

Temporal Trends and Interest in Coronary Artery Calcium Scoring Over Time: An Infodemiology Study

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Abstract

Objective: To evaluate interest in coronary artery calcium (CAC) among the general public during the past 17 years and to compare trends with real-world data on number of CAC procedures performed.

Methods: We used Google Trends, a publicly available database, to access search query data in a systematic and quantitative fashion to search for CAC-related key terms. Search terms included *calcium test*, *heart score*, *calcium score*, *coronary calcium*, and *calcium test score*. We accessed Google Trends in January 2021 and analyzed data from 2004 to 2020.

Results: From 2004 to December 31, 2020, CAC-related search interest (in relative search volume) increased continually worldwide (+201.9%) and in the United States (+354.8%). Three main events strongly influenced search interest in CAC: reports of a CAC scan of the president of the United States led to a transient 10-fold increase in early January 2018. American College of Cardiology/American Heart Association guideline release led to a sustained increase, and lockdown after the global pandemic due to COVID-19 led to a transient decrease. Real-world data on performed CAC scans showed an increase between 2006 and 2017 (+200.0%); during the same time period, relative search volume for CAC-related search terms increased in a similar pattern (+70.6%-1511.1%). For the search term *coronary calcium scan near me*, a potential representative of active online search for CAC scanning, we found a +28.8% increase in 2020 compared with 2017.

Conclusion: Google Trends, a valuable tool for assessing public interest in health-related topics, suggests increased overall interest in CAC during the last 17 years that mirrors real-world usage data. Increased interest is seemingly linked to reports of CAC testing in world leaders and endorsement in major guidelines.

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Health-related information is available to the general public more widely than ever before and can have a significant influence on patients' behavior.¹ Data on search query volume may provide valuable insights into patterns of disease and population behavior. Indeed, search engine activity represents a modern, validated additional tool to evaluate behavioral changes over time and by geographic location.^{2,3} This has sparked a new research discipline termed infodemiology focusing on the study of the determinants and the distribution of health information.⁴ Google Trends represents a

publicly available online tool for analyzing trends in online search volumes for the Google search engine. The beneficial role of health evaluation by assessing real-time (online) information in a range of diseases and conditions, including infectious diseases and cardiovascular health, has been shown in several studies.⁵⁻⁸ Monitoring online search trends might provide additional guidance to public health officials and disease control experts by assessing the public response to public health issues.³

According to the Centers for Disease Control and Prevention data, cardiovascular

disease (CVD) still represents the leading cause of death, irrespective of sex and race, in the United States.⁹ Thus, the establishment of comprehensive risk assessment tools and the broad implementation of effective prevention measures are crucial for overall public health. Coronary artery calcium (CAC), as a representative of overall atherosclerotic burden including the coronary arteries, represents a quantitative computed tomography (CT)-based marker that complements CVD risk assessment.¹⁰ Numerous studies have confirmed the effectiveness and accuracy of CAC in CVD risk estimation for asymptomatic patients.^{11,12}

The most recent 2018 American Heart Association (AHA)/American College of Cardiology (ACC) Guideline on the Management of Blood Cholesterol¹³ and the 2019 ACC/AHA Guideline on the Primary Prevention of Cardiovascular Disease¹⁴ implemented CAC scanning as a part of CVD risk assessment (IIA recommendation). In borderline to intermediate-risk patients, CAC scores provide substantial information for the optimization of preventive interventions for CVD. For instance, CAC scores can guide statin therapy and represent an additional stratification tool among those with borderline CVD risk scores.^{13,14}

It is, however, less well known how trends in online search interests in CAC-related terms, as a potential indicator for public pursuit of health information, have developed in the long term and in response to the release of the respective guidelines. Using Google Trends, we analyzed temporal trends in online search volumes for terms related to CAC. We additionally hypothesized a decrease in the respective online search in response to the ongoing COVID-19 pandemic. Because of redirected health care resources toward the COVID-19 crisis, online search interests for COVID-19-related information have peaked with increasing infection rates.¹⁵ This, in turn, might suggest a diversion of the proportion of other health care-related online searches in favor of COVID-19. To our knowledge, this is the first study that evaluates long-term and temporal trends in CAC online search interests.

METHODS

Google Trends is an online search tool accessible to the public to gain insights on search

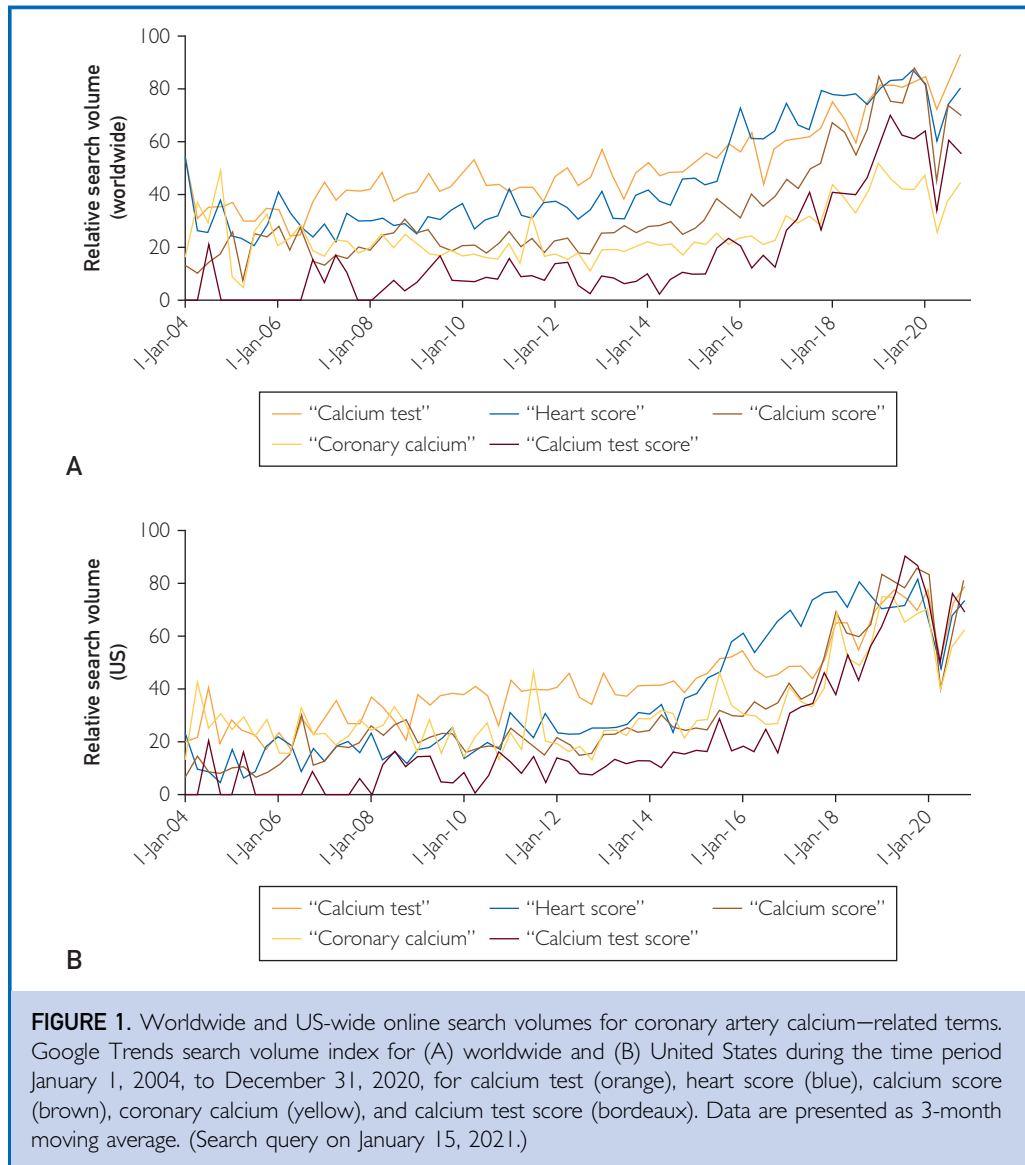
patterns by analyzing a portion of all web queries on the Google Search website and other affiliated sites, based on time and geographic region. The home interface of the website (<https://trends.google.com/>) enables the input of search terms or topics into a query field with 1 to a maximum of 5 terms at a time.

After search terms of interest are entered, Google Trends allows adjustment for location and time period. The time period can be set for the overall period, that is, since Google has made these data available in 2004, or any other customized time range. Data are presented by Google Trends as time graphs, heat-maps, related topics, and related queries.

Search data on Google Trends are normalized to both location and time period and reported as relative search volume (RSV) on a scale of 0 to 100. An RSV value of 100 on the time graph represents the peak interest for a search term in a given time range and the selected location. RSVs at all other time points within the specified time range are relative to that peak. A detailed description is provided by Google, and further details have been published elsewhere.¹⁶

We used Google Trends to identify terms related to CAC, including *calcium test*, *heart score*, *calcium score*, *coronary calcium*, and *calcium test score*. Terms were initially selected at the discretion of the authors with the help of the built-in Google Trends function that suggests most commonly queried related terms. All terms were queried as search terms as they were not classified as topics by Google Trends at the time of this study.

We queried both worldwide and US results for the time range from January 1, 2004, to December 31, 2020, with the final data acquired on January 15, 2021. In our initial analysis, we identified several peaks in public interest that we explored further by setting narrower time ranges. We evaluated RSV data for search terms individually to visualize the temporal trend of a search term instead of comparing the RSV between key terms. Such comparisons are provided in the [Supplemental Figures](http://www.mayoclinicproceedings.org) (available online at <http://www.mayoclinicproceedings.org>) as pooled graphs. Further quantitative data analysis was achieved by downloading the data sets in .csv format for all terms and time



ranges of interest. We calculated Spearman correlation coefficients to evaluate the degree of association of temporal trends between search terms. For geographic trends, the *trendsR* package in R was used to retrieve weekly search data for 2006, 2016, and 2020 (January 1–December 31) for worldwide and US-wide searches. Countries and US states were depicted as color-coded heatmaps based on the RSV indices using R software package, version 4.0.3 (R Foundation for Statistical Computing).

To link our findings with real-world data, we obtained estimated numbers on diagnostic radiologic examinations in the United States

reported in the 2017 IMV CT Benchmark Report.¹⁷ We compared the change in public interest in search terms related to CAC with the change in number of CAC procedures performed in a given year. Percentage changes are reported with the initial value as the baseline. Statistical significance for year-wise comparison of RSV for all CAC-related search terms was calculated using 1-sided Mann-Whitney *U* test for nonparametric parameters. Significance was assumed for *P* values of less than .05.

Finally, we evaluated public use of the Google tool “near me,” a feature that Google introduced in 2014. It allows users to instantly search for current needs, predominantly in

TABLE. Google Trends Data and CAC Scan Procedures Performed in 2006 and 2017

	Real-world data	Google Trends data					P value
	(million) No. of CAC scan procedures	Calcium test	Heart score	(mean RSV) Calcium score		Calcium test score	
2006	0.50	22.83	16.75	16.75	21.83	2.25	
% change	+200.0	+109.9	+323.9	+151.2	+70.6	+1511.1	
2017	1.50	47.92	71.00	42.08	37.25	36.25	.004

Google Trends relative search volume (RSV; by annual mean) in the United States and number of coronary artery calcium (CAC) procedures performed (in millions) for 2006 and 2017. Google Trends data mirror trends observed by real-world data. Mann-Whitney *U* test was used for statistical significance comparing yearly RSV for all CAC-related search terms (2017 vs 2006). $P < .05$ was considered significant.

terms of consumer behavior. Analyzing such data can give valuable hints about approximated interest in undergoing a CAC scan based on the assumption that someone who adds the term *near me* in an online search is more likely to act on the search query in the near future.

RESULTS

Interest in terms related to CAC increased continually both worldwide and in the United States since Google made search query data publicly available in 2004 (Figure 1; Supplemental Figure 1, available online at <http://www.mayoclinicproceedings.org>). When comparing data from Google Trends with real-world data on CAC procedures performed, we detected a similar trend. Real-world data on CAC procedures showed a 3-fold increase for the available time periods between 2006 and 2017. During the same time period, RSV for search terms related to CAC significantly increased, with +70.6% to 1511.1% higher search volumes in 2017 compared with 2006 (Table).

Correlation coefficients confirm a strong positive agreement between trends of individual query terms. Based on worldwide searches, the highest correlation with other query terms was ascribed to the term *calcium score*, sharing a correlation coefficient of 0.79, 0.80, 0.61, and 0.83 with *calcium test*, *heart score*, *coronary calcium*, and *calcium test score*, respectively (Supplemental Table 1, available online at <http://www.mayoclinicproceedings.org>). For the same query terms based on searches in the United States, we found an equally marked correlation. The search term *calcium score* shared correlation coefficients of 0.80, 0.79, 0.80, and 0.85 with *calcium test*, *heart score*,

coronary calcium, and *calcium test score*, respectively (Supplemental Table 2, available online at <http://www.mayoclinicproceedings.org>).

Geographically, worldwide and US-wide search volumes for search terms related to CAC increased in a number of countries over time. Whereas worldwide search volumes could be recorded for 8 countries in 2006, we noted search query volumes for 31 countries in 2020. In 2020, the highest RSV was recorded in Ireland, followed by the United States, Malaysia, Singapore, Philippines, and Australia. For the United States, we could detect a similar increase in search volumes for *heart score* in 2006 for 20 states and in 2020 for 40 states. Specifically, the eastern states had the highest search volumes (Figure 2).

Comparing the mean RSV of the past 2 years (2019 and 2020) with the 2 years in which Google started making search query data available (2004 and 2005) revealed a marked increase in public interest. Based on worldwide searches, we report changes in RSV of +130.6%, +161.2%, +330.1%, +65.7%, and +2078.1% for the key terms *calcium test*, *heart score*, *calcium score*, *coronary calcium*, and *calcium test score*, respectively. In the same order of search terms, the mean RSV of the past 2 years changed by +196.2%, +462.3%, +710.0%, +136.8%, and +1441.2% compared with the mean RSV of 2004 and 2005 in the United States. The overall mean of RSV changes for the 5 search terms related to CAC was thus +201.9% for worldwide search volume and +354.8% in the United States (Figure 1; Supplemental Figure 1).

A sudden and unprecedented increase in search requests for search terms related to

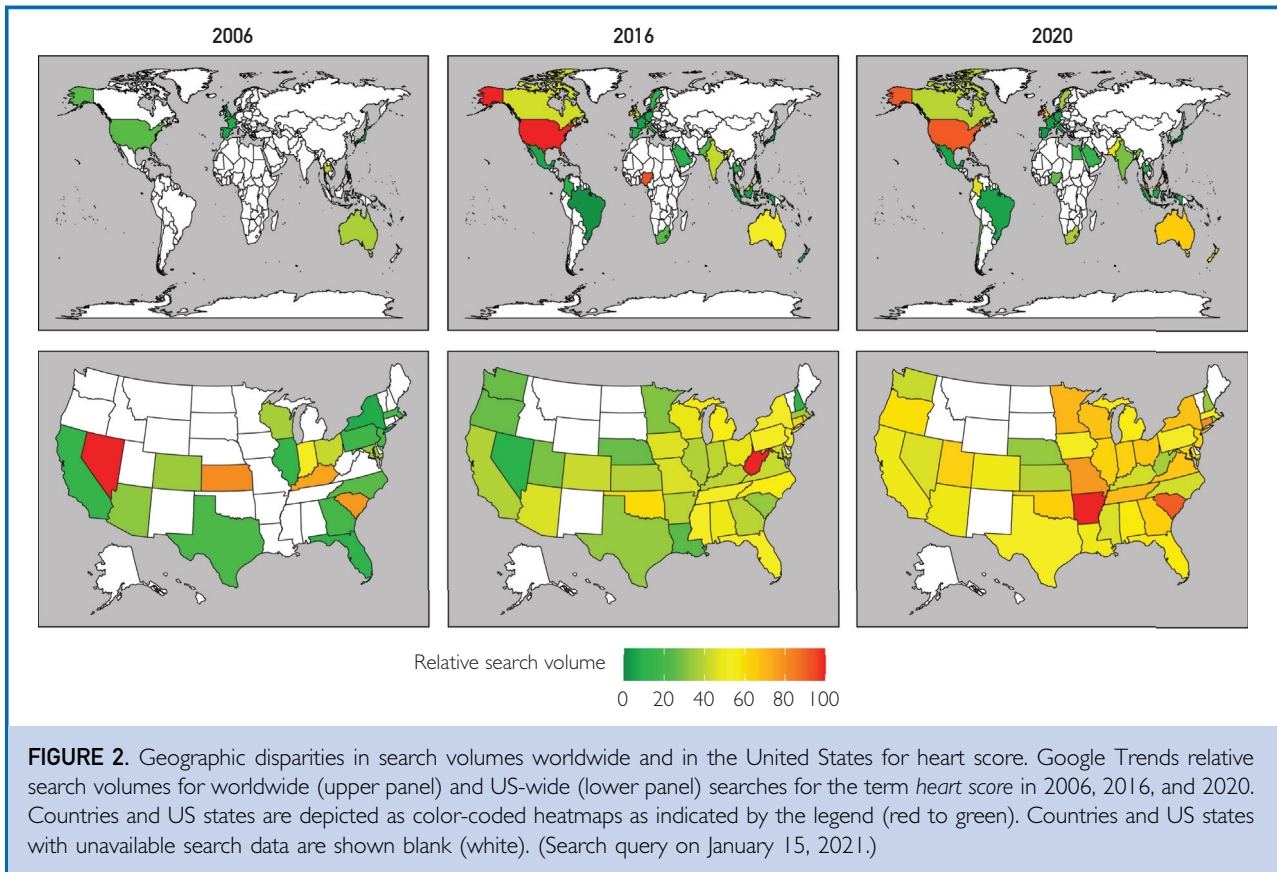


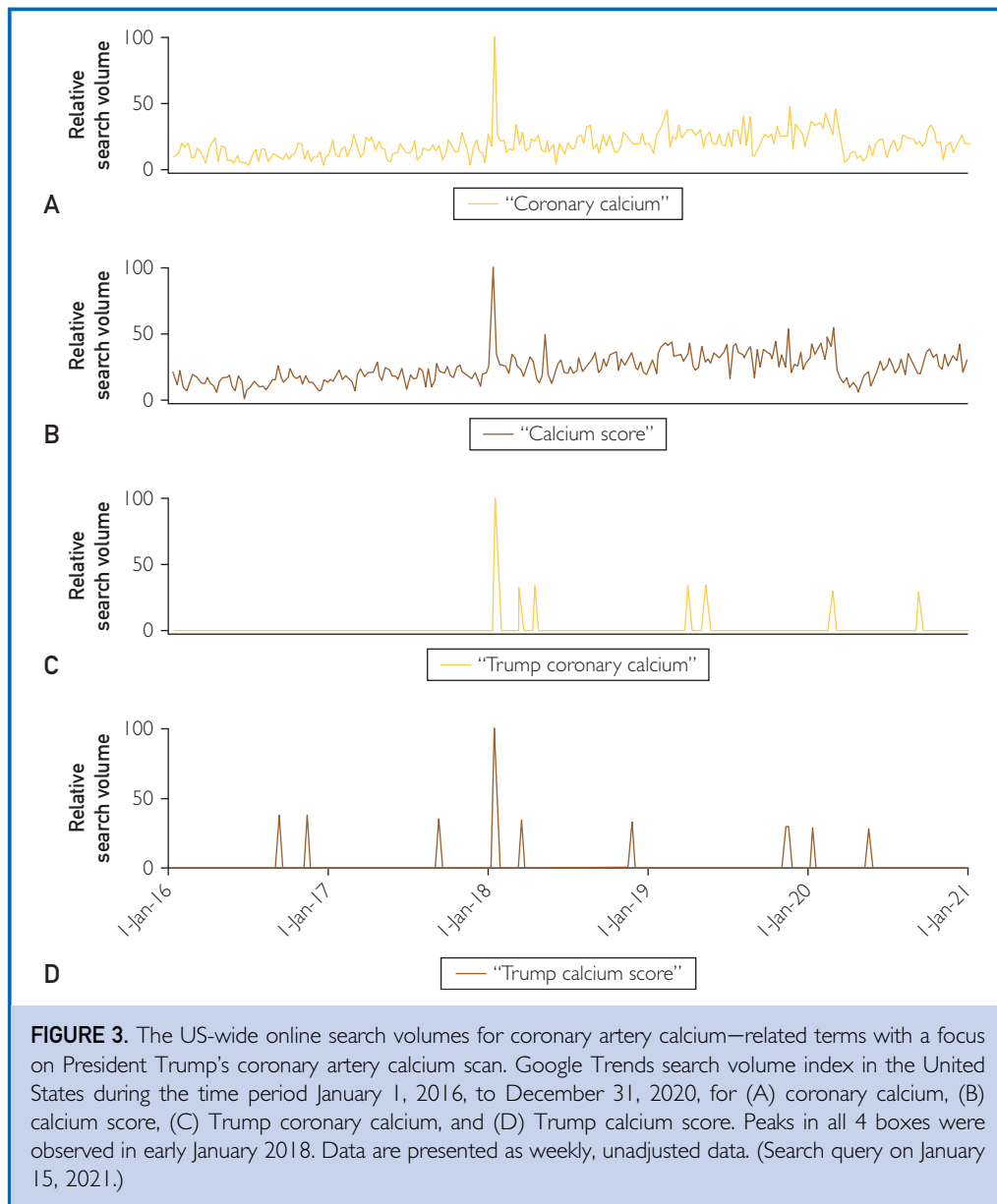
FIGURE 2. Geographic disparities in search volumes worldwide and in the United States for heart score. Google Trends relative search volumes for worldwide (upper panel) and US-wide (lower panel) searches for the term *heart score* in 2006, 2016, and 2020. Countries and US states are depicted as color-coded heatmaps as indicated by the legend (red to green). Countries and US states with unavailable search data are shown blank (white). (Search query on January 15, 2021.)

CAC was observed in the week from January 14 to January 20, 2018 (Figure 3A and B; Supplemental Figure 2, available online at <http://www.mayoclinicproceedings.org>). After searching for *coronary calcium* and *calcium score* in major national newspapers for that time range and identifying news articles reporting on President Trump's calcium scores, we combined the 2 search terms with *Trump*, resulting in a peak at exactly the same time (Figure 3C and D). The mean change in RSV for both search terms showed a 10-fold increase in comparing the mean RSV of the 3 years before the RSV in the respective week in January 2018. However, search volume decreased rapidly thereafter, suggesting only a transient increase.

After the release of the 2018 AHA/ACC Guideline on the Management of Blood Cholesterol as well as the 2019 ACC/AHA Guideline on the Primary Prevention of Cardiovascular Disease, we detected a sustained increase lasting until today. Comparing the time range

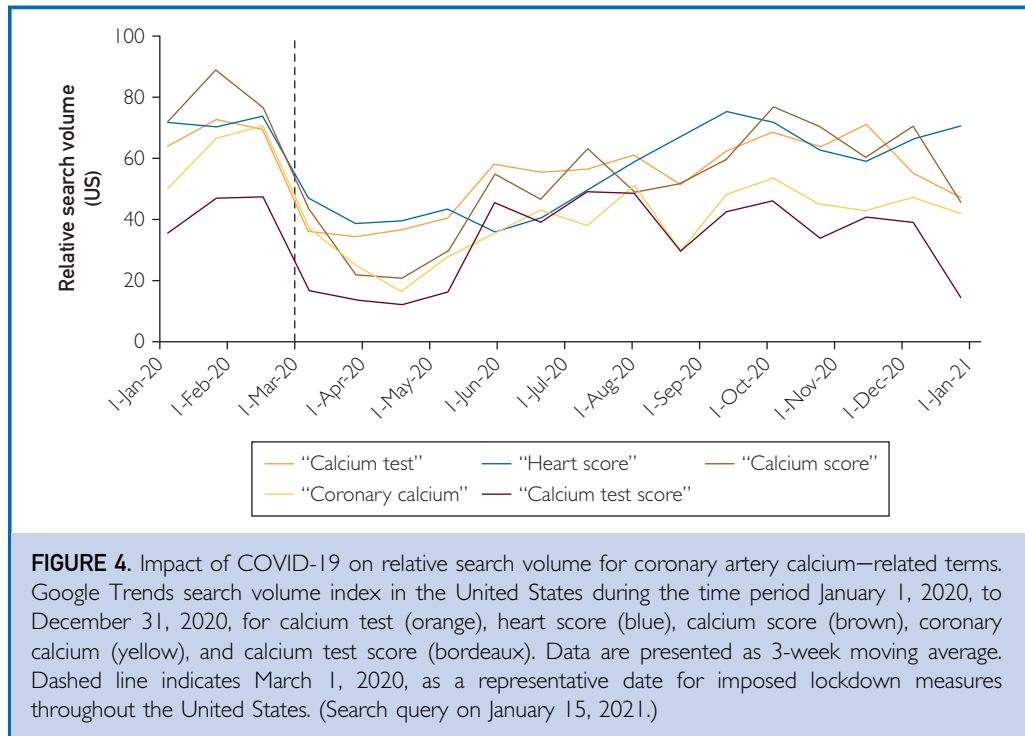
from the release of the 2018 AHA/ACC Guideline in October 2018 to the release of the 2019 ACC/AHA Guideline in March 2019 with the preceding 21 months in the United States, we report significant RSV changes in all CAC-related search terms. Specifically, online searches for *calcium test*, *heart score*, *calcium score*, *coronary calcium*, and *calcium test score* changed during this time period by +18.9%, -3.9%, +41.9%, +50.7%, and +34.4%, respectively. In the 21 months following both guideline releases, we noticed a partial yet not significant increase in mean RSV between April 1, 2019, and December 31, 2020, of +7.2%, -4.0%, -3.6%, -10.1%, and +30.4% for the search terms *calcium test*, *heart score*, *calcium score*, *coronary calcium*, and *calcium test score*, respectively (Supplemental Table 3, available online at <http://www.mayoclinicproceedings.org>).

To address transient trends in light of the ongoing COVID-19 pandemic, we observed RSV to be lowest in March-April 2020



(Figure 4). RSV in March–April 2020 compared with the 2 preceding months changed by -38.0% , -38.9% , -53.7% , -38.3% , and -65.3% for the terms *calcium test*, *heart score*, *calcium score*, *coronary calcium*, and *calcium test score*, respectively. During the following months July–August 2020, we noted a partial recuperation of search volumes by $+37.1\%$, $+26.0\%$, $+47.5\%$, $+16.3$, and $+167.1\%$ for the respective search terms.

Using Google’s near me feature, we identified a similar, steady increase in interest in search volumes for CAC scan (Supplemental Figure 3, available online at <http://www.mayoclinicproceedings.org>). For example, RSV for the term *coronary calcium scan near me* changed by $+306.4\%$ between 2017 and 2020. During the same time period, search volumes for *coronary calcium CT scan* increased by $+28.8\%$, thus indicating an overall growing search interest in CAC scans (Supplemental Figure 3).



DISCUSSION

Interest in CAC Over Time

We observed a consistent increase in CAC-related query terms on Google Trends during the past 17 years as well as a strong increase in CAC query terms combined with the near me feature during the past 4 years. Together, these findings indicate an increase in general public awareness of the existence of CAC scanning as well as a potentially sincere interest in undergoing such a diagnostic procedure. Our observations suggest that adoption of CAC scanning into therapy guidelines led to a sustained increase in search interest, whereas surges in search activity related to news media events did not produce a lasting effect.

CAC scoring has become one of the most important tools for practicing clinicians in prevention of CVD.¹⁸ For instance, it is now widely accepted that a CAC score of 0 is a strong negative risk factor.¹⁹ However, individuals with a high CAC score ($CAC \geq 1000$) are considered a distinct risk group, and aggressive preventive intervention is recommended.²⁰ In addition, the prognostic power of CAC across risk factor burden, sex, and

ethnicity has repeatedly been confirmed.²¹⁻²³ Finally, the role of CAC in preventive cardiovascular medicine has been formally acknowledged, not least by the adoption into the 2018 AHA/ACC Guideline on the Management of Blood Cholesterol and the 2019 ACC/AHA Guideline on the Primary Prevention of Cardiovascular Disease.

The “Trump Effect”

We noted a strong but transient increase in search interest for CAC-related terms in January 2018 following news reports that the president of the United States had undergone a repeated CAC scan. Media reports focused on interpretation of the president’s CAC score of 133 (approximately 50th percentile for age, sex, and race), including a comparison with individuals of his age and subsequent speculation on the president’s health condition. As our observed changes in search behavior show, such media events can be useful in promoting medical or preventive diagnostics. Patients may be prompted to actively seek out health care professionals to inquire about CVD prevention strategies or may be more open to

discussion of these topics in case they are brought up in the patient-physician setting.^{24,25} On the other hand, contrary to adoption of CAC scanning into major guidelines, this news event did not lead to a sustained increase in RSV of search terms related to CAC.

Release of Guidelines

Beginning in fall 2018 and beyond, search interest for CAC has been continually increasing. Previously not strongly endorsed by major guidelines, CAC quantification in patients with a borderline or intermediate-risk profile has been acknowledged by the 2018 AHA/ACC Guideline on the Management of Blood Cholesterol published November 10, 2018,¹³ and the 2019 ACC/AHA Guideline on the Primary Prevention of Cardiovascular Disease published March 17, 2019.¹⁴ As guideline recommendations are usually not widely circulated or discussed outside the scientific and medical community, a possible explanation for the increasing public interest in CAC might be a broad communication of guideline recommendations. In addition, there may be a heightened awareness of the importance of CAC scanning among primary care physicians, who in turn were more likely to discuss this topic with their patients.

The effect of guideline releases on certain outcome parameters, such as screenings conducted or drug prescriptions, has been reported previously.^{26,27} Expectedly, these changes usually occur over time as the new guidelines are slowly implemented by clinicians. For example, following the release of the 2009 US Preventive Services Task Force guidelines on screening mammography, despite initial controversy and unfavorable public perception, this guideline nevertheless led to a clear increase in mammography rates 2 years after its release.²⁶ A similar pattern was seen after the release of the 2013 ACC/AHA blood cholesterol guidelines on statin treatment. Whereas statin use remained basically unchanged the year after guideline release, prescription of higher dose statins was observed in the years after.²⁷

Online Searches for CAC-Related Terms During COVID-19 Pandemic

We report a decline in online search interests in the United States for CAC-related terms

with the ongoing COVID-19 crisis. Specifically, beginning with the lockdown measures throughout March 2020, the search volumes for CAC-related terms were lowest in March-April 2020. This is also concordant with the postponement of routine diagnostic and therapeutic procedures by policymakers and health care providers to alleviate the impact of COVID-19 on the health care system.²⁸ Potential explanations for the decrease in CAC search volumes might be as follows: individuals interested in CAC-related terms might increasingly avoid contact with the health care system in fear of a SARS-CoV-2 infection; and CAC screening programs have been postponed by health care providers, resulting in decreased search interest.

Comparison With Real-World Data

Comparing results of our Google Trends analysis showing increased search volumes for CAC to the absolute numbers of CAC scans throughout the United States, we specifically observed similar long-term increases. This is in line with previously published reports indicating a predictive capability of passively generated search query data such as Google Trends.^{7,29} Public interest as depicted by Google Trends thus bears the potential to mirror real-world usage data. This has several potential implications for CVD prevention: online search volumes might indicate public health trends in preventive measures for CVD as represented by CAC; and changes in CVD prevention paradigms and the implementation of new guideline recommendations might be mirrored by online search volumes, allowing a check for online searches as a potential indicator of effective guideline communication. In addition, given the nearly instant availability of search volume data, CAC-related online search trends could complement large and costly generation of databases as well as population analyses. Thus, online search trends might be useful in short-term evaluation of primary prevention campaigns intended to increase awareness of CVD and CAC assessment.

A Global Perspective

Global interest in CAC increased during the past decade, and search queries for CAC-related terms were detected in an increasing number of countries. The rise of the middle class and

associated adoption of dietary and lifestyle transitions in these rapidly developing economies have been linked to enormous public health challenges. Globally, CAC assessment to improve cardiovascular risk estimation thus may be of increasing relevance. For instance, in India, for which we could observe increasing search volumes over time, mortality rates related to coronary heart disease and type 2 diabetes are steadily increasing.³⁰ Notably, in China, CVD has become the leading cause of death, requiring effective strategies to foster primary prevention and patient education.³¹ With CVD-related death rates rising across the globe, there is an increasing worldwide need for effective preventive measures. As CAC scans can guide preventive interventions, future research might include actually performed CAC screenings as an additional marker of preventive efforts.

Limitations

Our study is subject to several limitations. These include, most importantly, that interest in CAC does not necessarily reflect a sincere interest in actually undergoing a CAC scan. However, positive agreement between these variables is to be expected. As RSV is presented only on the basis of peak interest in a given time range and location, we cannot distinguish nationwide or state-level differences during a given time. In selecting a particular time range (eg, whole year), the RSV changes are based on the new peak interest value within that time range. If this were to change in the future and if Google Trends made absolute numbers of searches available, future research could possibly include comparisons of state-level differences over time and offer insights into a more granular analysis of public interest. The 2017 IMV CT Benchmark Report has its own set of limitations with real-world data on CAC procedures.¹⁷ Because of the relatively low volume of cardiac CT scans compared with regular CT scans and variable reimbursement for such tests, estimates of CAC scan numbers show a great variance. An additional limitation is the number of query terms we have selected throughout our study. We present only a sample of all possible query terms that could potentially be associated with CAC. Also, we cannot exclude that the chosen query terms may have been entered for other reasons (ie, by scientists or health

care professionals themselves). Linguistically, terms related to a specific subject may also change over time and are not free of geographic bias. Overall, however, we believe that our comprehensive approach has captured the most representable set of search terms related to CAC while this study was being conducted.

CONCLUSION

Our data using Google Trends show an overall increase in interest in CAC in the United States and worldwide during the last 17 years, seemingly linked to reports of CAC testing in world leaders and endorsement in major guidelines. Data on the near me feature suggest a similar increase in interest to specifically undergo a CAC scan. These results generally underline real-world increasing numbers of actually performed CAC scans.

SUPPLEMENTAL ONLINE MATERIAL

Supplemental material can be found online at <http://www.mayoclinicproceedings.org>. Supplemental material attached to journal articles has not been edited, and the authors take responsibility for the accuracy of all data.

Abbreviations and Acronyms: ACC = American College of Cardiology; AHA = American Heart Association; CAC = coronary artery calcium; CT = computed tomography; CVD = cardiovascular disease; RSV = relative search volume

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Potential Competing Interests: The authors report no competing interests.

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