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Comprehending the impact of #Breastcancer, #Breastsurgery and related hashtags on Twitter: A content and social network cross-sectional analysis #Breastcancer#Breastsurgery

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ABSTRACT

Background: Early detection along with improved locoregional and systemic therapies have decreased breast cancer mortality and allowed for the clinical implementation of breast conserving surgical options, in turn reducing the clinical and psychosocial impact of mastectomy. To what extend this has been successfully conveyed through social media for breast cancer awareness, has not been previously investigated.

Methods: This study presents a content and social network cross-sectional descriptive study of Twitter and Google trends data worldwide from platform launch (2006 and 2004 respectively) until May 15th, 2022, in agreement with the STROBE guidelines. Tweets associated with the hashtags #Breastcancer, #Breastsurgery, #Oncoplasticsurgery, #Mastectomy, #Breastreconstruction, #Breastconservingsurgery were licensed and downloaded through the Vincitas and Tweetbinder online platforms. Associated available demographics, namely username, biography, location, date and language of post, were extracted from the Twitter dataset while interest percentage, location and language of search were extracted from the Google trends dataset.

Results: A total of 390111 unique tweets were generated by 127284 unique users, with 2 users engaging with all six hashtags. Original tweets constituted on average 39.1% [Min 30.7% to max 47.2%] of the total. Hashtag frequency increased on Twitter for all six searches during October, the breast-cancer awareness month, but not on Google trends. Cancer survivors engaged much more often with the hashtag #Breastcancer and #Mastectomy, whereas #Breastsurgery, #Oncoplasticsurgery, #Breastconservingsurgery, #Breastreconstruction were mostly used by health professionals.

Conclusion: In this large qualitative and quantitative dataset, geo-temporal oscillations on Twitter and Google trends for hashtags relevant with breast cancer provide preliminary insights on information flow and user engagement. Understanding the effective use of social media platforms may provide the niche for disseminating evidence and promoting education on the surgical options of patients with breast cancer.

1. Introduction

Multiple systematic reviews have highlighted that online communities may improve the welfare amongst breast cancer survivors, by enabling them to navigate through cancer- or treatment-related experiences whilst obtaining relevant information [1,2]. Recently, a meta-analysis of 39 studies, assessing the effectiveness of social media (SoMe) and mobile health interventions for cancer screening, demonstrated that mobile reminders and social media education prompted more participants in

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engaging with screening programmes [Odds Ratio; OR 1.49 (95% confidence interval (CI) 1.31–1.70)] [3]. Twitter analysis studies in the context of breast cancer (BC) have mainly focussed on information exchange pattern prediction and user hubs or patient well-being implications of online communities [4,5].

Breast cancer remains the most diagnosed cancer among women worldwide with a steadily increasing trend [6]. In 2020, there were 2.3 million estimated new cases, resulting in 684 996 BC related deaths, with a disparate number occurring in low-income countries [7]. Despite mastectomy (Mx) being the historical mainstay of BC for decades, the oncologic safety of breast conserving surgery (BCS) followed by radiotherapy (RT), has been confirmed with 20-year survival data, in landmark randomised control trials (RCTs) [8,9]. Building upon the establishment of BCS + RT oncological safety, further steps in improving operative morbidity and aesthetic outcomes, were taken with the introduction of oncoplastic techniques. Oncoplastic Breast Surgery (OBS) has provided solutions regarding the significant psychosocial and clinical morbidity that follows Mx, allowing for the expansion of breast conservating surgical options without compromising oncological outcomes [10–12]. Of note, the increasing body of contemporary clinical evidence suggests that survival rates after BCS + RT appear to even be better in comparison to Mx, albeit potential selection bias and variable follow-up timelines [13–19]. Nonetheless, the paradox of rising Mx trends and even contralateral Mx in the absence of clinical indication has been noted, with relevant studies suggesting that this may be largely patient driven [16,20].

Whether social media may have already and could in future, educate life choices such as mastectomy or breast conservation amongst breast cancer patients, has not been previously investigated. The present social network and content analysis of Twitter data and Google trends aims to highlight current patterns of user engagement with selected hashtags, namely #Breastcancer #Breastsurgery #Oncoplasticsurgery, #Breastconservingsurgery #Breastreconstruction and #Mastectomy make predictions as to how these networks of information may influence health outcomes and patient choices.

2. Methods

The present study is a content and social network cross-sectional analysis, conducted according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [21]. The present study aimed to clarify whether SoMe successfully capitalise on their potential as informative means in conveying surgical options amongst breast cancer patients, healthcare professionals and other counterparts.

2.1. Sample size calculation

To comprehend this interaction, we hypothesised that, if SoMe truly provide means of information and interaction flow to their full potential, there should not be any discordance across hashtags for patients/survivors (considered as the exposed group) in comparison to all other counterparts (unexposed group) users. To calculate the adequacy of our cohort sample size in light of ensuring statistical creditability of outcomes, we calculated the ratio of users confidently identified as patients/survivors [N = 27905] and those [N = 140972] categorised in other pre-defined user groups, including patient advocacy and support groups and non-profit organisations, medical professionals and researchers, medical societies including public hospital units, companies (including merchandise and private clinics and hospitals), marketing companies and representatives, journals/journalists and writers (medical and lay included), entrepreneur (individual and companies). Users were categorised into groups of interest for the purposes of the present study through manual indexing of the available username and biography (Fig. 1). If categorization was not feasible due to the lack of discriminatory information, users were categorised as unknown, therefore reducing the possibility of Twitter bots negating data quality. From this calculation, we excluded users [N = 6591] not confidently categorised in any of the pre-defined groups. Therefore, exposed vs. unexposed group ratio was 1:5. In our null hypothesis e.g., similar representation of all involved parties across all hashtags, we assumed a 10% miss for the patient group (those who do not tweet or hashtag) and a 9% for those are professionally involved (patient advocates/authorities, medical professionals, industry) who engage with hashtags as part of trade interactivity. These values correspond to outcomes of 90% for the exposed and 91% for the unexposed groups. In unmatched cohort sample size calculation, of two-sided confidence interval pre-set at 95% (equivalent to $P < 0.0001$) and power of 95%, a total of 131344 users [N = 21891 exposed and N = 109453 unexposed] users should be included as minimum to achieve acceptable statistical significance. Our cohort was significantly larger than the suggested sample size [22].

2.2. Twitter dataset

Tweets associated with the following hashtags #Breastcancer #Breastsurgery #Oncoplasticsurgery #Breastconservingsurgery #Breastreconstruction and #Mastectomy were downloaded from Twitter creation (2006) till the 15th of May 2022 through the Vincitas and Tweet binder online platform purchased license. Date of post, username, biography and location, tweet description (organic, retweets, and replies) and language of post were collected (Fig. 1). Data containing sensitive user information was anonymised and individual tweets, post deduplication were allocated individual random numbers (Random Number Generator Freeware) to ensure user concealment. Key file stored in a password protected NHS computer (Fig. 1).

2.3. Google Trends dataset

“Breast Cancer”, “Breast Surgery”, “Oncoplastic Surgery”, “Breast Conserving Surgery”, “Breast Reconstruction” and “Mastectomy” were utilised as search terms to explore the Google trends platform. Of note, Google Trends does not display total numbers of searches over time but provides population-adjusted data reflecting the popularity of the search at a given time (interest %). Therefore, large populations with large numbers of searches will not necessarily produce the greatest search interest. Google trends (interest, language, location) were collected from the initial Google public offering year (2004) till the 15th of May 2022. No user concealment or randomisation was necessary for this dataset.

2.4. Incidence and mortality of breast cancer dataset

Age standardised rates (ASR) of breast cancer worldwide incidence and mortality data were collected between 1998 and 2021 from the Globocan database [7].

2.5. Study primary and secondary outcomes

The primary outcomes of this present study were to identify the a) frequency and correlation of trending hashtags and related search terms between Twitter and Google Trends from 2006 till 2022. b) the characteristics and interactions of users among hashtags [mean, SD]. Secondary outcomes included a) correlation of Twitter and Google temporal changes along with pattern

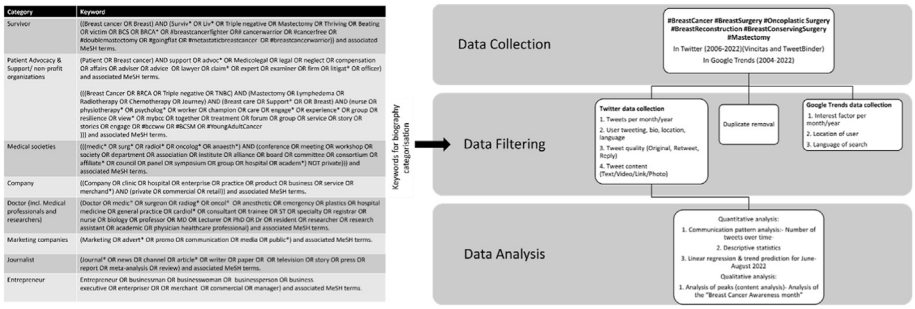

Fig. 1. Flowchart of Methods and text mining keywords.

prediction, causation and putative interactions of tweets and google trend interest index, expressed as linear regression slope value and 95% CI.

2.6. Qualitative and statistical analysis

Descriptive statistics, more specifically standard curve interpolation and simple linear regression analysis between continuous variables, month/year (independent variable) and number of tweets/google interest (dependent variable) were conducted with GraphPad Prism V.9. Friedman comparison test was implemented to allow for inter-hashtag variation among user groups of interest. A p-value <0.05 was considered statistically significant. Mortality and incidence of breast cancer are shown as age standardised rate (ASR) Graphical representation of data was undertaken with GraphPad Prism V.9. Global map depicted in Fig. 6 created with Mapchart online freeware [23]. Statistical analysis of user distribution across analysed hashtags was conducted with GraphPad Prism V.9 (Ordinary ANOVA). P value data were visually represented by edge thickness of Cytoscape network V. 3.9 [24].

3. Results

3.1. Temporal patterns of user engagement in Twitter and Google trends

The incidence ASR of breast cancer worldwide has been steadily increasing reaching to 47.8 per 100000 people in 2020 (Fig. 2A) [7]. Despite this alarming increase, the mortality ASR has displayed the inverse pattern decreasing from 17.8 per 100000 in 1998 to 13.6 in 2020 (Fig. 2A). We sought to explore how these trends are reflected in modern social media and primary search engines and how changes in surgical management of breast cancer have been communicated though these platforms in the last decades. Google interest for selected keywords (Fig. 2B) and historical tweets (Fig. 2C) associated with the predefined hashtags, were analysed from platform conception till the 15th of May 2022. A total of 390111 unique tweets were generated by 127284 users (Fig. 2B). The #Breastcancer hashtag retrieved, as expected, the highest number of tweets at 307249, #Breastsurgery 36234 tweets while #Mastectomy retrieved 41147 tweets.

Looking into hashtags corresponding to different types of surgery, #Breastreconstruction claimed 2493 tweets, followed by #Oncoplasticsurgery with 1578 tweets, and #Breastconservingsurgery with 1466 tweets (Fig. 2C). Simple linear regression slopes were significantly different between hashtag groups [$P < 0.0001$] with a noticeable uptrend of #Breastcancer tweets especially since 2008 onwards (Fig. 2C). Of interest, #Breastsurgery and #Mastectomy slopes did not display any significant difference ($P = 0.63$). Similar, yet not as notable, uptrend was recorded for #Breastsurgery, #Breastreconstruction, #Breastconservingsurgery and #Oncoplasticsurgery hashtags with tweet numbers peaking between 2017 and 2018. Similar trends were not recorded in the Google trends dataset (Fig. 2B). Simple linear regression slopes for "Breast Cancer" as search term "Breast Surgery", "Breast Conserving Surgery, "Breast Reconstruction" and "Oncoplastic Surgery" displayed a downtrend except for "Mastectomy" (Fig. 2C). Slope comparison between Breast Surgery, Mastectomy and all other breast conserving options highlighted that the first two hashtags followed a congruent trend increase ($P = 0.97$) in contrast to all other breast conserving options ($P = 0.048$) (Fig. 2D).

To further investigate temporal factors that may affect Twitter and Google trends pattern differences, we focussed the analysis on a monthly breakdown between years 2018–2021. Evidently, number of tweets and google interest increased for the #Breastcancer hashtag and relevant search term, every October coinciding with the Breast Cancer awareness month. Cumulative mean of tweets for all months between 2018 and 2021 was 4143 tweets [SD: 2569] with an October$^{2018\text{-}2021}$ increased mean of 17813 tweets [SD: 1364] (Fig. 3A). A similar uptrend with tweet numbers doubling during the October months between 2018 and 2021, was observed for all the other hashtags, namely #Oncoplasticsurgery, #Breastconservingsurgery, #Breastreconstruction and #Mastectomy except for #Breastsurgery [cumulative mean$^{2018\text{-}2021}$ 431.3 [SD: 130.3] vs. October $^{2018\text{-}2021}$ 532.5 [SD: 124.0] (Fig. 3A).

Regarding Google trends analysis, a similar spike of interest was noted for #Breastcancer, #Breastsurgery, #Breastreconstruction, #Oncoplasticsurgery, #Mastectomy in October $^{2018\text{-}2021,}$ in comparison to other monthly data. Of note, in contrast to Twitter data, #Breastconservingsurgery was the search term not congruently yielding a doubling of interest in October months (Fig. 3B). **3.2 Qualitative characteristics of users**.

There were 127284 unique users across all hashtags, of which 95027 have interacted with the #Breastcancer hashtag, 7467 with #Breastsurgery, 451 with #Breastconservingsurgery, 920 with #Breastreconstruction 22880 with #Mastectomy and 539 with the #Oncoplasticsurgery hashtag (Fig. 4A–G). Main contributors for #Breastcancer hashtag were breast cancer survivors (21.36%) followed by merchandise and private health service companies (17.27%) and then by medical/allied healthcare professionals (13.68%) (Fig. 4C). This user distribution was significantly different in comparison to that of other hashtags except for #Mastectomy which displayed an even higher percentage of survivor engagement (31.24%) (Fig. 4C).

Overall, Breast cancer survivors comprised 5.44% of the #Breastsurgery, 5.01% of #Oncoplasticsurgery, 7.32% of #Breastconservingsurgery and 4.89% of #Breastreconstruction audience respectively. The highest engagement of merchandise, marketing and private health service companies was noted at 17.18% with #Breastreconstruction hashtag (Fig. 4B–F). In contrast, medical/

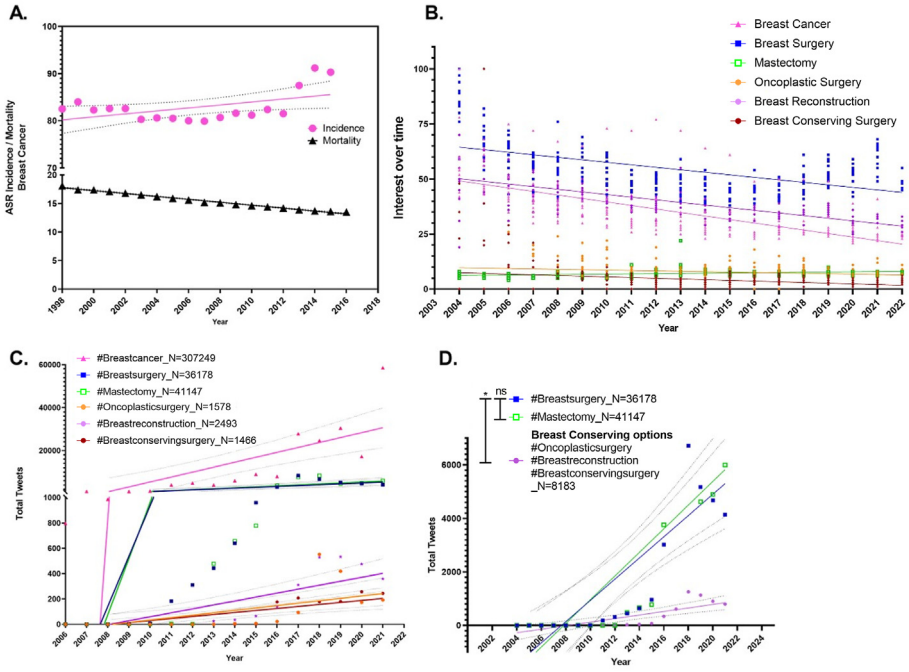

Fig. 2. Global incidence and mortality of breast cancer (A). Temporal changes in Google (B) and Twitter (C) trends for #Breastcancer, **#Breastsurgery, #Oncoplasticsurgery, #Breastreconstruction, #Breastconservingsurgery, Mastectomy hashtags and search terms**. (A) Age-standardized rate (World) per 100 000, incidence, (males and females) vs global mortality Age-standardized rate (World) per 100 000, mortality (males and females). Data obtained from Globocan.[2] (B) Google search interest over time and (C) Total tweets since Twitter creation #Breastcancer [Linear slope: 3319; 95% CI: 2304 to 4333], #Breastsurgery [Linear slope: 464.8; 95%CI: 258.7 to 670.9] #Oncoplasticsurgery [Linear slope: 22.8; 95% CI: 7.38 to 38.2] #Breastreconstruction [Linear slope: 69.2; 95% CI: 17.9 to 68.3] #Breastconservingsurgery [Linear slope: 43.5; 95% CI: 10.19 to 49.6], #Mastectomy [Linear slope: 461.4; 95%CI: 261 to 667.8]. Crude total numbers per year displayed as pink triangles (Breast Cancer) [Linear slope: −1.6; 95% CI: −1.8 to −1.3], blue squares (Breast Surgery) [Linear slope: −1.1; 95% CI: −1.4 to −0.9], orange circles (Oncoplastic Surgery) [Linear slope: −0.18; 95% CI: −0.48 to 0.12], green squares (Mastectomy)" [Linear slope: 0.1; 95% CI: −0.05 to 0.26], burgundy octagons (Breast conserving surgery)" [Linear slope: −0.32; 95% CI: −0.53 to −0.1] and purple stars (Breast reconstruction) [Linear slope: −1.2; 95% CI: −1.4 to −1], per year. (D) Slope comparison between #Breastsurgery (blue) #Mastectomy (green) and all breast conservation or reconstruction related hashtags (#Oncoplasticsurgery #Breastreconstruction #Breastconservingsurgery). Ordinary ANOVA of #Mastectomy vs #Breastsurgery [Dunnett's multiple comparisons test mean difference 139.9 (95% CI of diff. −1627 to 1907, P = 0.97)] and breast conservation or reconstruction related hashtags vs #Breastsurgery [Dunnett's multiple comparisons test mean difference 1779 (95% CI of diff. 12.04 to 3546, P = 0.048)]. Interpolation curve and 95% CI. Interest over time: Numbers represent search average interest (Monthly crude data/12) relative to the highest point on the chart for the given region and time. A value of 100 is the peak popularity for the term.

allied healthcare professional group was found to interact primarily with the #Oncoplasticsurgery (46.9%), #Breastsurgery (45.21%), #Breastconservingsurgery (43.68%), #Breastreconstruction (30.33%) hashtags and less so with #Breastcancer (13.68%) and #Mastectomy (19.15%) (Fig. 4A–F). Of note, only 2 (0.001% of total) users engaged with all six hashtags (Fig. 4H). Interestingly, significant user overlap (N = 12337; 9.7% of total users) was noted between #Breastcancer and #Mastectomy, which may explain the similarities in user distribution between these two hashtags (Fig. 4A, C, Fig. 4H).

3.2. Qualitative characteristics of tweets

Exploring the qualitative characteristics of tweets, most were posted in English followed by Spanish, a finding applicable to all hashtags (Fig. 5A). The distribution of organic tweets/retweets and replies was 46%–54% for #Breastcancer, 34%–66% for #Breastsurgery, 37%–63% for #Oncoplasticsurgery, 36%–64% for #Breastreconstruction, 39%–61% for #Breastconservingsurgery and 43%–57% for #Mastectomy (Fig. 5B). The hashtag with the highest organic tweet percentage was #Breastcancer. Finally, most users had not opted in for Twitter location services and thus country of tweet origin was pre-set at worldwide for 61.8% of the users [range per hashtag 72–52.5]. Of the users with enabled location services, of the majority of users engaging with the #Breastcancer (15.57%), #Breastsurgery (27.58%) #Breastconservingsurgery (14%) hashtags, were located in the United States of America (U.S.A) at the time of the tweet (Fig. 6A and B). Intriguingly, the same did not hold true for the #Oncoplasticsurgery (23.6%) and #Breastreconstruction (16.3%) hashtags, where most users were in Great Britain, at the time of the tweet going online (Fig. 6B).

4. Discussion

The present social network and content analysis of Twitter data and global Google trends aimed to clarify whether social media successfully capitalise on their potential as informative means in conveying mainstay and novel surgical options amongst breast cancer patients, healthcare professionals and other counterparts. A total of 390111 unique tweets were generated by 127284 unique users. While only 0.001% of users engaged with all hashtags, 9.7% of the total users engaged with #Mastectomy and #Breastcancer. Intriguingly, while popularity of all hashtags has been increasing with variable rates in Twitter, the same pattern did not hold true for Google trend interest analysis, a finding that may be highlighting a significant disparity between Twitter and Google search engagement. Of note, #Breastsurgery and #Mastectomy number of tweets vs. time slopes did not display a statistically significant difference. For #Breastsurgery, the uptrend may be due to medical professional engagement while for #Mastectomy due to survivor and patient advocacy organisation interaction.

Although the causative factors behind the differential user

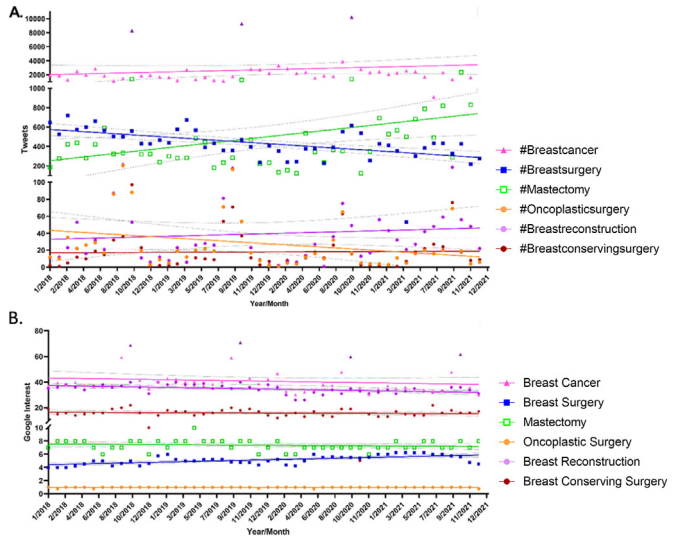

Fig. 3. Twitter engagement and Google search interest between 2018–2021 with monthly breakdown for #Breastcancer #Breastsurgery #Oncoplasticsurgery #Breastreconstruction, #Breastconservingsurgery, #Mastectomy. Crude total numbers per month displayed as Breast Cancer (pink triangle), #Breastsurgery (blue square), #Oncoplastic surgery (orange circle), #Breastreconstruction (purple star), #Breastconservingsurgery (burgundy octagon), #Mastectomy (green square) per year. Y axes reflect number of tweets for graph A whereas y axis reflects monthly interest for examined search term in graph B. Dark purple triangles indicate data collected on the month of October, (breast cancer awareness month).

engagement with different hashtags cannot be safely deduced from the present dataset, our data highlight a significant discordance across user hashtag engagement, therefore leading to the rejection of our main hypothesis, where the SoMe potential in education was considered fulfilled. Whether a rational connection that assumes that, if Twitter is used for purely educational purposes, then an equal engagement with Google should be expected stands, or if advertisement and trade are the sole tweet purposes, with ipso facto expected discordance with Google search frequency should be expected, remains to be elucidated. The overt nature of SoMe use, content and user engagement, has been strongly highlighted in the context of the COVID-19 pandemic misinformation with "super-spreader" accounts often associated with low-credibility sources engaging highly with a significant number of leaf users [25].

From another viewpoint, an intriguing finding was that patient awareness regarding availability of oncoplastic surgery remains limited, despite being a very popular topic amid breast surgeons. These findings are congruent with a USA-based survey study, in which one third of patients undergoing either breast conserving surgery or breast "removal" reported that they were not made aware by their clinicians of other surgical options [26]. It is possible that a proportion of the patients that reported unaware of other surgical options, may not have been eligible for those operations. Nonetheless, that is unlikely to apply for the entirety of that patient group and the lack of information giving warrants further investigation. Even though tools to assist clinicians in providing more comprehensive information giving sessions are available, the effectiveness of information sharing in correlation with patient outcomes through social media has not been assessed. Future studies exploring the impact of information sharing between medical professional and patient hubs, upon patient decision making would undoubtedly be valuable in comprehending the effectiveness of information flow and dissemination.

Over the past decades, correlating to the expansion of social media and the availability of internet access, the dynamics between healthcare professionals and patients have shifted. Patients have been increasingly turning to the Internet for knowledge on common infirmities, including clinical news and management options [21,22]. Equally medical professionals engage with Web 2.0 for educational purposes, clinical updates but also in particular cases for personal gain including personal brand building and internet publicity gain [27,28]. Such personal gain practices may compromise patient trust to the medical profession equally online and offline [29–31]. In recent years, the patient community has formed an expanding online, social media group in congruence with expanding capacities of social mass media services. However, how factual, and medically accurate is the information shared across these platforms remains debatable Whilst the online interaction between patients and medical professionals is expected, to an extend the information flow across these hubs remains largely unpredictable and stochastic. Therefore, to understand these information hubs or even their degree of overlap across social media may provide the means to harness them in view of building efficient and reliable communication and education hubs.

From a patient viewpoint, Twitter has undeniably offered valuable resource of psychological support and belonginess to a significant number of people battling cancer [32]. In this work, we highlight that patient engagement with BC surgical options and innovation remains low. On contrair, patients appear to engage more with more "traditional" treatment options, such as Mastectomy. Whether more intuitive selection of post hashtags or a more integrated marketing and patient education approach may assist in patient decision making remains to be implemented and retrospectively investigated in the future. Of note, such an approach should bear feasible alternatives in disseminating knowledge to patients without access to the internet or to those less versed to technological literacy [33,34]. Notably, in 2022, 70.4% of Twitter users were male, while only 29.6% female, highlighting yet another putative confounder in the context of BC information dissemination through this platform [36–38]. Furthermore, to preserve patient trust towards healthcare professionals in the virtual setting, a dire need for structured ethical guidelines has risen [33,34]. Preferably, these should extend beyond ethical considerations and incorporate practical directions as to optimal use of written language to decrease ambiguity and misinterpretation, how to effectively safety net online, when to escalate to face-to-face consultations and how to ensure continuity and integrity of care online [35–45]. Last but not least, the modern version of patient advocacy stems from the HIV/AIDS activism in the 1980s and breast cancer awareness movements in the 1990s [46]. Therefore, the steadily increasing participation of patient advocacy groups in breast cancer-related social media hubs should not come as a surprise despite the overall limited participation of female users in other Twitter hubs. To formulate strong support and information exchanging hubs, breast cancer survivors, family and social circle members created of one of the most robust health-related online community pulling in a significant proportion of the commercial as well as healthcare regulatory service interest. Whether the drive to initiate such a powerful online community lies in the need to reform systemic health barriers to meet individual need given the commonality of breast cancer and consequently the breadth of its financial and psychosocial impact, the increasing engagement of widely recognised individuals such as actresses or a combination of these and multiple other variables remains to be clarified [46,47]. Nonetheless, what is certain is that the raw power of the patient and patient advocacy group engagement with social media remains to be wielded to provide an accessible hub of evidence-based information dissemination and propagation.

The present work reflects an in depth, descriptive analysis of Twitter and Google search trends. Therefore, significant limitations

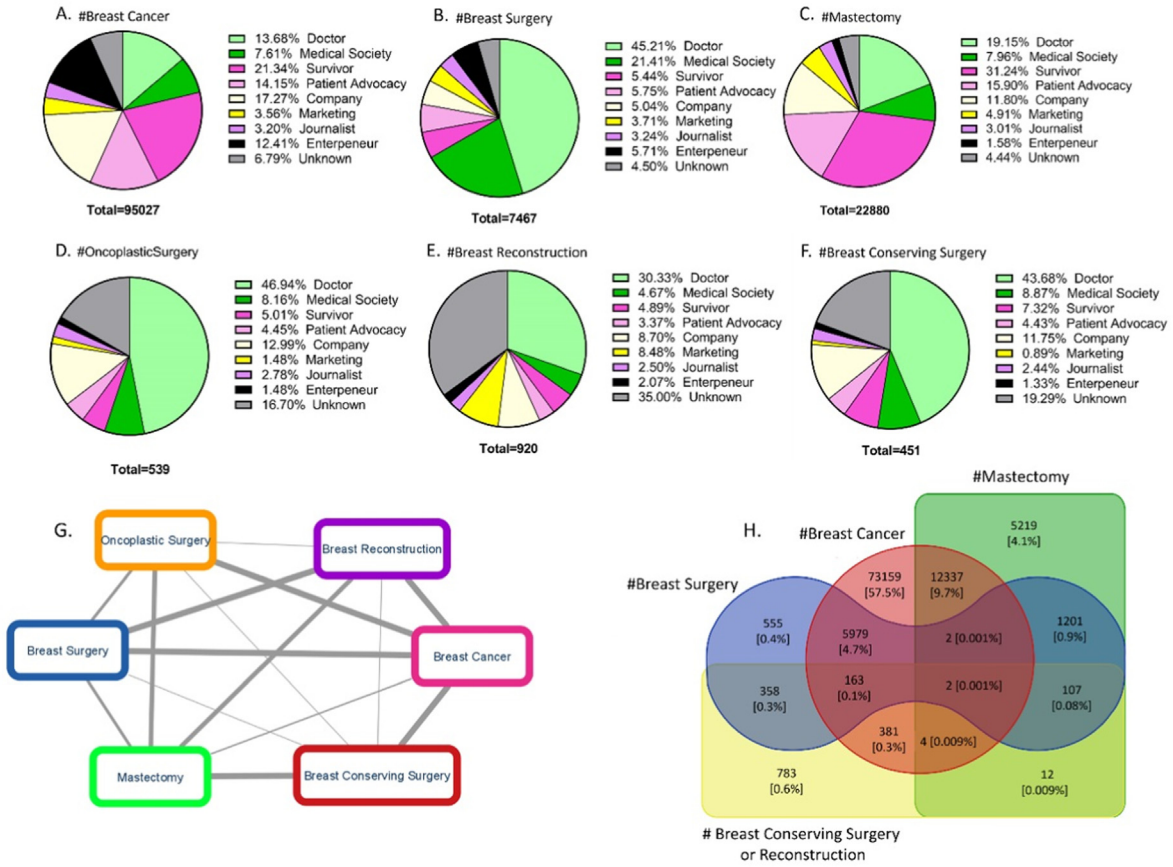

Fig. 4. Unique user distribution (professional, social categorization) per for selected hashtags #Breastcancer (A) #Breastsurgery (B) #Mastectomy (C) #Oncoplasticsurgery (D) #Breastreconstruction (E) #Breastconservingsurgery (F). Network of Dunn's multiple comparison test of user distribution per category: #Breastcancer vs. #Breastsurgery ($P < 0.0001$), #Breastcancer vs. #Breastconservingsurgery ($P < 0.0001$), #Breastcancer vs. #Breastreconstruction ($P < 0.0001$), #Breastcancer vs. #Mastectomy ($P = 0.03$), #Breastsurgery vs. #Oncoplasticsurgery ($P = 0.01$), #Breastsurgery vs. #Breastconservingsurgery ($P = 0.041$), #Breastsurgery vs. #Breastreconstruction ($P = 0.0002$), #Breastsurgery vs. #Mastectomy ($P = 0.009$), #Breastsurgery vs. #Oncoplasticsurgery ($P = 0.003$), #Mastectomy vs. #Oncoplasticsurgery ($P = 0.004$), #Mastectomy vs. #Breastconservingsurgery ($P < 0.0001$), #Mastectomy vs. #Breastreconstruction ($P = 0.0006$), #Breastreconstruction vs. #Breastconservingsurgery ($P = 0.047$), #Breastreconstruction vs. #Oncoplasticsurgery ($P = 0.04$). Edge width: 0.5 dpi (thin) $P < 0.05$ (*); 1 dpi $P < 0.01$ (**); 2 dpi $P < 0.001$ (***); 3 dpi $P < 0.0001$ (****). User overlap between hashtags (H).

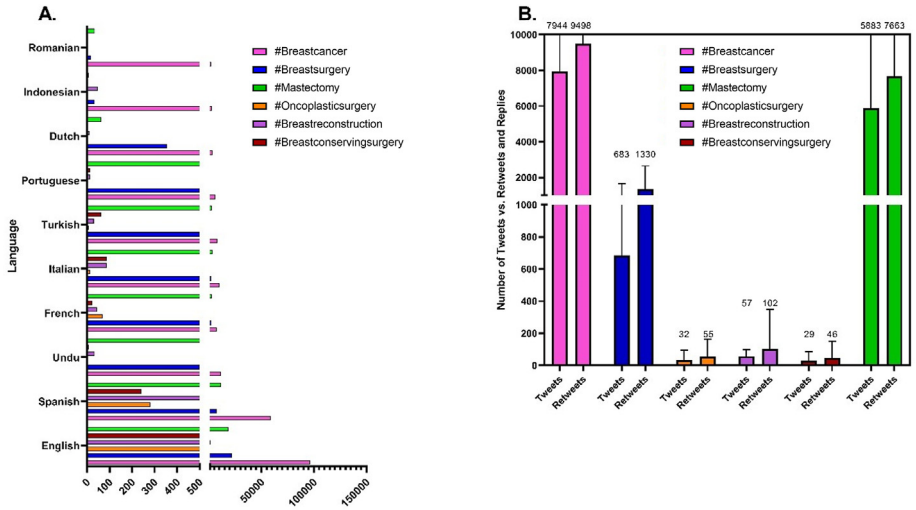

Fig. 5. Top ten most common languages (A) and organic tweet vs. retweet and replies to distribution in twitter (B) for selected hashtag tweets. Tweets vs. retweets distribution for selected hashtags #Breastcancer #Breastsurgery #Mastectomy #Oncoplasticsurgery #Breastreconstruction #Breastconservingsurgery. Median value displayed above each bar.

including the lack of comparability between tweet numbers and google interest index need to be highlighted. Additionally, hashtags variants have not been explored in the present dataset given the inability to download and process this vast information due to mass

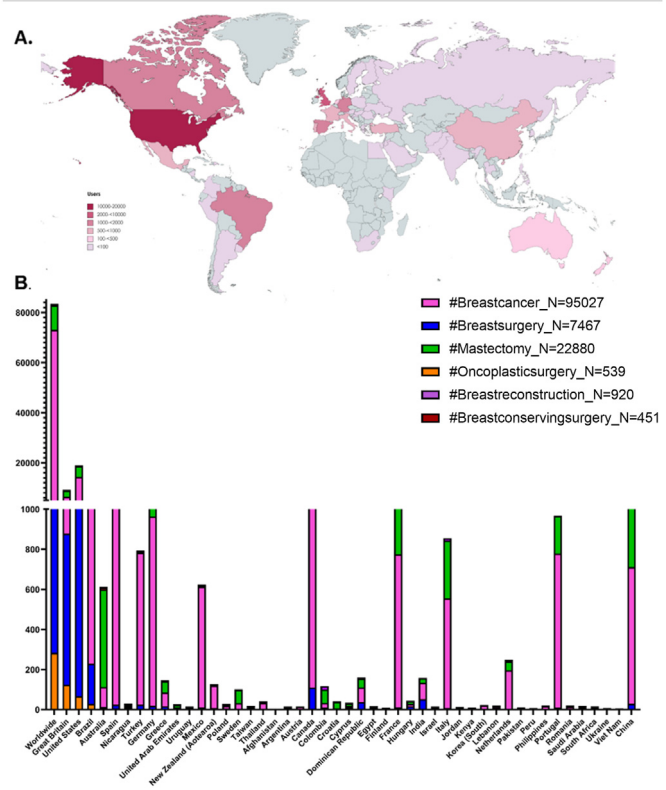

Fig. 6. World map with the number of tweets for #Breastcancer (A). Total Twitter users per country engaging with #Breastcancer (pink) #Breastsurgery (blue) #Mastectomy (green) #Oncoplasticsurgery (orange) #Breastreconstruction (purple) #Breastconservingsurgery (burgundy) (B).

user confidentiality. As hashtags such as #Breastcancer do not include parent hashtags e.g. #Breast #Cancer, to confidently assess how many users may employ a combination of hashtags (e.g., #Breast AND #Cancer) in addition to those identified to engage with the #Breastcancer hashtag was not feasible. Thus, this reflects a fundamental restriction in delineating user representativeness. In view of future research, the hashtag list explored in the present work should be expanded in view of better understanding information flow across patient and other counterpart hubs on social media. Whilst not an exhaustive list, future research would benefit from the inclusion of hashtags such as #lumpectomy, #bcsm, #breastcancersurgery, #breastcancerawareness, #breastcancersurvivor and #goingflat. Of note, the present study does not explore the quality of content shared for individual hashtags, therefore regular evaluations of the Twitter content, if deemed appropriate for comprehensive medical information sharing, will be required to ensure the quality and rigor of the scientific content to minimise misinterpretation. Of note the present work does not incorporate analysis of other SoMe platforms such as Instagram or TikTok despite their reported popularity across patient hubs. The reasoning for omitting these platforms lays with the lack of official API wrappers and analytics tools that would enable rigorous historical data extraction.

However, these limitations were largely inherent to the nature of the study and the herein addressed null hypothesis. Data credibility is largely dependent upon user intentions and the quality of their interaction with the Web 2.0 platforms. Of note, while hashtags used to sample Twitter were in English, there were no restrictions placed upon language of organic or re-tweet, therefore presenting a more realistic data sample. Additionally, in contrast to aggregate data analysis, the present work explores raw data at a single tweet level since Twitter launch, which in turn enables formal statistical analysis, specific to the null hypothesis, in contrast to exploratory aggregate data analysis.

4.1. Conclusions

Collectively, this is the first quantitative and qualitative dataset available, examining temporal and geographical variations of Twitter and Google trends for #Breastcancer, #Breastsurgery, #Oncoplasticsurgery, #Mastectomy, #Breastreconstruction and #Breastconservingsurgery and highlighting respective user engagement with the named hashtags and make predictions as to how these networks of information may influence health outcomes and patient choices. It appears that the potential of Twitter for education and communication among stakeholders remains to be capitalised on. Healthcare professionals need to be made aware of this whilst a coordinated effort needs to be initiated from medical education and regulatory bodies to equip future doctors with effective tools of engaging with patients online. In the future, such efforts may be formalised as soft skill courses integral to the medical and nursing school curriculum. Further initiatives should focus on the development of a framework for conduct and communication and promotion of educational content alongside with standardisation of hashtags, to reap maximum benefit for breast cancer patients from the pool of social media.

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CRediT authorship contribution statement

Stavroula L. Kastora: Study design, Data acquisition, Quality control of data and algorithms, Formal analysis, interpretation, Formal analysis, Manuscript preparation, Manuscript editing, Manuscript review. **Andreas Karakatsanis:** Conceptualization, Study design, Quality control of data and algorithms, Formal analysis, interpretation, Formal analysis, Manuscript editing, Manuscript review. **Yazan A. Masannat:** Conceptualization, Study design, Manuscript editing, Manuscript review.

Data availability

All data used in this study are publicly available through the sources referenced in the “Methods” section. The aggregated datasets analysed in this study are available from the corresponding author on reasonable request.

Declaration of competing interest

The authors declare no competing interests.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejso.2023.01.016.

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