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Neurosurgical Operative Videos: An Analysis of an Increasingly Popular Educational Resource

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■ **OBJECTIVE:** Surgical education has increasingly relied on electronic learning. In particular, online operative videos have become a core resource within neurosurgery. We analyze the forums for neurosurgical operative videos.

■ **METHODS:** Operative videos from 5 sources were reviewed: 1) the NEUROSURGERY Journal YouTube channel; 2) the American Association of Neurological Surgeons Neurosurgery YouTube channel; 3) The Neurosurgical Atlas Operative Video Cases; 4) *Operative Neurosurgery*; and 5) *Neurosurgical Focus: Video*. Title, year of publication, senior author, institution, country, and subspecialty were documented for each video.

■ **RESULTS:** A total of 1233 videos showing 1247 surgeries were identified. Ten videos included >1 surgery; of those, there was a median of 2 surgeries (interquartile range, 2.0–2.5) per video. The most frequently represented subspecialties included vascular (48.3%), tumor (35.2%), and skull base surgery (27.5%), with almost 40% of videos showing >1 category. Videos were submitted by investigators from 28 countries, but 82.1% of the videos originated in the United States.

■ **CONCLUSIONS:** Neurosurgical operative videos have become increasingly common through a variety of online platforms. Future efforts may benefit from collecting videos from underrepresented regions and subspecialties, providing

long-term follow-up data and showing techniques for managing complications.

INTRODUCTION

Surgical education has traditionally been built on graduated hands-on operative experience, supplemented by textbooks, lectures, cadaver laboratories, and formal surgical courses. However, the rapid pace of technology has opened other educational avenues, such as online lectures and courses, virtual dissections, and simulation training. The COVID-19 (coronavirus disease 2019) pandemic has highlighted the importance, application, and adaptability of these electronic resources, because trainees have had less operative experience and may need to continue social distancing measures for a protracted period.¹⁻⁵

Operative videos represent another educational tool for trainees as well as for established surgeons. Operative videos in neurosurgery can be traced back to Gazi Yasargil's early recordings of his microsurgical cases; videos are now simpler to record, store, and transmit in high definition (two-dimensional [2D] or three-dimensional [3D]). As aptly stated by Robert Spetzler, "It is true that watching a brilliant surgeon's video will not make you one, but recognizing what is possible and seeing it done will inspire you to be a better surgeon and to achieve that goal."⁶

Several operative video libraries have been collated and published. For the purpose of this analysis, we sought to include video

Key words

- Education
- e-Learning
- Multimedia
- Online
- Video

Abbreviations and Acronyms

2D: Two-dimensional

3D: Three-dimensional

AANS: American Association of Neurological Surgeons

CNS: Congress of Neurological Surgeons

IQR: Interquartile range

JNS: *Journal of Neurosurgery*

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collections that have been sponsored and/or endorsed by neurosurgical leadership. These include the Congress of Neurological Surgeons (CNS)/NEUROSURGERY and American Association of Neurological Surgeons (AANS)/*Journal of Neurosurgery* YouTube channels, as well as The Neurosurgical Atlas by Aaron Cohen-Gadol. Furthermore, whereas surgical videos had previously been relegated to supplementary material in mainstream publications, 2 journals now facilitate the publication and distribution of stand-alone videos: *Operative Neurosurgery* and *Neurosurgical Focus: Video*. In this article, we analyze the features of these forums for neurosurgical operative videos.

METHODS

Video Sources

YouTube Channels. A search of YouTube channels using the term “neurosurgery” yielded several channels that are sponsored by individual surgeons and/or institutions. Two channels with operative videos were identified that are sponsored at the level of national neurosurgical leadership: NEUROSURGERY Journal and AANS Neurosurgery.

The NEUROSURGERY journal channel contains supplemental operative videos from articles published in NEUROSURGERY publications, which includes *Neurosurgery*, the official journal of the CNS. It also contains several miscellaneous surgical videos, a tutorial for accessing the features of NEUROSURGERY publications online, and lectures given at previous meetings of the CNS.

AANS Neurosurgery, the YouTube channel of the AANS, shows operative videos related to the publications of its official journal, the *Journal of Neurosurgery* (JNS). In addition, it includes videos from the Rhoton Collection, a core curriculum developed by the AANS and the Society of Neurosurgery, interviews of “Leaders in Neuroscience,” and historical films.

For our analysis, only surgical videos were included, whereas video libraries featuring cadaveric dissections (e.g., the Rhoton Collection) and/or using a lecture format were excluded.

The Neurosurgical Atlas Operative Case Videos. In addition to these YouTube channels, the operative videos of The Neurosurgical Atlas were included because of the ongoing partnership between The Neurosurgical Atlas, the AANS, and JNS. The Neurosurgical Atlas is designed as an electronic textbook with multiple sections, including volumes (similar to textbook chapters), neuroanatomy, grand rounds lectures, and operative case videos. For our analysis, only the Operative Case Videos section was included. Although a YouTube channel for The Neurosurgical Atlas exists, a more complete list of operative videos was identified on The Neurosurgical Atlas Web site (<https://www.neurosurgicalatlas.com/>).

Journals. *Operative Neurosurgery*, a journal that falls under the umbrella of NEUROSURGERY publications, focuses on operative techniques, anatomy, and technology in an effort to guide operative practice. A variety of submission formats are encouraged, one of which is a surgical video. All operative videos were included with the exception of *Operative Neurosurgery's* recently developed Spetzler Collection, which was excluded given its unique focus on a particular subset of vascular cases.

Similarly, *Neurosurgical Focus: Video* is a new quarterly publication that falls under the umbrella of the JNS Publishing Group. It is a platform for the exclusive publication of surgical videos. All videos published at the time of this writing were included.

Video Characteristics

Manual curation of each operative video from the aforementioned video sources was compiled in a database (Microsoft Excel version 16.37 [Microsoft, Redmond, Washington, USA]). Video characteristics (subspecialty and 2D vs. 3D format), source, patient demographics (age and sex), and senior author information (name, institution, and country) were compiled. Videos showing >1 patient were annotated along with individual patient demographics. For subspecialty designations, each video was annotated as relating to ≥ 1 core neurosurgical subspecialties: tumor, vascular, skull base, spine, pediatrics, functional, peripheral, and/or trauma. For the 2 YouTube channels, the number of views for each video was recorded. Data collection for all videos was completed by May 8, 2020.

Data Analysis

All analyses were performed using R (version 3.5.1; RStudio, <https://rstudio.com>) with either base stats package or rstatix (version 0.4.0; <https://cloud.r-project.org/package=rstatix>). Figures were generated using ggplot2 (version 3.2.1; Tidyverse, <https://ggplot2.tidyverse.org>). Visualizations of intersecting sets were generated using UpSet (<https://ieeexplore.ieee.org/document/6876017>). Geocoding was performed using ggmap (version 3.0.0, <https://CRAN.R-project.org/package=ggmap>) and map data were obtained from the maps package (version 3.3.0, <https://CRAN.R-project.org/package=maps>).

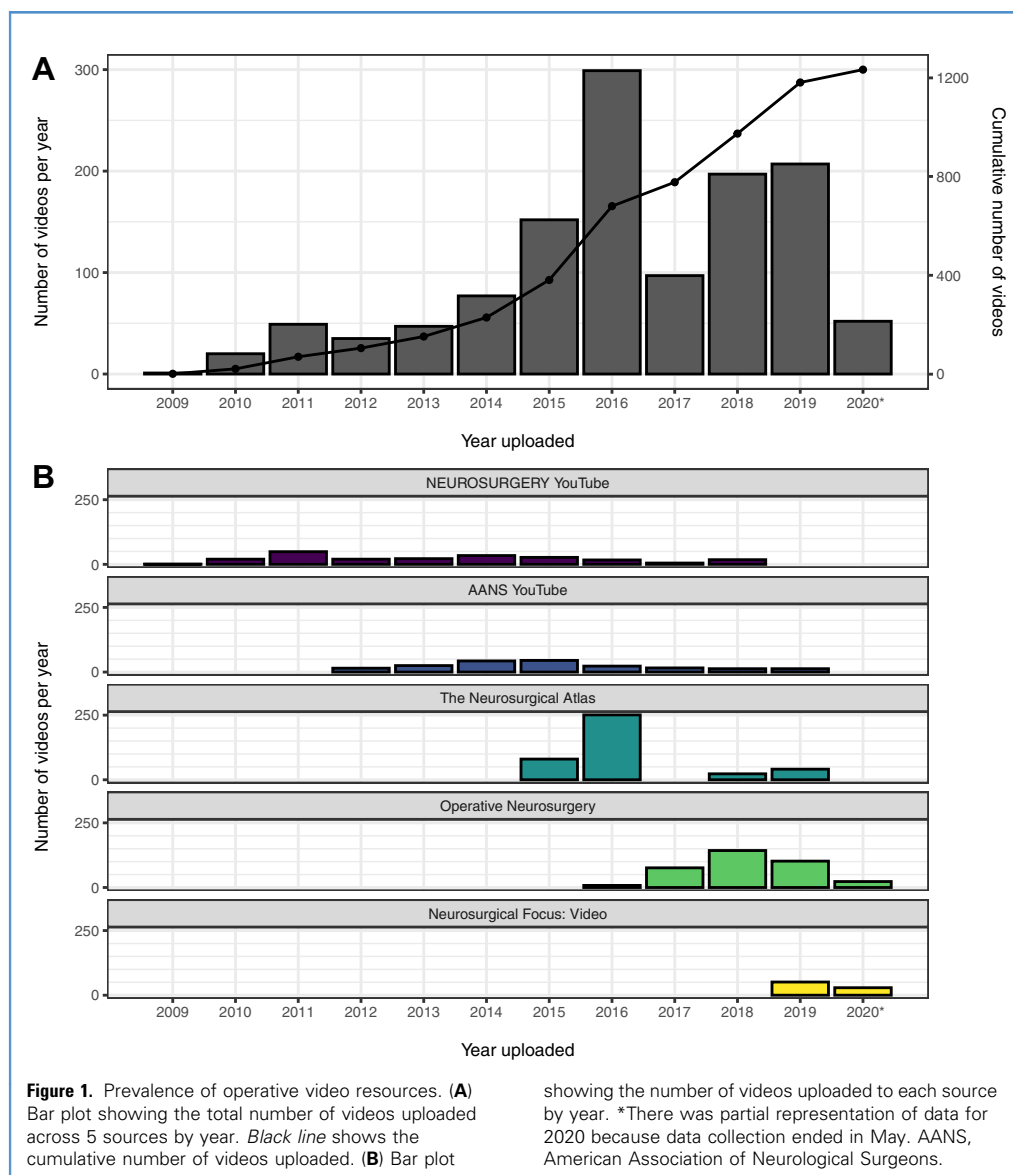
Significance level α was set to 0.05 for all analyses except after multiple testing correction, where α was set to 0.1. Normality of continuous variables was assessed using the Shapiro-Wilk test. Continuous variables were summarized using median and interquartile range (IQR). Comparisons across groups were performed with the Kruskal-Wallis test and post hoc pairwise Dunn test with Benjamini-Hochberg correction. Count data were compared across groups using the χ^2 test followed by post hoc pairwise Fishers exact test with Benjamini-Hochberg correction.

Analysis of the number of hits/views for each video was limited to the 2 YouTube channels. The number of hits for each video was analyzed per subspecialty and pairwise comparisons were performed between videos that were related versus those that were unrelated to each subspecialty. The number of hits was normalized to the number of years for which each video was accessible.

RESULTS

Operative Video Libraries

A total of 1233 videos showing 1247 procedures and totaling 140 hours of runtime were analyzed, with years of publication ranging from 2009 to 2020 (Figure 1A). The Neurosurgical Atlas contained the most individual videos ($n = 395$), followed closely by *Operative Neurosurgery* ($n = 352$). Ten videos involved multiple patients. Of the videos containing multiple patients, the median number of patients per video was 2 (IQR, 2.0–2.5). Conversely, the NEUROSURGERY YouTube channel included 59 short videos



showing different portions of 22 individual surgeries, with a median of 2 videos per surgery (IQR, 2–3).

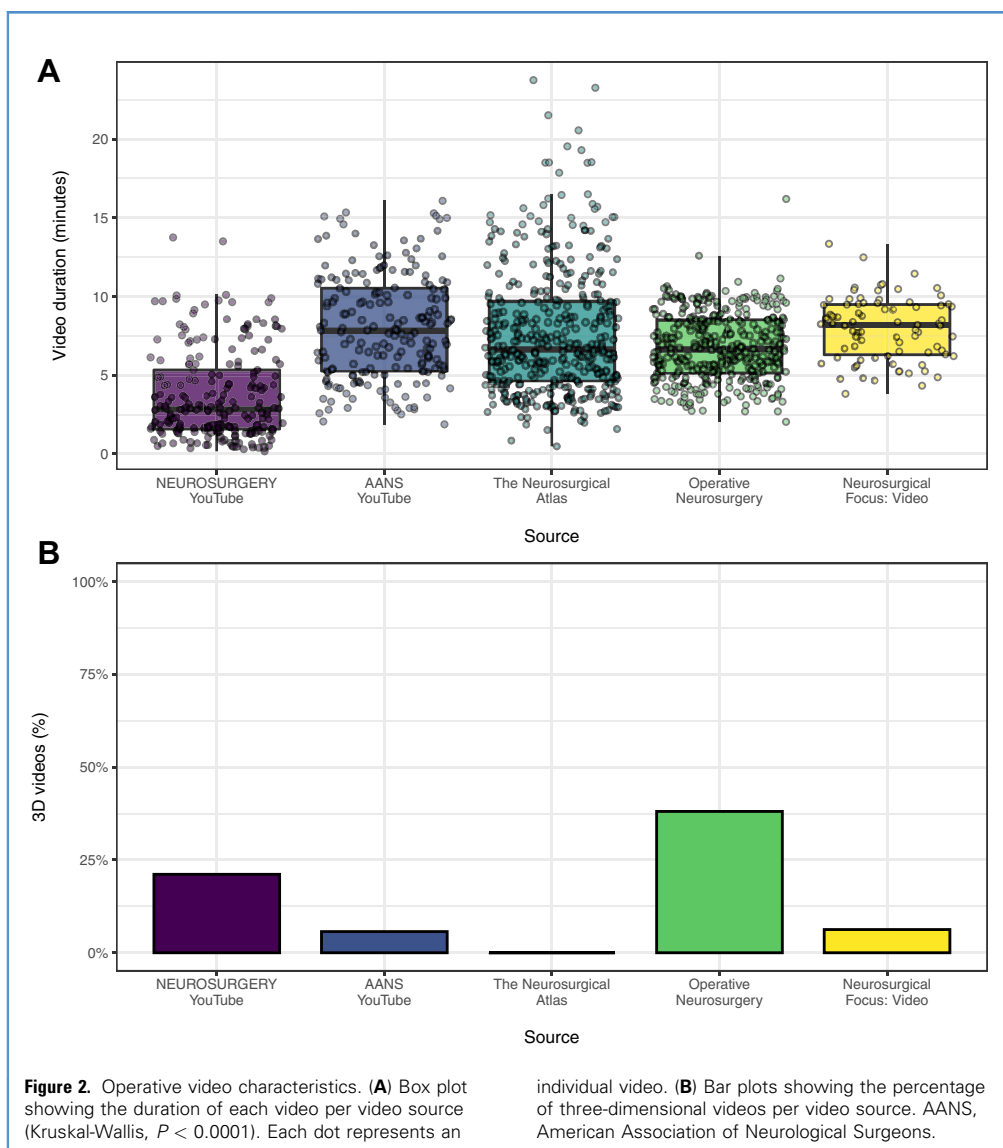
Of the 5 video sources that were surveyed, the NEUROSURGERY YouTube channel was the first to be established and began posting videos in 2009, whereas the newest source, *Neurosurgical Focus: Video*, released its first issue in July 2019 (Figure 1B). The spike in videos in 2016 corresponded to the official launch of *The Neurosurgical Atlas*, which uploaded 251 of their 395 videos that year. An average of 10.2 videos have been uploaded per month so far in 2020 (adjusting for the number of months included in the analysis), compared with 17.3 videos per month in 2019, and 16.4 videos per month in 2018. The number of new operative videos uploaded to the AANS YouTube page has declined each year since 2015, and a new operative video has not been uploaded to the NEUROSURGERY YouTube page since

mid-2018. In contrast, new videos are being continuously published through the *Operative Neurosurgery* and *Neurosurgical Focus: Video* formats.

Video Characteristics

Median video length was 6.5 minutes (IQR, 4.3–8.9), with significant variation between sources (Kruskal-Wallis, $P < 0.0001$). The distribution of video length per source is shown in Figure 2A. The median length of videos from the NEUROSURGERY YouTube channel was 2.9 minutes (IQR, 1.6–5.3), which was significantly lower than that of videos from all other sources (Dunn adjusted, $P < 0.1$).

Of the 1233 videos, 1038 (84.2%) were 2D, whereas only 195 (15.8%) were 3D. Overall, 38% of the videos associated with *Operative Neurosurgery* were 3D, as were 21% of the operative videos on the NEUROSURGERY YouTube channel, with *Neurosurgical*



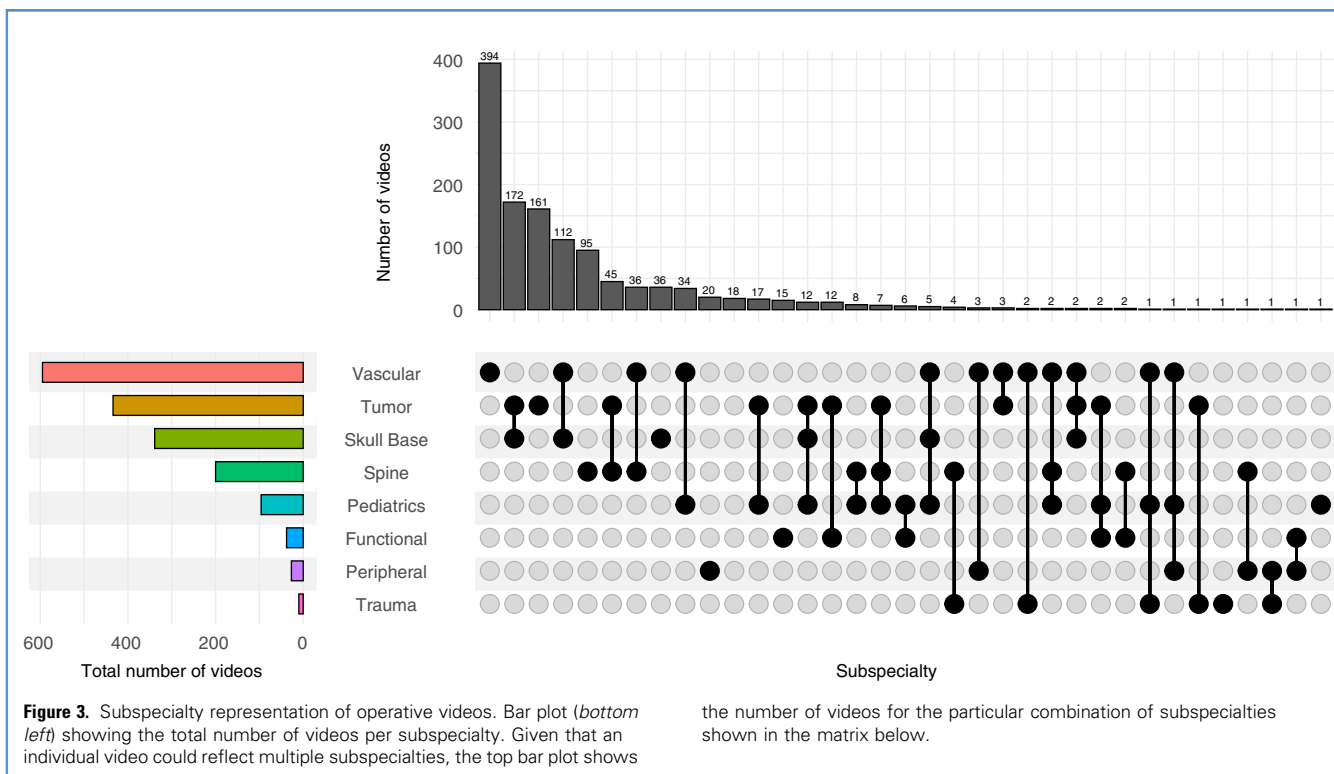
Focus: Video, the AANS YouTube channel, and The Neurosurgical Atlas following with 6.25%, 5.7%, and 0%, respectively (Figure 2B).

Subspecialty Representation

Overall, the most highly represented subspecialties included vascular (48.3% of the videos), tumor (35.2%), and skull base surgery (27.5%) (Figure 3). Spine, pediatrics, functional, peripheral, and trauma followed with 16.2%, 7.8%, 3.1%, 2.2%, and 0.8% of the videos, respectively. In addition, 52 videos (4.2%) showed endoscopic surgery (data not shown). Overall, 40.8% of all videos represented >1 subspecialty. The most common subspecialty overlaps included 1) skull base and tumor (175 videos), and 2) vascular and skull base (112 videos). With the exception of 1 video, all pediatric videos overlapped with another subspecialty as well.

Pairwise comparisons showed significant variability in subspecialty representation across video sources (adjusted Fisher, $P < 0.1$) (Supplementary Figure 1). The NEUROSURGERY YouTube channel had significantly more peripheral cases than did the other platforms, The Neurosurgical Atlas had fewer spine cases, and *Neurosurgical Focus: Video* had a higher percentage of skull base videos.

Overall, there was a median of 492 hits (IQR, 255–1,043) per video, with the AANS YouTube channel having a median of 936 hits per video (IQR, 525–1684), compared with the NEUROSURGERY YouTube channel, which had a median of 273 hits per video (IQR, 144–435; Wilcoxon $P < 0.001$). Videos pertaining to tumor and spine cases had statistically more hits compared with unrelated videos (Dunn adjusted, $P < 0.1$), whereas vascular videos showed statistically fewer hits than nonvascular videos (Dunn adjusted, $P < 0.1$) (Figure 4).



Geographic Representation

Aside from the 395 videos of The Neurosurgical Atlas, which were contributed by Dr. Aaron Cohen-Gadol of the Indiana University School of Medicine, the largest contributing institutions included University of California, San Francisco (63 videos), the Barrow Neurological Institute (59 videos), the University of Utah (35 videos), the Mayo Clinic in Rochester, Minnesota (33 videos), the University of Pittsburgh (25 videos), Rutgers New Jersey Medical School (21 videos), and the University of Washington, University of Wisconsin, and Emory University (19 videos apiece). A total of 12 videos originated from Helsinki University General Hospital, the single largest contributing institution from outside the United States.

Geographically, senior investigators from 28 countries contributed operative videos to the 5 video sources (Figure 5). A total of 1004 of the 1233 videos (81.4%) were contributed by the United States. Furthermore, 82.9% of videos from the AANS YouTube channel, 61.5% of videos from the NEUROSURGERY YouTube channel, 75.9% of Operative Neurosurgery videos, and 63.7% of Neurosurgical Focus: Video publications were contributed by surgeons within the United States. Internationally, the countries to contribute the most videos were Japan (29 videos), Brazil (27 videos), China (23 videos), Italy (18 videos), and Germany (16 videos).

DISCUSSION

Electronic Learning (e-Learning)

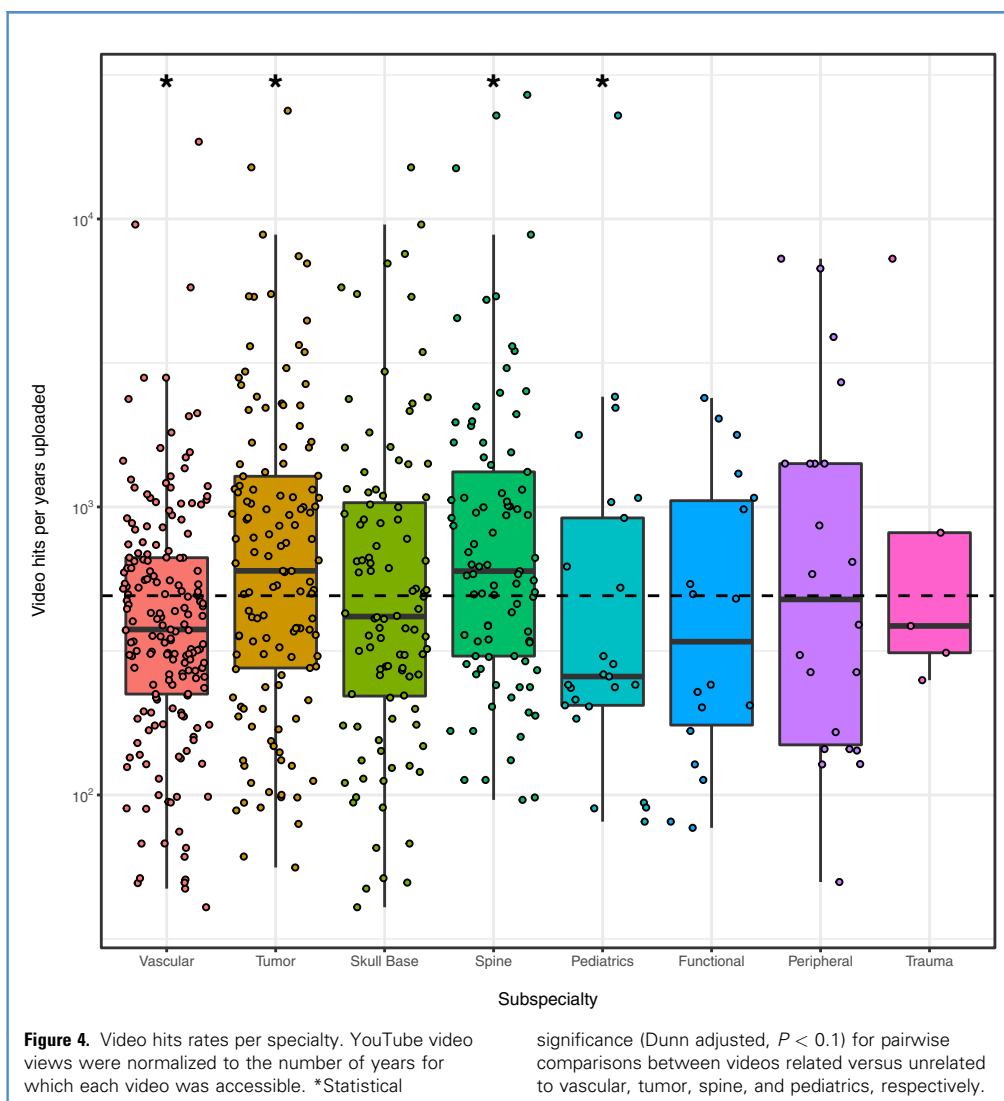
Over the last 20 years, education at all levels has undergone radical change brought about by the digital revolution and the

ever-increasing access to information. Increasingly, curricula have adopted e-learning, which refers to an approach to teaching and training that uses electronic media to facilitate learning.⁷⁻⁹ e-Learning may occur in either a synchronous fashion, in which the instructor and learner interact in real time, or an asynchronous manner, in which the material has been prerecorded. In either case, e-learning relies on the use of Web 2.0 tools (dynamic tools and technologies that provide access to user-generated content). These tools include Web sites, wikis, blogs, and social networking sites, all of which can be harnessed by medical educators.¹⁰⁻¹³

Within neurosurgery, numerous electronic resources, including but not limited to the Neurosurgical Survival Guide app, The Neurosurgical Atlas, CNS Nexus, and the online version of the Rhoton Collection, have emerged. By including links to journal articles, virtual lectures and grand rounds, 3D anatomic models and dissections, and other educational materials, these resources have been combined with traditional learning styles to create a new form of multifaceted learning.

The Role of Operative Videos

Online operative videos have become a core electronic resource within neurosurgery. Surgical videos serve several critical roles. First, such videos are an invaluable resource for neurosurgical trainees. As stated by James Rutka, "If a picture is worth a thousand words, just imagine the relative worth in words of an operative video!"¹⁴ It is not surprising, therefore, that many medical students and residents use online videos to supplement their traditional learning and prepare for cases.^{15,16} Data from The Neurosurgical Atlas project show that

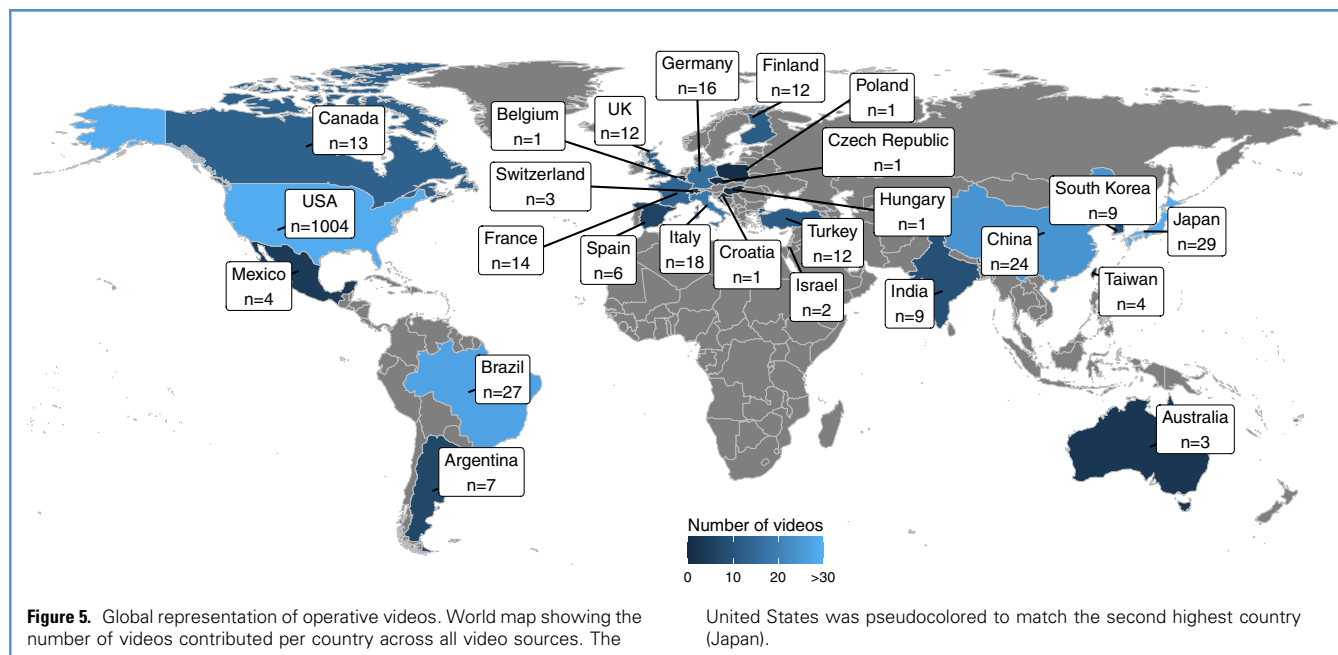


operative videos have become increasingly popular over time, with the Web site logging an increased number of video sessions.^{10,17} The increased Web traffic has been attributed largely to an increase in trainee engagement, with a large proportion of the visitors being in the 18–34 year age group. Residents who participate in video-based training have been shown to achieve learning milestones in shorter amounts of time, presumably because of the ability to repeatedly watch a video before performing the procedure.¹⁸ Conversely, videos of trainees can be used to assess their operative skills. Assessment tools have been developed to confirm the competency of general surgery trainees and have been shown to be highly reliable, thereby providing an objective way to grade surgical competence.^{19–21} Such videos may become an integral part of the Accreditation Council for Graduate Medical Education’s Milestones Project for Neurological Surgery in the future.²²

Although used primarily by surgical trainees, operative videos can also facilitate postgraduate education. A study that used

optoelectronic and video motion analyses to record kinematic data showed that consistent specific movements and tasks are performed by experienced neurosurgeons when performing microvascular anastomoses.²³ Using edited operative videos to continually review the technical steps performed by master neurosurgeons is key to refining the science, as well as the art of neurosurgery throughout our careers.¹⁴ A survey of neurosurgeons in India¹⁵ found that 88% of senior neurosurgeons reported that online neurosurgical videos helped improve their surgical skills.

Whether used by neurosurgical trainees or established attendings, Web-based operative videos seem to play an important role globally, particularly in low-to-middle-income countries in which limited resources restrict the access of many surgeons to journals, cadaver laboratories, workshops, and conferences.^{7,24} Although there are also barriers to the use of Web-based resources, including limited technology, limited access to the Internet, limited user support, and language and cultural barriers, the free



nature of many electronic resources offers an opportunity to expand neurosurgical educational efforts to the developing world.^{7,15,24,25} A survey of neurosurgeons in India¹⁵ found that 88% of senior neurosurgeons, 91% of junior consultants, and 80% of resident trainees found online videos helpful in improving their surgical skills. The investigators concluded that e-learning platforms can help provide educational opportunities to neurosurgeons across globally diverse environments: trainees, consultants, and senior surgeons in urban, semiurban, and rural areas alike. Anyone with Internet access anywhere in the world can watch online videos and learn from them. This low-cost resource avoids the expenses associated with journals and textbooks and is readily available to all neurosurgeons worldwide.

Geographic and Subspecialty Representation in Operative Videos

Given the theoretic usefulness of online operative videos for facilitating global neurosurgical education, are such videos being used on an international scale? Analytics data from The Neurosurgical Atlas suggest that the online resource is being used globally. Between 2016 and 2017, although the single largest group of people accessing the site came from the United States (29% of viewers), the remainder came from Brazil (6%), India (4%), and a variety of other countries.¹⁰ In an updated analysis between 2018 and 2019, the overall breakdown was similar, with 39% of viewers originating from the United States, 5% from India, and 4% from Brazil, but impressively, users from 208 individual countries accessed the Web site.¹⁷

Conversely, although electronic resources are being used by an international audience, contributions to those resources seem to be more consolidated. A survey of neurosurgeons in India found that although most respondents used online videos, only 6% had previously uploaded videos of their own.¹⁵ Similarly, in the current

study, of the 1233 videos that were reviewed, 1012 (82.1%) were contributed by institutions based in the United States. Although these numbers are skewed by the inclusion of The Neurosurgical Atlas videos, all 395 of which came from a single source, the trend holds true when broken down by video platform, with most videos being contributed by surgeons within the United States.

Our study also shows that in addition to geographic consolidation, the operative videos are heavily weighted toward several neurosurgical subspecialties (tumor, vascular, and skull base in particular), which account for 35.2%, 48.3%, and 27.5% of the videos, respectively. Overall, 86% of the videos in this study were related to ≥ 1 of these subspecialties. At the other end of the spectrum, functional, peripheral nerve surgery, and trauma account for only 5.9% of the overall videos. Spine surgery, in particular, is notable for representing a relatively low percentage (16.2%) of the overall videos, but a relatively high percentage of the overall hits, suggesting a demand for additional spine-related videos. Further analyses of the number of views or hits should be used in the future to help guide calls for additional videos.

The disparity in subspecialty representation is likely caused, at least in part, by the technicalities of recording video during a surgery. The intraoperative microscopes and endoscopes used during tumor, vascular, and skull base cases have built-in recording features that afford the audience the same view seen by the surgeon, whereas these technologies are not typically required for many of the other subspecialties. Nevertheless, Web site analytical data have shown that among visitors to The Neurosurgical Atlas site, general neurosurgical topics were viewed the most frequently, and that other subspecialty topics (tumor, vascular, pain, epilepsy, and spine) were viewed with a similar frequency.¹⁰ There seems to be demand for a well-rounded assortment of videos, particularly if these videos are to be used to build or supplement a neurosurgical curriculum. Overhead lights

with built-in cameras, miniature cameras mounted to headlights, and other emerging technologies can be used to capture surgical recordings without a microscope or endoscope. In addition, the “Call for Videos” format used by *Neurosurgical Focus: Video* provides a unique opportunity to guide the topics of videos that are submitted to the journal. Upcoming topics include “Surgery for craniocervical deformity and instability,” “Surgery for pain”, and “Craniosynostosis,” suggesting a recognition by the editors that these are areas that have been underrepresented.

Quality Control

Operative videos that are accessible online, particularly those that are found on user-generated video-sharing sites, come with an important caveat: many have not been peer reviewed, and the reliability of the content has not been verified.²⁴ Without academic oversight, poor-quality videos showing false information and poor techniques can make their way onto the Internet, particularly when there are conflict of interest issues in play (e.g., videos that highlight specific instrumentation rather than a surgical technique).¹⁸ Calls for a more scholarly approach have resulted in the development of validated scoring scales, such as the DISCERN instrument.^{26,27} DISCERN is a rating tool that assigns a score out of 80 based on 15 questions that are each rated on a scale of 1–5. Although initially designed to evaluate written consumer health information, the DISCERN instrument has also been used to grade online videos based on critical assessments of their content.^{18,28,29} An analysis of the top 160 videos on YouTube related to neurosurgery used the DISCERN instrument to evaluate each video and showed that videos that were created by physicians and academic institutions were of higher quality.²⁹ However, the DISCERN tool was specifically designed to assess resources for patients and the lay public, rather than operative videos to be watched by other surgeons. Other criteria are likely to be of value when evaluating a surgical video. The same study of neurosurgical YouTube videos found that of the 24 operative videos that were identified, only 33% had auditory commentary, and only 25% provided educational learning points, thereby lessening their educational impact. The investigators called for clinicians and institutions to “hold themselves and each other to a higher standard of content creation.”²⁹

In contrast, the video sources that were analyzed in the current study are examples of high-quality video libraries that are endorsed by senior neurosurgical leadership, national/international neurosurgical associations, and respected neurosurgical publications. In particular, *Operative Neurosurgery* and *Neurosurgical Focus: Video* are unique and forward-thinking resources that emphasize the importance of the peer-review process. A breakdown of the number of videos uploaded each year suggests that investigators are increasingly turning to these journals as a destination for their videos, rather than YouTube channels. Videos published in these journals are indexed in PubMed, which has likely contributed to their popularity. The journals have a more formal structure for their submissions: videos are encouraged to include a brief history and physical, pertinent imaging, positioning, exposure, closure, and postoperative imaging, in addition to the critical aspect of the surgery. Including these details, and remaining concise, is essential for ensuring that these videos maximize their educational potential.¹⁵ It is equally important to include sufficient follow-up information, so that the viewer may

understand the impact of various surgical techniques on the patient’s outcome. Videos that highlight techniques for managing complications should be encouraged; viewers are otherwise at risk of developing a false sense of security by watching highly selected videos that show only the best outcomes.¹⁵

A modified DISCERN instrument that takes these factors into consideration may be useful both as part of the peer-review process as well as for neurosurgeons viewing a published video. Features that can be assessed include: 1) disclosure of conflicts of interest, 2) audio commentary, 3) history and physical examination, 4) preoperative imaging, 5) discussion of preoperative decision making, 6) patient positioning, 7) exposure and closure, 8) annotation of the relevant anatomy with labels, and 9) discussion of the postoperative course and long-term follow-up. Depending on the targeted forum for the video, a short discussion with educational learning points may follow the operative portion of the video, as well. Developing such a tool may assist in maintaining high standards for neurosurgical operative videos, thereby maximizing their educational impact.

Limitations

There are several important limitations to this study. The current analysis is not a complete inventory of the existing operative videos, because there are numerous YouTube videos that are sponsored by individual surgeons and/or institutions. Our goal was to provide an overview of those videos that are specifically endorsed by reputable neurosurgical organizations. We provide a snapshot of the available videos, but because new videos are frequently uploaded, the numbers cited in the current study may rapidly change. In addition, the video sources that were selected for analysis are based in North America, which is an important confounder when considering the analysis of geographic representation. Future studies are necessary to truly assess the global contribution to neurosurgical operative videos, which was not within the scope of the present study. Future studies may also provide more detailed analyses of operative videos dealing with an individual surgical technique.

Operative videos are only 1 component of the electronic resources that are used to supplement neurosurgical education. The *Neurosurgical Atlas*, for instance, contains not only operative video cases, but also volumes with text-based explanations of various topics, as well as grand rounds webinars. These other multimedia formats are important elements of building a full neurosurgical curriculum, but a full analysis of these resources was outside the scope of our study. In addition, although previous publications have used Web 2.0 analytics to study Web traffic data, we were unable to do so because such tools are limited to the owners of the individual Web site.^{10,13,17} However, knowing which operative videos are most frequently viewed would help identify the need for additional video topics in a dynamic manner.

CONCLUSIONS

Neurosurgical operative videos are a useful educational adjunct, both for neurosurgical trainees as well as for the continued education of neurosurgery attendings. Most of the operative videos that are accessible have come from surgeons in the United States and relate to tumor, vascular, and/or skull base cases. Although

these videos are typically of high quality, future efforts may benefit from the curation of videos highlighting underrepresented subspecialties, providing long-term follow-up data, and demonstrating techniques for managing complications.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

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& editing. **L. Madison Michael:** Supervision, Writing - review & editing. **Jonathan E. Martin:** Supervision, Writing - review & editing. **Markus Bookland:** Supervision, Writing - review & editing. **David S. Hersh:** Conceptualization, Project administration, Supervision, Writing - original draft, Writing - review & editing.

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APPENDIX

