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Patient Interest in Robotic Total Joint Arthroplasty Is Exponential: A 10-Year Google Trends Analysis

Joseph C. Brinkman, MD [a, *], Zachary K. Christopher, MD [a], M. Lane Moore, BS [b], Jordan R. Pollock, BS [b], Jack M. Haglin, MD [a], Joshua S. Bingham, MD [a]

[a] Department of Orthopedic Surgery, Mayo Clinic Arizona, Phoenix, AZ, USA
[b] Mayo Clinic Alix School of Medicine, Scottsdale, AZ, USA

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ABSTRACT

Background: The use of robotics in arthroplasty continues to increase. Patient demand, patient expectations, and patient-directed marketing by industry and care providers each likely contributes to its increasing popularity. Trends in patient interest have not been well described. We used the online Google Trends tool to analyze trends in national public interest toward robotic and nonrobotic arthroplasty between 2011 and 2021.

Material and methods: Google Trends online was queried for search terms related to nonrobotic hip and knee arthroplasty in addition to robotic hip, robotic knee, and general robotic arthroplasty between January 1, 2011, and December 31, 2021.

Results: Google Trends Data demonstrated a significant linear increase in online searches related to nonrobotic total knee and hip arthroplasty. Online search volume for robotic hip arthroplasty was significant and linear, while that of robotic knee arthroplasty was significant and exponential. When combined, robotic joint arthroplasty demonstrated an exponential trend over the 10-year period. This increase was noted to be statistically significant when compared with nonrobotic arthroplasty search volume.

Conclusion: Our study demonstrates that public interest in robotic total joint arthroplasty has increased significantly from 2011 through 2020. When compared with online search volume for conventional arthroplasty, this increasing growth is statistically significant. Public interest in robotic arthroplasty is anticipated to continue to increase, and care providers should be aware of this trend that impacts patient perceptions and expectations. Despite significant growth in interest for robotic arthroplasty, there is incomplete evidence supporting its use over nonrobotic arthroplasty. Additional high-quality studies are needed to inform provider decision-making and appropriately guide public interest in robot-assisted arthroplasty.

Introduction

The use of robotics has increased substantially in orthopedic surgery and particularly in the field of hip and knee arthroplasty. A recent review of the Nationwide Inpatient Sample demonstrated technology-assisted total knee arthroplasties (TKAs) steadily increased from 1.2% in 2005 to 7.0% in 2014 [1]. Current methods include robotic arm-assisted procedures, robot-guided cutting jigs, and robotic milling using a range of active to passive systems [2]. Semi-active robotic systems are the current market leaders in utilization. These types of robotics provide a haptic guide to prepare bone cuts based on a preoperative template. Robotics in total joint arthroplasty (TJA) have several proposed benefits for surgeons and patients. Notably, robotic arm-assisted TJA have been shown to be more accurate than manual on radiographic evaluation of component position [3,4]. However, the evidence is variable, and robotics has yet to translate to improvements in clinical outcomes [5,6]. Despite the lack of definitive long-term benefits, robot-assisted arthroplasty continues to gain popularity among surgeons [7].

* Corresponding author. Department of Orthopedic Surgery, Mayo Clinic Arizona, 5881 E Mayo Blvd., Phoenix, AZ 85054, USA. Tel.: +1 480 326 7636.
E-mail address: Brinkman.Joseph@mayo.edu

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The reason for increased utilization of robotics is likely multifactorial, but patient demand may be a contributing factor. Industry marketing campaigns have introduced the public to the allure of robotic surgery, which has led to patients inquiring about robotics in surgical consultations. However, this trend has not been well described in the literature. One way to assess public interest on the topic is to evaluate internet search data. Google Trends is one open-source platform that allows users to track historical search data as well as current trends. Recently Google Trends has been utilized to evaluate interest in platelet-rich plasma (PRP) injections for hip and knee osteoarthritis [8]. Currently there is no available literature on public interest in robotic THA and TKA based on internet searches.

The purpose of this study is to assess public interest in robotic THA and robotic TKA over a 10-year period using Google Trends analysis. Google Trends is a free and open-source tool that tracks online search volume. The data are presented as a relative search volume (RSV), which is the search volume of a term compared with the peak popularity of a certain term during a defined time frame. The peak popularity of a term is assigned a value of 100, and for any desired search term, Google Trends reports an RSV stratified by geographic location and time. We hypothesize that searches related to robot-assisted total hip and knee arthroplasties have increased substantially over the last decade and that these searches have outpaced searches for conventional TJAs during the same time period.

Material and methods

Search queries

The search terms of our study were designed according to a previous Google Trends analyses on hip and knee arthritis. Search terms related to robotic hip and knee arthroplasties were searched in addition to robotic arthroplasty as a whole. Moreover, search terms representing normal hip and knee arthroplasty (ie, non-robotic) were also utilized in order to provide a comparative group for analysis. Accordingly, the following keywords relating to robotic hip and knee arthroplasty were used: “robotic”, “mako”, “knee”, “hip”, “joint”, “surgery”, “replacement”, “arthroplasty”. Additionally, the following keywords relating to general arthroplasty were used: “arthroplasty”, “replacement”, “surgery”, “hip”, “knee”, “joint”, and “total”. Only Google Trend search data from the United States geographic area were utilized in this analysis.

Temporal trends

To examine temporal trends in public interest for robotic THA and TKA, various combinations of the previously mentioned keywords were entered into the Google Trends tool. The resulting data for interest volume per term were compiled into a database. The data were collected for a 10-year interval between January 1, 2011, and December 31, 2020, throughout the United States. The best-fit linear, quadratic, and exponential growth models were used, with the strength of each model being determined by standard measures of accuracy, including mean absolute percentage error (MAPE), mean absolute deviation (MAD), and the mean squared deviation (MSD). MAPE is a measure of prediction accuracy and measures the accuracy as a percentage. A lower MAPE value signifies a model with a lower error and better accuracy. MAD is a measure of variability that designates the average distance between an observation and its mean. A lower MAD value signifies a model with less spread and variability. MSD is a measurement of how close a regression line is to a set of data points. The lower the MSD value, the better the forecast. Together, these 3 measurements were used to effectively assess the strength and fit of a model (eg, linear, quadratic, and exponential). The model with the lowest MAPE, MAD, and MSD measurements was used for further analysis. To assess whether the public interest in robotic THA and TKA increased significantly over the 10-year time interval, a regression analysis was utilized.

Seasonal trends

To determine seasonal trends of interest in robotic THA and TKA, the monthly Google Trends data from January 1, 2011, through December 31, 2020, were grouped by month and by season (spring = March-May, summer = June-August, fall = September-November, winter = December-February). Microsoft Excel (Microsoft Corp, Redmond, WA) was used for statistical analysis.

Results

Robotic hip arthroplasty

Between January 1, 2011, and December 31, 2021, Google Trends Data demonstrated a statistically significant increase in RSV of robotic hip arthroplasty, with an R^2 value of 0.522 and $P < .001$. These data represented a linear increase in search volume, as a linear model was the most accurate line of best fit. The measures of accuracy of MAPE, MAD, and MSD were 68.9, 3.9, and 33.4, respectively, in the linear model (Fig. 1).

The greatest interest in robotic hip arthroplasty was during the months of June, September, and November, and the least interest was observed in April and August. The most interest was generated for robotic hip arthroplasty during the fall season (Fig. 2).

Robotic knee arthroplasty

Between January 1, 2011, and December 31, 2021, Google Trends Data demonstrated a statistically significant increase in RSV of robotic knee arthroplasty, with an R^2 value of 0.760 and $P < .001$. These data represented an exponential increase in search volume, as an exponential model was the most accurate line of best fit. The measures of accuracy of MAPE, MAD, and MSD were 6.6, 0.4, and 0.3, respectively, in the exponential model (Fig. 3).

The greatest interest in robotic knee arthroplasty was during the months of June, August, and November. The least interest was observed in March, May, and September. The most interest was generated for robotic knee arthroplasty during the summer season.

Conventional hip and knee arthroplasty

Over the evaluated time period, Google Trends Data demonstrated linear increases in RSV related to conventional hip and knee arthroplasty. For hip arthroplasty, this increase demonstrated an R^2 value of 0.78745 and $P < .001$ (Fig. 4), while for knee arthroplasty, the R^2 was 0.6977 and $P < .001$ (Fig. 5). These data represented linear increases in search volume, as the linear model was the most accurate line of best fit for both trends. For hip arthroplasty, the measures of accuracy of MAPE, MAD, and MSD in the model were 4.8, 2.9, and 15.8, respectively, and for knee arthroplasty, these measures of accuracy were 5.2, 3.2, and 17.4, respectively.

Data for both conventional and robotic hip and knee arthroplasties were combined to allow comparison between robotic vs conventional arthroplasty for both joints (Fig. 6). Between January 1, 2011, and December 31, 2021, Google Trends Data demonstrated a statistically significant increase in conventional TJA RSV, with an R^2 value of 0.800 and $P < .001$. These data represented a linear increase in search volume, as a linear model was the most accurate line of best fit. For this same comparison in the robotic arthroplasty group, this increase was noted to be exponential with an R^2 value of 0.744 and $P < .001$.

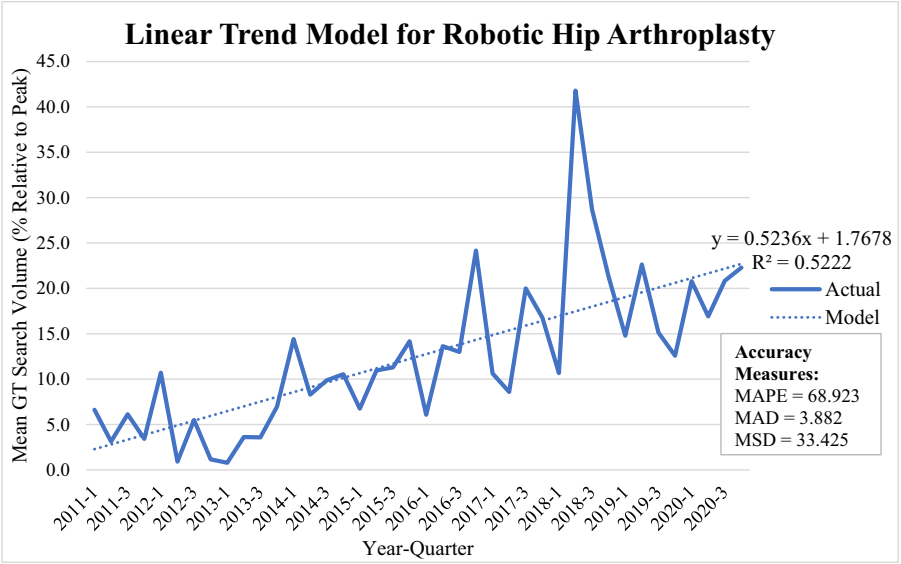

Figure 1. Linear trend model for robotic hip arthroplasty between January 1, 2011, and December 31, 2020. GT, Google Trends.

Discussion

The goal of this study was to assess public interest in robotic and nonrobotic TJAs over a 10-year period. Our results demonstrated a significant linear increase in online searches related to nonrobotic TKA and THA throughout the study period. The online search volume for robotic hip arthroplasty was significant and linear, while that of robotic knee arthroplasty was significant and exponential. When combined, robotic joint arthroplasty demonstrated an exponential trend over the 10-year period. This increase was noted to be statistically significant when compared with nonrobotic arthroplasty search volume.

Previous work has demonstrated increasing information-seeking behavior of patients in the digital age [9]. In orthopedics, it has been previously noted that patients are increasingly searching for treatments such as PRP and stem cell injections for osteoarthritis [8,10]. The current study adds to the limited number of reports regarding patient interest in orthopedics, and to our knowledge, it presents the first analysis to focus on surgical factors or technique with regard to hip and knee arthroplasty. Our results align with previous reports, and together, they demonstrate that patients are increasingly searching for information related to emerging or advanced treatments in orthopedics. For each of the categories examined, searches for conventional arthroplasty were higher in overall volume than searches for robotic arthroplasty. This may be explained by a greater overall awareness of conventional arthroplasty considering the recency of the technological advancement that has made robotic assistance affordable. However, the trends examined over time demonstrated a significant linear increase in searches related to robotic hip arthroplasty and a significant exponential increase in searches for robotic knee arthroplasty over the 10-year study period. Combined together, robotic arthroplasty demonstrated a significantly greater and exponential trend than conventional arthroplasty. The trends reported in the current study are the first to note an exponential, rather than

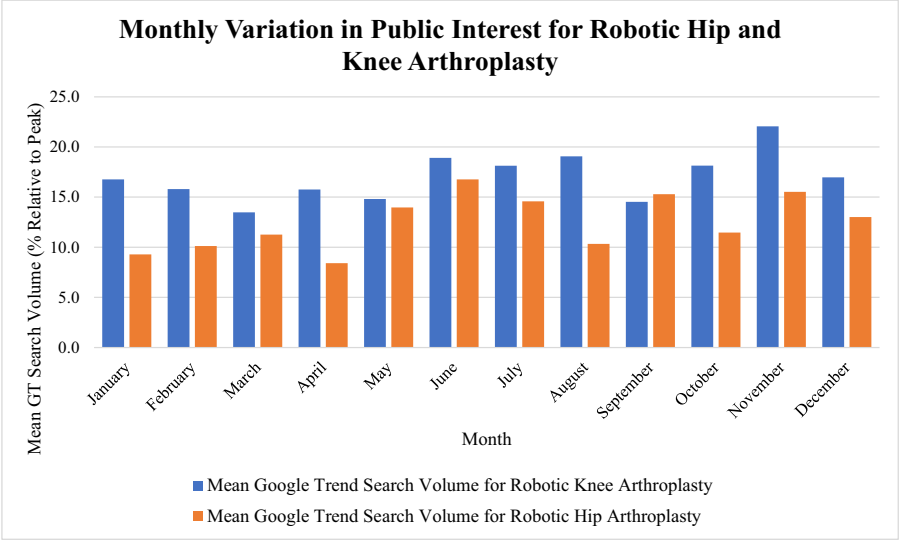

Figure 2. Monthly variation in public interest for robotic hip arthroplasty vs robotic knee arthroplasty between January 1, 2011, and December 31, 2020. GT, Google Trends.

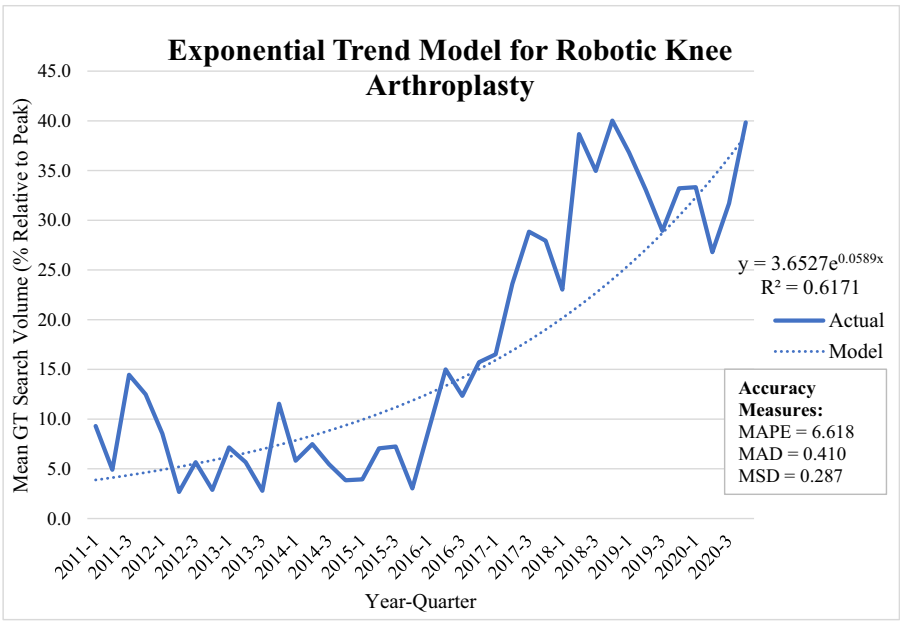

Figure 3. Exponential trend model for robotic knee arthroplasty between January 1, 2011, and December 31, 2020. GT, Google Trends.

linear, increase in online search trends. This suggests that online interest for robotic arthroplasty is increasing at a greater rate than that for other examined treatments and may be expected to continue at an increased pace.

Although first-generation robots were originally introduced in the early 2000s, several robotic systems are available in the United States including the Mako (Styker, Fort Lauderdale, FL), Navio (Smith & Nephew Inc., Memphis, TN), ROSA (Zimmer Biomet, Warsaw, IN), OMNIBotics (OMNIlife Science, Raynham, MA), and TSolution One (Think Surgical Inc., Fremont, CA). The increasing patient interest in robotic vs nonrobotic arthroplasty is currently not supported by evidence of superior clinical outcomes utilizing these systems despite their theoretical advantages. In traditional knee arthroplasty, it is well documented that accurate implant positioning and balanced flexion-extension gaps significantly affect implant stability, implant survivorship, and patient outcomes [11-13]. As such, there have been several previous investigations into implant positioning, limb length and alignment, learning curve, postoperative outcomes, and cost-effectiveness with robotic arthroplasty with an attempt to demonstrate advantages. When compared to conventional jig-based TKA, robotic knee arthroplasty has been associated with increased accuracy, improved implant positioning, and a reduction in outliers [3,14-16]. However, this has not translated into clinical benefits for patients at midterm to long-term follow-up [17,18]. Similarly, robotic hip arthroplasty has been correlated with improved implant

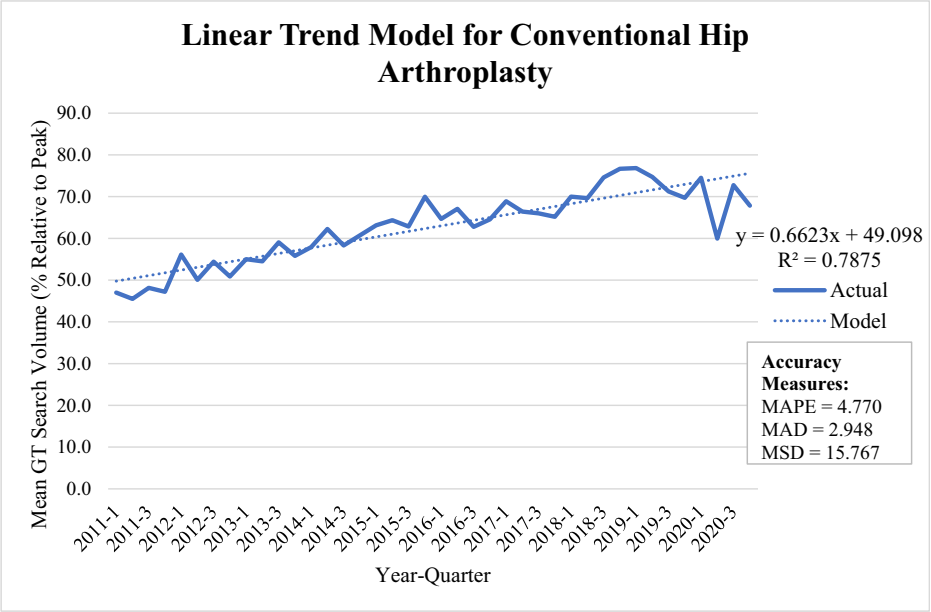

Figure 4. Linear trend model for conventional hip arthroplasty between January 1, 2011, and December 31, 2020. GT, Google Trends.

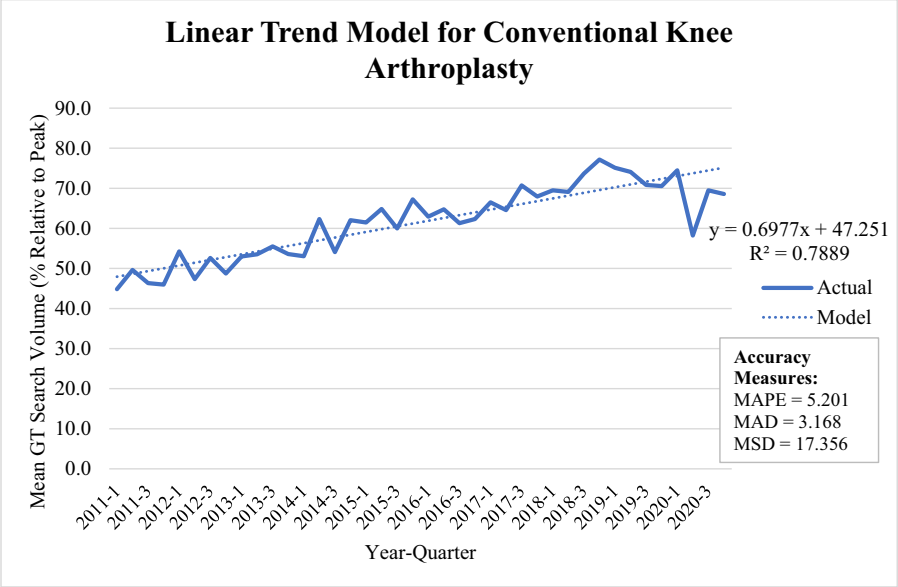

Figure 5. Linear trend model for conventional knee arthroplasty between January 1, 2011, and December 31, 2020. GT, Google Trends.

positioning, which in theory would allow for an ideal center of rotation, biomechanics, and wear rates; however, there have yet to be a report of improved functional outcomes, leg length discrepancy, or postoperative complications compared with conventional total hip arthroplasty [19-22]. Some of these conflicted findings may be reflected in the heterogeneity of the research design or the implant studied. Therefore, it seems that the increased public interest in robot-assisted arthroplasty does not reflect the equivalency being reported between robotic and traditional arthroplasty with regard to patient outcomes demonstrated in these reports. There is a need for further high-quality studies dedicated to patient outcomes in robotic arthroplasty considering the current literature in addition to the rising public interest.

As noted, clinical trials are incomplete and conflicted regarding potential clinical benefits of robotic over conventional TJA, yet public interest appears to be rapidly increasing. The reason for this increase in public awareness and interest in robot-assisted joint arthroplasty is likely multifactorial. It is well recognized that patients are increasingly using the internet to access health-related information, and some reports suggest it is the preferred means of obtaining information [23,24]. Particularly in cases involving new or emerging technology, this online research can contribute to an exaggerated understanding of the benefits vs risk of treatments, known as “science hype” [25]. A recent study by Pagani et al. [26] demonstrates that this concept may inflate patient perceptions of robotic arthroplasty, as they demonstrated in a survey of 588 randomly selected patients that the majority of respondents believed robot-assisted arthroplasty led to better results (69%), fewer complications (69%), less pain (59%), and a faster recovery (62%) than conventional arthroplasty despite there being

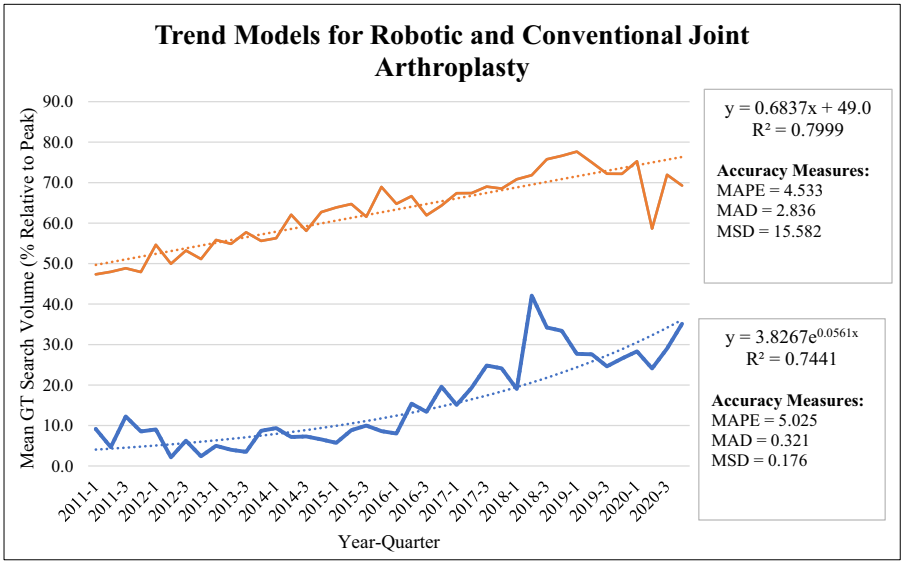

Figure 6. Trend models for conventional (linear; orange) and robotic (exponential; blue) total hip and knee arthroplasties between January 1, 2011, and December 31, 2020. Trend lines demonstrated by actual volume (solid) and modeled volume (dashed). GT, Google Trends.

no literature to demonstrate superiority in any of these realms. This sense of overestimating the capabilities of robotic arthroplasty among the public may lead to misinformation and unrealistic preoperative expectations among patients. This early interest in robotic arthroplasty has likewise been promulgated by industry partners as companies have invested heavily on the promise of robotics [27]. Additionally, the required support staff and expense of robotics require a certain threshold for the average arthroplasty surgeon to break even, which could impact clinical decision-making and may influence surgeons to overutilize this resource once they have invested [28,29]. Although there is subjective pressure driven by patient demand, perceived psychological patient satisfaction, and industry as well as surgeon advertising, objective data should precede widespread application of the technology.

Our results also allow for analysis of the impact that seasonal variation and the COVID-19 pandemic had on public interest in robotic arthroplasty. The greatest interest in robotic knee arthroplasty was in the summer, while that toward robotic hip arthroplasty was in the fall. Findings regarding public interest in robotic hip arthroplasty are similar to those regarding public interest in PRP therapy for hip and knee osteoarthritis, which was found to peak in October [10]. It is challenging to understand this trend in detail but may reflect an attempt by patients to seek treatment toward year end once deductibles have been met. Additionally, decreases in online search volume were noted during the COVID-19 pandemic for robotic knee and robotic hip arthroplasties. Similar findings have been reported in public interest toward nonrobotic TJA as a result of the pandemic [30]. These results likely reflect decreased willingness to attend health clinics, interact with the public, or perceived inability to access this care during the pandemic.

Several limitations should be considered along with this study. First, although Google Trends provides nation-wide search volume data, it has a limited scope. It does not include demographic information, geographic reports, or absolute search volume. Accordingly, it is challenging to analyze the specific groups analyzed in the current study, and the groups included for analysis may not represent the entire US population. It also does not include information regarding online search volume performed using other online search engines. Lastly, it remains unclear how closely online search volume correlates with actual public interest, requests, or expectations regarding robotic TKA or THA, but we believe search volume to be a useful and meaningful proxy measure for patient interest.

Conclusions

Our study demonstrates that public interest in robotic TJA has increased significantly from 2011 through 2020. When compared with online search volume for conventional arthroplasty, this increasing growth is statistically significant. Public interest in robotic arthroplasty is anticipated to continue to increase, and care providers should be aware of this trend that impacts patient perceptions and expectations. Despite significant growth in interest for robotic arthroplasty, there is incomplete evidence supporting its use over nonrobotic arthroplasty. Additional high-quality studies are needed to inform provider decision-making and appropriately guide public interest in robot-assisted arthroplasty.

Conflicts of interest

The authors declare that there are no conflicts of interest.

References

[1] Antonios JK, Korber S, Sivasundaram L, et al. Trends in computer navigation and robotic assistance for total knee arthroplasty in the United States: an analysis of patient and hospital factors. Arthroplasty Today 2019;5:88.
[2] Jacofsky DJ, Allen M. Robotics in arthroplasty: a comprehensive review. J Arthroplasty 2016;31:2353.
[3] Deckey DG, Rosenow CS, Verhey JT, et al. Robotic-assisted total knee arthroplasty improves accuracy and precision compared to conventional techniques. Bone Joint J 2021;103-B:74.
[4] Ng N, Gaston P, Simpson PM, et al. Robotic arm-assisted versus manual total hip arthroplasty. Bone Joint J 2021;103-B:1009.
[5] Agarwal N, To K, McDonnell S, Khan W. Clinical and radiological outcomes in robotic-assisted total knee arthroplasty: a systematic review and meta-analysis. J Arthroplasty 2020;35:3393.
[6] Jeon S-W, Kim K-I, Song SJ. Robot-assisted total knee arthroplasty does not improve long-term clinical and radiologic outcomes. J Arthroplasty 2019;34:1656.
[7] Sherman WF, Wu VJ. Robotic surgery in total joint arthroplasty: a survey of the AAHKS membership to understand the utilization, motivations, and perceptions of total joint surgeons. J Arthroplasty 2020;35:3474.
[8] Strotman PK, Novicoff WM, Nelson SJ, Browne JA. Increasing public interest in stem cell injections for osteoarthritis of the hip and knee: a Google trends analysis. J Arthroplasty 2019;34:1053.
[9] Pesälä S, Virtanen MJ, Sane J, et al. Health information-seeking patterns of the general public and indications for disease surveillance: register-based study using lyme disease. JMIR Public Health Surveill 2017;3:e86.
[10] Cohen SA, Zhuang T, Xiao M, et al. Google trends analysis shows increasing public interest in platelet-rich plasma injections for hip and knee osteoarthritis. J Arthroplasty 2021;36(10):3616.
[11] Devers BN, Conditt MA, Jamieson ML, et al. Does greater knee flexion increase patient function and satisfaction after total knee arthroplasty? J Arthroplasty 2011;26:178.
[12] Scott CEH, Oliver WM, MacDonald D, et al. Predicting dissatisfaction following total knee arthroplasty in patients under 55 years of age. Bone Joint J 2016;98-B:1625.
[13] Abdel MP, Ledford CK, Kobic A, Taunton MJ, Hanssen AD. Contemporary failure aetiologies of the primary, posterior-stabilised total knee arthroplasty. Bone Joint J 2017;99-B:647.
[14] Hampp EL, Chughtai M, Scholl LY, et al. Robotic-arm assisted total knee arthroplasty demonstrated greater accuracy and precision to plan compared with manual techniques. J Knee Surg 2019;32:239.
[15] Park SE, Lee CT. Comparison of robotic-assisted and conventional manual implantation of a primary total knee arthroplasty. J Arthroplasty 2007;22:1054.
[16] Bellemans J, Vandenneucker H, Vanlauwe J. Robot-assisted total knee arthroplasty. Clin Orthop Relat Res 2007;464:111.
[17] Song E-K, Seon J-K, Yim J-H, Netravali NA, Bargar WL. Robotic-assisted TKA reduces postoperative alignment outliers and improves gap balance compared to conventional TKA. Clin Orthop Relat Res 2013;471:118.
[18] Yang HY, Seon JK, Shin YJ, Lim HA, Song EK. Robotic total knee arthroplasty with a cruciate-retaining implant: a 10-year follow-up study. Clin Orthop Surg 2017;9:169.
[19] Rösler J, Perka C. The effect of anatomical positional relationships on kinetic parameters after total hip replacement. Int Orthop 2000;24:23.
[20] Siebel T, Käfer W. [Clinical outcome following robotic assisted versus conventional total hip arthroplasty: a controlled and prospective study of seventy-one patients]. Z Orthop Ihre Grenzgeb 2005;143:391.
[21] Chen X, Xiong J, Wang P, et al. Robotic-assisted compared with conventional total hip arthroplasty: systematic review and meta-analysis. Postgrad Med J 2018;94:335.
[22] Karunaratne S, Duan M, Pappas E, et al. The effectiveness of robotic hip and knee arthroplasty on patient-reported outcomes: a systematic review and meta-analysis. Int Orthop 2019;43:1283.
[23] Jacobs W, Amuta AO, Jeon KC. Health information seeking in the digital age: an analysis of health information seeking behavior among US adults. Cogent Social Sci 2017;3:1302785.
[24] Eheman CR, Berkowitz Z, Lee J, et al. Information-seeking styles among cancer patients before and after treatment by demographics and use of information sources. J Health Commun 2009;14:487.
[25] Caulfield T, Condit C. Science and the sources of hype. Public Health Genomics 2012;15:209.
[26] Pagani NR, Moverman MA, Puzzitiello RN, et al. Online crowdsourcing to explore public perceptions of robotic-assisted orthopedic surgery. J Arthroplasty 2021;36:1887.
[27] Booth RE, Sharkey PF, Parvizi J. Robotics in hip and knee arthroplasty: real innovation or marketing ruse. J Arthroplasty 2019;34:2197.
[28] Banerjee S, Cherian JJ, Elmallah RK, et al. Robotic-assisted knee arthroplasty. Expert Rev Med Devices 2015;12:727.
[29] Williams SB, Prado K, Hu JC. Economics of robotic surgery: does it make sense and for whom? Urol Clin North Am 2014;41:591.
[30] Jella TK, Samuel LT, Acuña AJ, Emara AK, Kamath AF. Rapid decline in online search queries for hip and knee arthroplasties concurrent with the COVID-19 pandemic. J Arthroplasty 2020;35:2813.