The Neurosurgical Atlas: advancing neurosurgical education in the digital age

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OBJECTIVE The advent of the internet and the popularity of e-learning resources has promoted a shift in medical and surgical education today. The Neurosurgical Atlas has sought to capitalize on this shift by providing easily accessible video and online education to its users on an international scale. The rising popularity of social media has provided new avenues for expanding that global reach, and the Atlas has sought to do just that. In this study, the authors analyzed user demographics and web traffic patterns to quantify the international reach of the Atlas and examined the potential impact of social media platforms on the expansion of that reach.

METHODS Twitter, Facebook, and Instagram metrics were extracted using each respective service’s analytics tool from the date of their creation through October 2019. Google Analytics was used to extract website traffic data from September 2018 to September 2019 and app data from January 2019 to October 2019. The metrics extracted included the number of platform users/followers, user demographic information, percentage of new versus returning visitors, and a number of platform-specific values.

RESULTS Since the authors’ previous publication in 2017, annual website viewership has more than doubled to greater than 500,000 viewing sessions in the past year alone; international users accounted for more than 60% of the visits. The Atlas Twitter account, established in August 2012, has more than 12,000 followers, primarily hailing from the United States, the United Kingdom, Canada, and Saudi Arabia. The Atlas Facebook account, established in 2013, has just over 13,000 followers, primarily from India, Egypt, and Mexico. The Atlas Instagram account (established most recently, in December 2018) has more than 16,000 followers and the highest percentage (31%) of younger users (aged 18–24 years). The Atlas app was officially launched in May 2019, largely via promotion on the Atlas social media platforms, and has since recorded more than 60,000 viewing sessions, 80% of which were from users outside the United States.

CONCLUSIONS The Neurosurgical Atlas has attempted to leverage the many e-learning resources at its disposal to assist in spreading neurosurgical best practice on an international scale in a novel and comprehensive way. By incorporating multiple social media platforms into its repertoire, the Atlas is able to ensure awareness of and access to these resources regardless of the user’s location or platform of preference. In so doing, the Atlas represents a novel way of advancing access to neurosurgical educational resources in the digital age.


KEYWORDS education; multimedia; international; social media

Neurosurgery training is evolving rapidly. For generations of neurosurgeons, learning from the operating room or cadaver laboratory was supplemented with a limited toolkit of high-cost educational resources, including textbooks, conferences, and in-person lectures. Modern advances in computing power and accessibility have enabled the development of online resources that can be delivered on demand to anyone with access to a suitable internet connection, often completely free of charge. These “e-learning” resources, which
include digital collections of operative videos, webinars, interactive atlases, and 3D models, now play a central role in the modern era of neurosurgical education for learners all across the globe.25

Since its internet launch in 2016, The Neurosurgical Atlas by Aaron Cohen-Gadol, MD, has established itself as a leading international resource for neurosurgical education and particularly for microneurosurgical techniques.24 The site currently features more than 480 text chapters (“volumes”), 9000 illustrations, 1100 educational videos, and 150 “grand-round” webinars presented by renowned neurosurgeons from across the globe.6 The Atlas also recently introduced a series of ultrarealistic, 3D virtual reality models for teaching the anatomy of the skull, brainstem, cavernous sinus, temporal bone, and cerebrovascular system.8–10,17 Users can access this entire digital collection for free, using their web browser (https://www.neurosurgicalatlas.com) or their iOS or Android device by downloading the recently released Atlas mobile app.

The Atlas is in a unique position within the current landscape of neurosurgical training because of its popularity among international and early-career surgeons. More than 50% of Atlas users between June 2016 and July 2017 were younger than 35 years, and more than 70% of page visits originated outside of the United States.6 Since then, the Atlas has expanded its social media presence significantly by attracting a global following on Twitter, Facebook, and Instagram. Many of the Atlas’ text volumes on the web version of the site have also been translated into Chinese to further expand accessibility. In light of these recent developments, it is appropriate to reevaluate the impact of the Atlas and to understand its function within the current state of global neurosurgical education.

In this study, we analyzed user demographics, webpage traffic patterns, and social media data to quantify the international reach of the Atlas. We examined website data over the previous year (September 2018 through September 2019) and overall social media analytics from their date of creation through October 2019. Our findings highlight the considerable global following of the Atlas and emphasize the significant role of digital platforms in the modern era of neurosurgical training.

**Methods**

Twitter metrics were extracted using Twitter Analytics. Data were available between October 1, 2015, and October 12, 2019. The collected variables describing the Twitter posts included the number of impressions (number of times a post was viewed by a user, regardless of whether the post was clicked on); engagements (number of times a post was clicked on to magnify the image or text or to view a video); retweets; likes; and URL clicks that each post received.

Demographic information on the followers (number of followers, age, sex, country of origin, and language) from the Atlas Facebook page was accessed via the Facebook Analytics tool. Data from January 2013 to October 2019 were included.

Similarly, Atlas Instagram metrics were collected using the Instagram Analytics tool. Information on the number of followers and their demographic information (age, sex, and country of origin) was extracted between December 2018 (account creation) and October 2019.

To track Atlas website and app traffic, Google Analytics was used. Google Analytics is a service provided by Google that both tracks and reports de-identified website traffic data. The data from the year leading up to the time of this writing (September 2018 to September 2019) were collected and included the following variables: number of page visits; visit duration; user demographic information (sex, age, and country of origin); percentage of new versus returning visitors; and type of mobile device used.

Institutional review board approval was not required for this study, because all data collected were de-identified and available via open-source analytics platforms.

**Results**

**Twitter**

The Atlas Twitter account was established at the same time as the website (August 2012). The account currently has 12,383 followers, 44% of whom are female. Followers of the Atlas are spread throughout the world; the United States is home for 42% of Atlas Twitter followers, the United Kingdom for 10%, Canada and Saudi Arabia for 5% each, and India and Mexico for 3% each (Table 1). Between October 2015 and October 2019, 739 tweets were sent from the Atlas Twitter account, and these tweets resulted in a total of 1,727,245 impressions, averaging 2337.3 impressions per tweet. The Twitter posts have had a total of 63,131 engagements (85.4 engagements per tweet). These tweets were retweeted 3886 times and have been liked 8486 times. In addition, the included URLs that send the user to the Atlas webpage were clicked 12,023 times.

**Facebook**

The Atlas Facebook page had a total of 13,031 followers as of October 2019 (Table 1). Of these followers, 65% are men and 34% are women. The followers’ age ranges are 18–24 years (16%), 25–34 years (51%), 35–44 years (20%), and 45–54 years (8%). In total, the Atlas Facebook page also has followers from 50 different countries. The top 4 countries with the largest following include India (15%), Egypt (14%), Mexico (12%), and the United States (7%). Users most commonly designate English (34%) as their primary language, and Spanish (16%) is the second most common designation.

**Instagram**

The Atlas added an Instagram account to its host of social media platforms in December 2018 (Table 1). As of October 2019, the Atlas Instagram account has posted 114 pieces of content (79 pictures, 35 videos) and boasts more than 16,000 followers (61% male; 89% are aged 18–44 years [31% aged 18–24 years, 46% aged 25–34 years, and 12% aged 35–44 years]). The United States is the nationality of the largest percentage of followers (17%), followed closely by Brazil (15%), Mexico (4%), India (4%), and Russia (5%). Followers were most active from 6 am to 3 pm (local times), with an average of 5500 followers active dur-
ing these times compared to 3900 followers active at other times (p < 0.001).

Website
Between September 2018 and September 2019, 501,857 viewing sessions of the Atlas website were logged, with an average of 3.35 pages viewed per session (Table 2, Fig. 1). Male viewers accounted for 59% of these sessions, and female viewers for 41%. The most common age groups among the viewers were 25–34 years (39%) and 35–44 years (21%). The vast majority of these views came from the United States (39%), followed by India (5%) and Brazil (4%) (Table 2, Fig. 2). Returning visitors accounted for 24% of these views, and new visitors accounted for 76%, with an average of 2.44 sessions per user. The website was accessed most commonly via a desktop computer (47%), followed closely by a mobile device (45%), and 8.4% of the visitors accessed the site using a tablet. Of mobile users, the majority (65.5%) were iPhone users, and the others were Android users (34%).

**TABLE 1. Demographics for users of the Atlas social media accounts**

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Twitter</th>
<th>Facebook</th>
<th>Instagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date initiated</td>
<td>August 2012</td>
<td>October 2013</td>
<td>December 2018</td>
</tr>
<tr>
<td>No. of users/followers</td>
<td>12,383</td>
<td>13,031</td>
<td>16,265</td>
</tr>
<tr>
<td>Sex (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>56</td>
<td>65</td>
<td>61</td>
</tr>
<tr>
<td>Female</td>
<td>44</td>
<td>34</td>
<td>39</td>
</tr>
<tr>
<td>Age range (%)*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18–24 yrs</td>
<td>NA</td>
<td>16</td>
<td>31</td>
</tr>
<tr>
<td>25–34 yrs</td>
<td>NA</td>
<td>51</td>
<td>46</td>
</tr>
<tr>
<td>35–44 yrs</td>
<td>NA</td>
<td>20</td>
<td>12</td>
</tr>
<tr>
<td>45–54 yrs</td>
<td>NA</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>Country(ies) (%)</td>
<td>United States (42)</td>
<td>India (15)</td>
<td>United States (17)</td>
</tr>
<tr>
<td></td>
<td>United Kingdom (10)</td>
<td>Egypt (14)</td>
<td>Brazil (15)</td>
</tr>
<tr>
<td></td>
<td>Canada (5), Saudi Arabia (5)</td>
<td>Mexico (12)</td>
<td>Mexico (4), India (4)</td>
</tr>
</tbody>
</table>

* Twitter Analytics did not provide the age ranges of its users.

**TABLE 2. Demographic information for Atlas website viewers over time**

<table>
<thead>
<tr>
<th>Demographic</th>
<th>2016–2017</th>
<th>2018–2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of viewing sessions</td>
<td>246,259</td>
<td>501,857</td>
</tr>
<tr>
<td>Sex (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>71</td>
<td>59</td>
</tr>
<tr>
<td>Female</td>
<td>29</td>
<td>41</td>
</tr>
<tr>
<td>Age range (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18–24 yrs</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>25–34 yrs</td>
<td>44</td>
<td>39</td>
</tr>
<tr>
<td>35–44 yrs</td>
<td>24</td>
<td>21</td>
</tr>
<tr>
<td>45–54 yrs</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td>≥55 yrs</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>Country(ies) (%)</td>
<td>United States (30)</td>
<td>United States (39)</td>
</tr>
<tr>
<td></td>
<td>Brazil (6)</td>
<td>India (5)</td>
</tr>
<tr>
<td></td>
<td>India (4)</td>
<td>Brazil (4)</td>
</tr>
<tr>
<td></td>
<td>China (3.5)</td>
<td>United Kingdom (3)</td>
</tr>
<tr>
<td></td>
<td>Germany (3)</td>
<td>Germany (2.5)</td>
</tr>
<tr>
<td></td>
<td>United Kingdom (2.5), Russia (2.5)</td>
<td>Canada (2.3), China (2.3)</td>
</tr>
<tr>
<td></td>
<td>Italy (2), Mexico (2), Spain (2)</td>
<td>Mexico (2), Italy (2), Spain (2)</td>
</tr>
<tr>
<td></td>
<td>Other (41)</td>
<td>Other (38)</td>
</tr>
</tbody>
</table>
App
Since its release in January 2019, the Atlas app has had 63,818 viewing sessions from new (60%) and returning (40%) users (Fig. 3). Demographically, the app was accessed primarily by viewers in the United States (22%), India (7%), and Brazil (6%) (Fig. 4). Other countries in which the app was accessed included Russia (5%), Germany (3%), the United Kingdom (3%), and Mexico (2%). More users accessed the app on an Android (52%) than on an iPhone (48%).

Discussion
The advent of the internet and the ensuing increase in resource accessibility has promoted a shift in the landscape of medical and surgical education.15,25–27 Learners are increasingly turning to multimedia platforms, and surgical videos in particular, to augment their learning from more traditional modalities (the classroom, the operating room, etc.). One recent survey of fourth-year medical students in Iowa found that 90% of the respondents turn to YouTube the night before a case to review what is expected for the following day.23 This finding was echoed in a similar study in India that examined the preferences of neurosurgical trainees and revealed that online neurosurgical videos were the most used resource for nearly 90% of the responders (87 of 98 [88.8%]).14 Since its launch in 2012, the Atlas has sought to promote and capitalize on
this shift by offering an open-access online platform that features comprehensive up-to-date information on the best neurosurgical practices.

Trends in overall Atlas website viewership data further support this observation. Since our previous publication, website traffic has more than doubled (Table 2). From 2016 to 2017, just over 246,000 viewing sessions of the Atlas website were completed, and more than 500,000 viewing sessions occurred in the last year alone. The consensus that this increase is largely a result of trainee engagement is reflected in the Atlas following: half of all website visitors (50%) and the vast majority of Facebook (67%) and Instagram (77%) followers are of trainee age (18–34 years). Although the age distribution of users has stayed largely the same over the years, it should be noted that female viewership has increased by more than 10% (currently at 41%). Given that this number is largely similar to the percentage of female viewers across each social media platform, it is likely that this increase reflects a broader trend of women interested in or entering the neurosurgical field. Indeed, although the percentage of female neurosurgical residents in the United States hovered around 12% in 2006, that number has increased to 17.5% according to data released by the American Medical Association in 2019.1,18

![Atlas app viewing sessions, according to month, since it was released. Weekly push notifications via the app provide another vehicle for the distribution of Atlas video content and correspond to spikes in the number of viewers. Data and chart from Google Analytics. (2019 Google.)](Fig3)

![Global Atlas app access since the release in January 2019. The darker shades represent more traffic. Data and chart from Google Analytics. (2019 Google.)](Fig4)
It should be recognized that this increased traffic is, at least in part, a result of the growing popularity of social media and its increased use as a promotional tool for the Atlas. Although the website was shown in our previous publication to be a sought-after resource in its own right, the advent of social media and its increasing popularity has served to increase demographic variability, augment overall global outreach, and provide a critical promotional platform for new adjuncts when they arise.6

For some time now, the use of social media in the context of medical and surgical education has been increasingly investigated. From nephrology to radiology, specialties are exploring the use of social media platforms to improve educational accessibility, and descriptive and analytical papers highlighting its use have been published over the past 10 years.4,5,7,13,20,22 Neurosurgeons also have begun to recognize this potential; academic journals have been publishing articles on the topic since 2016.2,3,16 The consensus in each of these instances is that social media has evolved to take on an ever-larger role in our daily lives and that those in the medical field are presented with an opportunity to use the positive aspects of this development to their benefit.

The Atlas has made an increased effort to do just that in recent years by recruiting a team of medical students and residents to manage its social media efforts and adding an Instagram account at the end of 2018. The abrupt growth in Instagram users in just 10 months suggests that the addition of this platform has tapped into a demographic different from that of the previous accounts. Although the United States is home for just 4% of Atlas Facebook followers, it is the most represented country when it comes to the Atlas Instagram account (Table 1). Younger users clearly show a preference for Instagram, in that those in the 18- to 24-year age range account for nearly twice as many Instagram followers as Facebook users. This is reflective of broader trends at large, recently highlighted in a study by the Pew Research Center, in which it was found that 75% of young adults (aged 18–24 years) were Instagram users, as opposed to just 57% of those aged 25–29 years, and 47% of those aged 30–49 years.21 Increasing demographic diversity is critical because social media audiences have already been found to increase website viewership; Atlas Twitter posts alone have accounted for more than 12,000 Atlas website visits since 2015.

The diversity of social media offerings has also been shown to be important when it comes to maximizing global outreach. Over the past year, users from 208 countries have accessed the Atlas website, which underscores its importance as an internationally recognized neurosurgical educational resource. More than 60% of Atlas website visitors come from outside of the United States, and 96% of its Facebook users, 83% of its Instagram users, and 58% of its Twitter users hail from somewhere outside of the United States. However, it is important to emphasize that the distribution between countries differs on the basis of the platform, which suggests that to increase website viewership and app use, a presence on all 3 platforms is likely to be beneficial. Although the United Kingdom, Canada, and Saudi Arabia have the highest representation among Atlas Twitter followers, India, Egypt, and Mexico do so on Facebook, whereas Brazilians seem to favor Instagram (Table 1). By maintaining a presence on each platform, the Atlas can sustain a broader reach regardless of the preferences of its users.

Finally, when it came time to institute a new multimedia resource altogether in the form of the Atlas app, the social media platforms were already in place and ready to be used as a promotional tool for its release. Although the app underwent a soft launch in January 2019, it was not until it went live in late May 2019 and was officially announced on social media platforms that we saw a large uptick in the number of downloads and daily users (Fig. 3). The advent of the Atlas app has increased user accessibility even further in that it can be downloaded to each user’s Apple or Android device home screen; 40% of visitors are return users, compared to just 26% of Atlas website users. The app also provides yet another tool for expanding the international reach of the Atlas, with nearly 80% of its users hailing from outside of the United States, compared to just 61% of its website visitors. The popularity of the app continues to grow; nearly 60% of visits are made by new viewers.

The evaluation of multimedia educational platforms using website analytics naturally presents limitations. Namely, we acknowledge that there is an important distinction between the number of website visits or social media interactions and measurement of the actual efficacy of each of those visits as a tool for learning neurosurgery. In this respect, we unfortunately are currently limited by the metrics available to us via the analytics tools at our disposal. As for the best way to capture the educational impact of each visit in the future, possibilities under consideration include the administration of a survey to measure the perceived benefit to users directly, as well as the addition of a quiz feature following articles or videos that could provide both a crude measurement of the efficacy of the section and a way for the user to cement their learning. In any case, this is certainly an intriguing area for future study.

Conclusions

The digitization of the modern era, coupled with the surging popularity of social media outlets, has fostered an environment in which access to and use of multimedia neurosurgical educational resources is possible on an unprecedented scale. The Neurosurgical Atlas aims to capitalize on this by combining e-learning resources with the information-sharing potential of a social media presence to promote neurosurgical best practice worldwide in both a novel and comprehensive way.

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Disclosures
Dr. Cohen-Gadol is the president and founder of The Neurosurgical Atlas.

Author Contributions
Conception and design: Cohen-Gadol, Teton, Hendricks. Acquisition of data: Freedman, Linzey, Onyewuenyi, Khaerera. Analysis and interpretation of data: Teton, Freedman. Drafting the article: Teton, Freedman, Tomlinson, Linzey, Onyewuenyi, Khaerera. Critically revising the article: Cohen-Gadol, Hendricks. Reviewed submitted version of manuscript: Cohen-Gadol, Teton, Hendricks. Approved the final version of the manuscript on behalf of all authors: Cohen-Gadol.

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