (response rate, 96.3%). Study data were collected and managed using REDCap electronic data capture tools (Harris et al., 2019; Harris et al., 2009). All surveys were completed between September 15, 2020 and November 17, 2020. A print version of the survey is provided in the Appendix.

All facilities were asked to report by month (March through September 2020) whether they had closed due to the pandemic, had operated at reduced capacity, and/or had operated at full capacity.

Facilities could choose all that applied; these response options were not mutually exclusive. Facilities that indicated periods of closure or reduced capacity were asked to report which specific imaging modalities were disrupted and how individuals were prioritized for breast cancer screening, diagnostic imaging, and breast biopsy services. All facilities were asked to report mechanisms of communicating with patients during the pandemic, changes to facility protocols to minimize COVID-19 spread (with 10 options to choose from, informed by expert opinion; Appendix), and whether same day interpretation of screening mammograms or same day biopsy for individuals with abnormal diagnostic imaging were offered before and during the pandemic.

Facility characteristics were obtained from the BCSC database, which includes facility-reported information on practice type, academic affiliation, facility location, profit status, and annual screening volume (Lee et al., 2016).

2.3. Data analyses

We described the distribution of facility characteristics. Description of COVID-19 facility survey responses for items on operational status (full capacity, limited capacity, closed) and changes to breast imaging services included all participating facilities. Description of survey items on prioritization of services were restricted to facilities who reported closing or operating at reduced capacity during some portion of the study period. Analyses were performed in SAS Version 9.4 (SAS Institute Inc., Cary, NC) and Stata 15.1 (StataCorp, College Station, TX).

3. Results

Of the 77 participating facilities, 22% were part of a multi-specialty breast center, 64% were full diagnostic radiology practices, and 12% were radiology practices limited to breast imaging only (Table 1). Approximately 18% were affiliated with an academic medical center, 52% were located in a hospital, and 68% were not-for-profit practices. Facility size varied widely, with 15% having an annual breast cancer screening volume less than 2000 examinations and 40% with 5000 examinations or more.

Seventy-five of the 77 facilities (97%) reported closing or operating

Table 1
Characteristics of 77 breast imaging facilities participating in the Breast Cancer Surveillance Consortium COVID-19 pandemic survey study.

	No.	% ^a
Practice type		
Multi-specialty breast center	17	22.1
Full diagnostic radiology practice	49	63.6
Radiology practice limited to breast imaging only	9	11.7
Non-radiology practice ^b	2	2.6
Academic affiliation		
No	63	81.8
Yes	14	18.2
Facility location		
Hospital	40	51.9
Office, not in hospital	35	45.5
Mobile van	1	1.3
Other	1	1.3
Profit status of practice		
Non-profit	49	68.1
For profit	23	31.9
Missing	5	(6.5)
Annual breast cancer screening volume		
<2000	10	14.7
2000 - 4999	31	45.6
≥5000	27	39.7
Not available	9	(11.7)

^a Percentage among non-missing responses. Where applicable, percent of responses missing or not available is given in parentheses.

^b Includes non-radiology clinics (e.g., Obstetrics and Gynecology) with mammography units.

at reduced capacity at some point during the study period. Only 14% of facilities operated at full capacity throughout March 2020, with less than 10% operating at full capacity in April and May 2020 (Fig. 1). While most facilities remained open throughout the study period, facility closures peaked in April 2020, with 26% of facilities reporting closing for at least some period of time during the month. All facilities had re-opened with at least some capacity for breast imaging services by August 2020. More than 70% of facilities operated at reduced capacity during March through May 2020. By September 2020, 86% of facilities were operating at full capacity, while 14% of facilities were still at reduced capacity. None of the facilities at reduced capacity in September 2020 had operated at full capacity since April 2020.

Facilities reported a wide variety of measures to reduce COVID-19 spread in their clinical settings (Table 2). All facilities completing this item on the survey (1 facility declined to respond) reported screening patients for COVID-19 symptoms onsite, required patients to wear masks, limited visitors accompanying patients, increased space between seating in waiting rooms, and had more frequent cleaning and sanitization of the facility and equipment. The remaining five response options were selected by more than 50% of facilities. Fourteen facilities reported additional other changes, including no longer taking walk-in appointments ($n = 6$), modifications to changing rooms and patient registration protocols ($n = 4$), employee COVID-19 screening ($n = 2$), plexiglass barriers at reception desks ($n = 1$), and the creation of additional waiting areas ($n = 1$).

A wide range of breast imaging services were affected across the 75 facilities that closed or operated at reduced capacity during the study period, (Table 3). Screening services were most commonly disrupted, with screening mammography, screening ultrasound, and screening MRI postponed or rescheduled due to the pandemic at more than 90% of facilities that offered these services. More than 50% of facilities reported that diagnostic imaging and biopsy services were disrupted. Phone calls were the most common mechanism (97%) used to inform patients of postponement and/or rescheduling of breast imaging services. Sixty percent of facilities reported offering same day interpretation of screening mammograms, and 70% offered same day biopsy for women with abnormal diagnostic imaging, compared to 64% and 71%, respectively, prior to the pandemic.

Among the 75 facilities that operated at reduced capacity or re-opened after closures, 93% prioritized diagnostic imaging over screening when re-opening after closures or during periods of reduced capacity (Table 3). In scheduling *diagnostic imaging*, facilities most commonly reported prioritization based on rescheduling of canceled

Table 2

Changes made to breast imaging service protocols to minimize COVID-19 spread during March–September 2020 among breast imaging facilities participating in the Breast Cancer Surveillance Consortium.

	N ^a	%
Safety measures to minimize COVID-19 spread		
Screen patients for COVID-19 symptoms onsite	76	100.0
Require patients to wear mask	76	100.0
Limit visitors accompanying patients	76	100.0
Increased space between seating in waiting rooms	76	100.0
Have more frequent cleaning and sanitization of facility and equipment	76	100.0
Pre-screen patients for COVID-19 symptoms via phone	73	96.1
Require hand sanitizing or washing when entering clinic	63	82.9
Use electronic instead of paper registration	62	81.6
Eliminated changing rooms and have patients change in procedure rooms	52	68.4
Remote check-in for patients, with call or text message when it is time to enter clinic	44	57.9
Other changes	14	18.4

^a One facility did not complete this item on the survey, resulting in a sample size of 76.

appointments and indication for exam (e.g., clinical symptoms vs. additional work-up vs. short-interval follow-up) (Table 4). Approximately 84% of facilities prioritized individuals who contacted the facility asking to schedule an appointment, and more than 70% of facilities reported considering individual characteristics, risk factors, and time since last imaging exam in prioritizing appointments for diagnostic breast imaging services. For biopsy services, more than 90% of facilities reported prioritization based on rescheduling of canceled exams, patient demand, patient characteristics and risk factors and level of suspicion on imaging (e.g., assessment category 5 vs. 4c vs. 4b vs. 4a).

For prioritizing *breast cancer screening* during periods of reduced capacity or re-opening after a closure, nearly all facilities (96%) reported rescheduling canceled appointments and 83% reported prioritizing individuals who contacted the facility to schedule an appointment. Patient characteristics and risk factors (73%) and time since last screening examination (71%) were also commonly reported.

4. Discussion

The results of our study indicate that nearly all breast imaging facilities experienced closures or periods of reduced capacity for breast imaging services during the initial months of the COVID-19 pandemic in

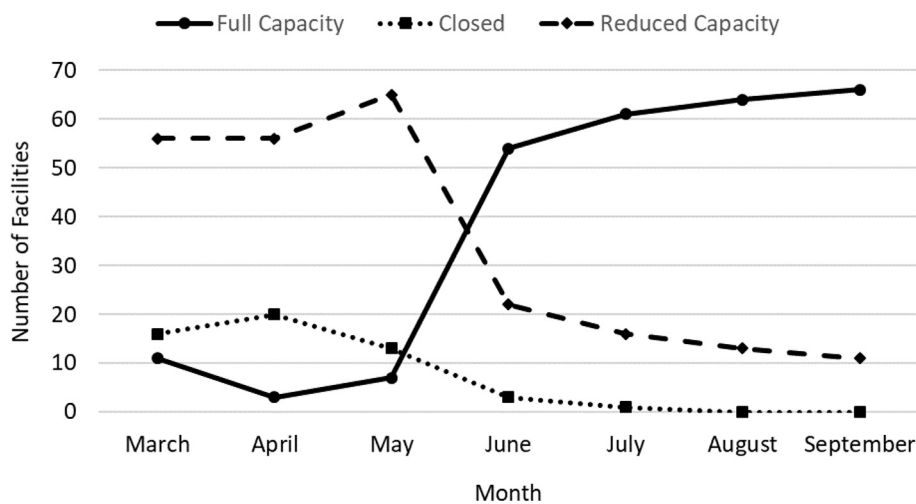


Fig. 1. Temporal trend in breast imaging facility operational status during March–September 2020 among 77 breast imaging facilities participating in the Breast Cancer Surveillance Consortium. Note that full capacity, closed, and reduced capacity status are not mutually exclusive; facilities could select all that apply during a given month.

Table 3
Impact of the COVID-19 pandemic on breast imaging services at facilities that had closed or operated at reduced capacity during March 2020–September 2020.

	N	%
Breast imaging services disrupted ^a		
Screening breast MRI	49/51	96.1
Screening mammography	64/69	92.8
Screening breast ultrasound	46/49	93.9
Diagnostic mammography for short-interval follow-up studies	42/64	65.6
Diagnostic breast MRI	33/52	63.5
Localizations	33/56	58.9
Core biopsies	34/58	58.6
Diagnostic mammography for symptomatic patients or additional evaluation of a recent mammogram	34/64	53.1
Diagnostic breast ultrasound	34/64	53.1
Modes of communication used to inform patients of postponement/rescheduling services		
Phone call	73/75	97.3
Electronic means (e.g., email, patient portal)	41/75	54.7
Mailed letter	36/75	48.0
Text message	33/75	44.0
Same day services offered		
Same day interpretation of screening mammograms	45/75	60.0
Same day biopsy for women with abnormal diagnostic imaging ^b	48/69	69.6
Diagnostic breast imaging prioritized over screening ^c	57/66	92.8

^a Number of facilities among those who offered the specified service(s) prior to the pandemic. Six facilities did not complete this item on the survey.

^b Item was not applicable for six facilities that did not perform diagnostic imaging and/or biopsy.

^c Item was not applicable for nine facilities that did not offer both screening and diagnostic imaging.

the United States. This is not surprising, given the need to preserve personal protective equipment in the early phase of the pandemic and to develop systems that could protect patients, staff, technologists, sonographers and radiologists. While breast imaging capacity appeared to rebound strongly by June 2020, approximately 1 in 7 facilities was still operating at reduced capacity in September 2020. During periods of reduced capacity or re-opening after closures, more than 90% of facilities reported prioritizing diagnostic breast imaging over screening, consistent with the greater urgency and high risk of cancer detection of diagnostic examinations. For diagnostic imaging, biopsies, and screening examinations, facilities primarily prioritized rescheduling canceled appointments, though facilities also considered other factors including individual characteristics and risk factors.

Our findings are consistent with prior studies reporting sharp declines in screening and diagnostic breast imaging during March through June 2020 (EPIC Health Research Network, 2020b; Norbash et al., 2020; Nyante et al., 2021; Song et al., 2021; Sprague et al., 2021; Whaley et al., 2020; Yin et al., 2020). The observed changes in utilization in those studies likely reflect the impact of facility closures and reduced breast imaging capacity at facilities, combined with patient willingness to attend medical clinics and patient access to medical care (e.g., loss of health insurance). Our study provides direct evidence of facility-level capacity to provide breast imaging services during the pandemic from a large and geographically-diverse sample of breast imaging facilities in

Table 4
Factors used for prioritization of breast imaging services during re-opening after closures or periods of reduced capacity due to the COVID-19 pandemic at 75 breast imaging facilities in the Breast Cancer Surveillance Consortium, March 2020–September 2020.

	Screening		Diagnostic ^a		Biopsy ^a	
	N	%	N	%	N	%
Rescheduling canceled appointments	72/75	96.0	57/64	89.1	54/55	98.2
Indication for examination ^b	N/A	N/A	57/64	89.1	N/A	N/A
Individuals who contact facility and want to come in	62/75	82.7	54/64	84.4	53/55	96.4
Patient characteristics and risk factors ^c	55/75	73.3	49/64	76.6	52/55	94.6
Time since last imaging exam	53/75	70.7	46/64	71.9	N/A	N/A
Suspicion of malignancy on imaging ^d	N/A	N/A	N/A	N/A	52/55	94.6
Other factors	7/75	9.3	2/64	3.1	2/55	3.6

N/A, not applicable.

^a Limited to facilities who reported offering these services.

^b For example: additional work-up vs. short-interval follow-up vs. clinical symptoms.

^c For example: age, anxiety, history of breast cancer.

^d For example: assessment category 5 vs. 4c vs. 4b vs. 4a.

the United States. These data will be important in helping understand trends in breast cancer diagnoses and outcomes during and after the pandemic, and the potential role of postponed imaging on advanced stage at diagnosis.

While the impact of capacity disruptions on breast cancer detection and outcomes remains unclear, one early COVID-period study found a 52% reduction in breast cancer diagnoses during March–April 2020 compared to January–February 2020 (Kaufman et al., 2020). A simulation modeling study estimated that there may be approximately 5000 excess breast cancer deaths (a 1% increase) in the US during 2020–2030 due to the pandemic’s short term impact on screening and diagnostic breast imaging (Sharpless, 2020). Our study indicates that breast imaging facilities were largely able to offer services at full capacity within six months of the pandemic’s onset in the United States, consistent with reports that mammography utilization has largely rebounded to close to normal levels during this time period (EPIC Health Research Network, 2020a). The severity of the impact on breast cancer mortality will likely depend on the speed and degree to which the cumulative deficit in screening mammography can be made up.

During the pandemic, facilities overwhelmingly adopted a wide variety of safety measures, as recommended in guidance from professional societies. We had originally hypothesized that facilities may also have increased same-day services to minimize the number of repeat patient visits and limit COVID-19 exposure. However, there appeared to be no substantial increase in the number of facilities that offered same-day interpretation of screening mammography or same-day biopsy after abnormal diagnostic imaging. Many facilities reported offering same-day interpretation of screening mammography or same-day biopsy after abnormal diagnostic imaging during the pandemic; however, these were generally the same facilities that offered these services prior to the pandemic, and in fact the proportion of facilities offering these same-day services declined slightly during the pandemic. It is likely that logistical challenges prevented further expansion of these services. It is also possible that concerns about personal risk of exposure to COVID-19 reduced the availability of staff and radiologists, particularly for performing biopsies during which physical distancing is not possible. Finally, patient preferences regarding same-day services during the pandemic remain unclear; some individuals may prefer to avoid lengthy same-day visits.

Consistent with expert-opinion guidelines from professional organizations (Davenport et al., 2020; RSNA COVID Task Force, 2020; Society of Breast Imaging, 2020; The COVID-19 Pandemic Breast Cancer Consortium, 2020), facilities appeared to use readily available information, including clinical indication for the examination, to prioritize breast imaging services according to urgency. This strategy is supported by a recent BCSC study of 1,722,820 mammograms among 854,230 individuals interpreted by 448 radiologists at 92 facilities (Miglioretti et al. [2021]). That study found that examination indication (e.g., screening, short interval follow-up, evaluation of symptoms, etc.), along with age and history of breast cancer, was strongly associated with the probability of cancer detection and provides evidence to support the implementation of risk-based prioritization in times of reduced breast imaging capacity.

For both diagnostic and screening indications, rescheduling canceled appointments was the most commonly reported priority, likely due to the relative ease of identifying these patients and the service orientation of breast imaging facilities. More tailored prioritization at the individual level during the pandemic requires accessibility of information about individuals' breast cancer risk and COVID-19 risk factors. Shared decision-making and communication among the patient, radiologists, and referring clinicians would be a preferred pathway, and also one that is particularly challenging in a rapidly changing pandemic (Vagal et al., 2020). Beyond examination indication, it was unclear to what extent facilities used or could easily access information on individual-level breast cancer risk factors to prioritize breast imaging appointments. Information on specific individual characteristics and risk factors used for prioritization was not collected, thus we could not determine to what extent breast cancer risk explicitly influenced prioritization and how this was balanced against consideration of COVID-19 risks. The recent analysis by Miglioretti et al. demonstrated that consideration of individual breast cancer risk factors, including age and personal history of breast cancer, further supports identification of women with high, moderate, and low cancer detection rates (Miglioretti et al. [2021]). The investigators concluded that the use of risk information to triage individuals for breast imaging services during periods of reduced capacity could result in detecting more cancers while performing fewer examinations compared with a non-risk-based approach. For example, the 12% of mammograms with *very high* and *high* cancer detection rates accounted for 55% of detected cancers while the 44% of mammograms with *very low* cancer detection rates accounted for 13% of detected cancers. Additional studies are needed to assess facility-level barriers to implementing tailored risk-based prioritization strategies.

Our study was limited in that facilities did not provide a rank ordering of factors used in prioritization, nor did we collect information on barriers to prioritization (e.g., limited accessibility of risk factor data), processes to implement prioritization, specific facility strategies to address the reluctance of individuals to attend screening or diagnostic services during the pandemic, or safety measures specifically enacted to protect facility staff. A number of additional factors are likely to have impacted breast imaging services, including disruptions to primary care services that refer individuals to breast cancer screening. We did not collect information on communication practices prior to the pandemic and thus were unable to assess changes in communication practices during the pandemic. Future studies, perhaps using qualitative study designs, are needed to understand the importance, processes, and challenges of prioritization during the pandemic.

The survey ascertained facility prioritization considerations when reopening after closures or during periods of reduced capacity. We did not collect information specifically on strategies for reducing the backlog of missed exams during periods of full capacity. A number of studies have demonstrated that substantial cumulative deficits in screening and diagnostic breast imaging accrued during the initial months of the pandemic. Facilities would need to exceed normal operating capacities to catch up on performing all these missed exams; it remains unclear to what degree this is possible or what strategies may be most frequently

used to accomplish this.

Finally, we did not examine facility capacity in direct relationship to patterns in local COVID-19 case burdens. The participating BCSC registries cover geographic areas that widely varied in the extent of per capita COVID-19 case counts to date (as of January 21, 2021), ranging from 1678 per 100,000 in Vermont to 8534 per 100,000 in Illinois (Centers for Disease Control and Prevention, 2021). Thus, our results provide a high-level overview of the impact of the pandemic on breast imaging facilities in the United States, including a broad spectrum of practice types, academic and non-academic practices, practice locations, and annual imaging volume.

In summary, the results indicate that facility capacity was greatly impacted in the initial months of the pandemic but largely recovered by September 2020, though some facilities continued to report less than full capacity at that time. Screening services were most severely impacted, though more than half of facilities also reported disruptions to diagnostic imaging and biopsy services. Facilities prioritized urgent breast imaging services based on examination indication, while also highly prioritizing rescheduling of canceled appointments. Prioritizing scheduling based on canceled examinations may have resulted in scheduling individuals at low breast cancer risk sooner than those at higher risk. Evaluation of facility-level outcomes in relation to prioritization strategies and explicit discussion of guiding principles for prioritization may help facilities develop strategies to support care and service goals in future times of capacity restriction.

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Dr. Janie Lee and Dr. Christoph Lee report receiving grants from GE Healthcare outside the submitted work. Dr. Christoph Lee also reports consultant fees from GRAIL, Inc., for work on a data safety monitoring board, and textbook royalties from Oxford University Press, McGraw Hill, Inc., and Wolters Kluwer, all outside the submitted work. Dr. Karla Kerlikowske is an unpaid consultant with GRAIL Inc. for the STRIVE study. No other conflict of interest disclosures were reported.

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Drafting of the manuscript: Sprague.

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Disclaimer

The statements presented in this work are solely the responsibility of

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Appendix A. Supplementary data

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References

- Ballard-Barbash, R., Taplin, S.H., Yankaskas, B.C., Ernster, V.L., Rosenberg, R.D., Carney, P.A., Barlow, W.E., Geller, B.M., Kerlikowske, K., et al., 1997. Breast Cancer surveillance Consortium: a national mammography screening and outcomes database. *AJR Am. J. Roentgenol.* 169, 1001–1008.
- Breast Cancer Surveillance Consortium, 2021. Breast Cancer Surveillance Consortium: Working Together to Advance Breast Cancer Research. <http://www.bcsc-research.org>. Accessed January 22, 2021.
- Centers for Disease Control and Prevention, 2021. CDC COVID Data Tracker. https://covid.cdc.gov/covid-data-tracker/#cases_casesper100k. Accessed January 22, 2021.
- Davenport, M.S., Bruno, M.A., Iyer, R.S., Johnson, A.M., Herrera, R., Nicola, G.N., Ortiz, D., Pedrosa, I., Policeni, B., et al., 2020. ACR statement on safe resumption of routine radiology care during the coronavirus disease 2019 (COVID-19) pandemic. *J. Am. Coll. Radiol.* 17, 839–844.
- EPIC Health Research Network, 2020a. Delayed Cancer Screenings – A Second Look. <https://ehrn.org/articles/delayed-cancer-screenings-a-second-look>. Accessed November 2, 2020.
- EPIC Health Research Network, 2020b. Preventive Cancer Screenings during COVID-19 Pandemic. <https://ehrn.org/articles/delays-in-preventive-cancer-screenings-during-covid-19-pandemic/>. Accessed November 2, 2020.
- Harris, P.A., Taylor, R., Thielke, R., Payne, J., Gonzalez, N., Conde, J.G., 2009. Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. *J. Biomed. Inform.* 42, 377–381.
- Harris, P.A., Taylor, R., Minor, B.L., Elliott, V., Fernandez, M., O'Neal, L., McLeod, L., Delacqua, G., Delacqua, F., et al., 2019. The REDCap consortium: building an international community of software platform partners. *J. Biomed. Inform.* 95, 103208.
- Kaufman, H.W., Chen, Z., Niles, J., Fesko, Y., 2020. Changes in the number of US patients with newly identified Cancer before and during the coronavirus disease 2019 (COVID-19) pandemic. *JAMA Netw. Open* 3, e2017267.
- Lee, C.I., Bogart, A., Germino, J.C., Goldman, L.E., Hubbard, R.A., Haas, J.S., Hill, D.A., Tosteson, A.N., Alford-Teaster, J.A., et al., 2016. Availability of advanced breast imaging at screening facilities serving vulnerable populations. *J. Med. Screen.* 23, 24–30.
- Miglioretti, D.L., Bissell, M.C.S., Kerlikowske, K., Buist, D.S.M., Cummings, S.R., Henderson, L.M., Onega, T., O'Meara, E.S., Rauscher, G.H., et al., 2021. A risk-based approach for triaging mammography examinations during periods of reduced capacity. *JAMA Netw. Open* 4, e211974.
- Norbash, A.M., Moore Jr., A.V., Recht, M.P., Brink, J.A., Hess, C.P., Won, J.J., Jain, S., Sun, X., Brown, M., et al., 2020. Early-stage radiology volume effects and considerations with the coronavirus disease 2019 (COVID-19) pandemic: adaptations, risks, and lessons learned. *J. Am. Coll. Radiol.* 17, 1086–1095.
- Nyante, S.J., Benefield, T.S., Kuzmiak, C.M., Earnhardt, K., Pritchard, M., Henderson, L.M., 2021. Population-level impact of coronavirus disease 2019 on breast cancer screening and diagnostic procedures. *Cancer*.
- Patt, D., Gordan, L., Diaz, M., Okon, T., Grady, L., Harmison, M., Markward, N., Sullivan, M., Peng, J., et al., 2020. Impact of COVID-19 on cancer care: how the pandemic is delaying cancer diagnosis and treatment for American seniors. *JCO Clin. Cancer Inform.* 4, 1059–1071.
- RSNA COVID Task Force, 2020. RSNA COVID-19 Task Force: Post-COVID Surge Radiology Preparedness. <https://www.rsna.org/-/media/Files/RSNA/covid-19/RSNA-COVID-19-PostSurgePreparedness.pdf>. Accessed November 2, 2020.
- Sharpless, N.E., 2020. COVID-19 and cancer. *Science* 368, 1290.
- Society of Breast Imaging, 2020. SBI Recommendations for a Thoughtful Return to Caring for Patients. https://www.sbi-online.org/Portals/0/Position%20Statements/2020/SBI-recommendations-for-a-thoughtful-return-to-caring-for-patients_April-16-2020.pdf. Accessed November 2, 2020.
- Song, H., Bergman, A., Chen, A.T., Ellis, D., David, G., Friedman, A.B., Bond, A.M., Bailey, J.M., Brooks, R., et al., 2021. Disruptions in preventive care: mammograms during the COVID-19 pandemic. *Health Serv. Res.* 56, 95–101.
- Sprague, B.L., Miglioretti, D.L., Lee, C.I., Perry, H., Tosteson, A.A.N., Kerlikowske, K., 2020. New mammography screening performance metrics based on the entire screening episode. *Cancer* 126, 3289–3296.
- Sprague, B.L., Lowry, K.P., Miglioretti, D.L., Alsheik, N., Bowles, E.J.A., Tosteson, A.A.N., Rauscher, G., Herschorn, S.D., Lee, J.M., et al., 2021. Changes in mammography utilization by women's characteristics during the first five months of the COVID-19 pandemic. *J. Natl. Cancer Inst.*
- Strategies, T., 2020. States with Elective Medical Procedures Guidance in Effect. In: https://www.acr.org/-/media/ACR/Files/COVID19/May-18_States-With-Elective-Medical-Procedures-Guidance-in-Effect.pdf. Accessed November 2, 2020.
- The COVID-19 Pandemic Breast Cancer Consortium, 2020. COVID-19 Pandemic Breast Cancer Consortium's Considerations for Re-entry. https://www.facs.org/-/media/files/covid19/covid_breast_consor_tium_reentry.ashx. Accessed November 2, 2020.
- Vagal, A., Mahoney, M., Allen, B., Kapur, S., Udstuen, G., Wang, L., Braley, S., Makramalla, A., Chadalavada, S., et al., 2020. Rescheduling nonurgent Care in Radiology: implementation during the coronavirus disease 2019 (COVID-19) pandemic. *J. Am. Coll. Radiol.* 17, 882–889.
- Whaley, C.M., Pera, M.F., Cantor, J., Chang, J., Velasco, J., Hagg, H.K., Sood, N., Bravata, D.M., 2020. Changes in health services use among commercially insured US populations during the COVID-19 pandemic. *JAMA Netw. Open* 3, e2024984.
- Yin, K., Singh, P., Drohan, B., Hughes, K.S., 2020. Breast imaging, breast surgery, and cancer genetics in the age of COVID-19. *Cancer* 126, 4466–4472.