

Institutional Collaboration in Plastic Surgery Research: A Solution to Resource Limitations

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Background: The current climate of health care reform and research funding restrictions presents new challenges for academic plastic surgery. Collaboration with private enterprise has been associated with greater research productivity in the general biomedical literature. This study seeks to analyze publication trends in *Plastic and Reconstructive Surgery* (PRS) to evaluate any changes in institutional collaboration over time.

Methods: Bibliographic data were retrospectively analyzed for all original research and discussion articles published in PRS from 2012 to 2016. The institutional affiliation for each publication was characterized from its author list as solely academic, private, government, or combinations of these (defined here as “institutional collaborations”). Annual National Institutes of Health (NIH) funding data were also collected over the same period, and associations were analyzed by linear regression.

Results: In total, 2,595 publications were retrieved from PRS between 2012 and 2016, of which 2,027 (78.1%) originated solely from academic institutions and 411 (15.8%) from institutional collaborations. Although the proportion of academic-only publications decreased from 82% to 74%, the proportion of institutional collaborations increased from 10% to 20% ($P = 0.038$). Concurrently, NIH funding declined from \$33.4 billion to a low of \$30.7 billion, which was associated with the decreasing proportion of academic-only publications ($P = 0.025$) and increasing proportion of institutional collaborations ($P = 0.0053$).

Conclusions: Traditional sources of academic research funding have been restricted during the politically and financially tumultuous recent years. With no signs of improving access to financial resources from the NIH, academic plastic surgeons may consider diversifying their institutional partnerships to continue pioneering advances in the field. (*Plast Reconstr Surg Glob Open* 2018;6:e1822; doi: 10.1097/GOX.0000000000001822; Published online 6 June 2018.)

INTRODUCTION

Plastic surgery is an innovative clinical specialty that leads research endeavors exploring a wide range of

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aesthetic and reconstructive challenges. As such, it is heavily reliant on extensive cooperation with a wide spectrum of surgical specialties.^{1–3} Collaboration in plastic surgery research has become more common as researchers reap the benefits of intellectual diversity outside of their home institution, seen in creative new approaches developed through exposure to other types of expertise.⁴ This finding is mirrored globally, as seen in bibliometric studies of South Korean, Chinese, and Irish surgical research publications.^{5–7} Collaboration can also increase the visibility and profile of the involved institutions. For example, in an academic-industrial collaboration, when researchers from Oxford University co-authored articles with GlaxoSmithKline, their articles were cited 4 times more often than comparable articles in their fields.⁸

Although collaboration is associated with increased citation rate of research literature, this finding does not address research productivity. Moreover, recent uncertainties in academic funding, such as the proposed National

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Institute of Health (NIH) budget cuts for 2018, may lead to a decline in research primarily affecting academic institutions.^{9,10} Prescient articles from nearly 3 decades ago predicted that any stagnation in NIH budget growth and funding constraints would push academic surgeons to partner with private enterprise to maximize productivity.^{11–13} Although private enterprise support is already associated with overall higher rates of citation and greater publication rates, it remains unknown whether a similar increase in collaboration is occurring within plastic surgery research.^{14,15}

This study seeks to determine if an association exists between new limitations in NIH funding and institutional collaboration by analyzing publishing trends in plastic surgery research over time.

METHODS

Data Source and Data Extraction

The plastic surgery journal *Plastic and Reconstructive Surgery* (PRs) was selected as our data source, given its status as a leading journal of the field, with the highest journal evidence index and highest impact factor among plastic surgery journals.¹⁶ A retrospective analysis of PRs from 2012 to 2016 was undertaken, and bibliographic data were retrieved for all original research and discussion articles from the content categories *Original Articles*, *Outcomes*, *Ideas and Innovations*, and *Technology and Innovations*. A customized web scraping software tool was developed using Python 3.6.1 (Python Software Foundation). This algorithm enabled us to automatically extract relevant data from the PRs website.

Outcomes

For each publication, the author list, institution of each author, type of institution, country of origin (derived from first author), year, and content category were noted and compiled into a database in Microsoft Excel 2016. Data extraction and subsequent categorization were verified by 2 additional co-authors.

For institution type, each publication was assigned 1 of 5 designated categories: academic-only, private-only, government-only, academic-private, and academic-government. Each author was categorized by determining the primary institutional affiliation listed in the PRs journal references online by Wolters-Kluwer and Ovid Technologies, Inc. Designations were then assigned to each publication according to the co-authors' primary institutional affiliation. The country of origin of each publication's lead author was used to group publications by continent: Africa, Asia, Australia, Europe, North America, and South America; and North America was further subgrouped into Canada/Mexico and the United States of America regions Northeast, Midwest, South, and West, according to the United States Census geographic divisions.¹⁷ Data regarding the type of study and content categories were also collected and analyzed for any significant trends over time.

Funding

Annual NIH funding data were obtained from publicly available Congressional Budget Office presentations and

testimony statements over the study period.¹⁰ To control for inflation and allow for comparisons in real monetary value, the NIH funding amount for each corresponding year was inflation-adjusted for 2016 U.S. dollars.¹⁸

Statistical Analysis

All statistics were performed using SPSS Statistics 24.0 (IBM Corp., Armonk, N.Y.). Counts and percentages for the number of publications falling into each institutional category were evaluated for each of the 5 years in the study period. Overall quantitative and specific regional publication trends over time were analyzed with linear regression and 2-sided *t* test on the slope parameter using a cutoff of $P < 0.05$ for statistical significance. Correlation between institutional affiliation and NIH funding were analyzed by Pearson's *r* correlation coefficient.

Publications arising from each region were then characterized by institutional type to examine any possible regional affinities toward specific institutional collaborations. Using each region's proportional contribution to overall PRs publications as the expected values, Chi-square testing was used to characterize potential region-specific institutional collaboration outliers using a statistical cutoff of $P < 0.01$. Because there were only 5 government-only publications in the entire dataset, and certain regions/continents lacked a minimum of 5 publications in each institutional category, government-only publications were excluded from this analysis, and Africa, Australia, Canada/Mexico, and South America were grouped into an "Other" category.

RESULTS

Publication Characteristics

In total, 2,595 publications were extracted from PRs between 2012 and 2016, with an average of 519 (SD, ± 43) publications each year. Of these, 78.1% were produced by academic-only institutions, 5.9% from private-only institutions, 0.2% from government-only institutions, 11.4% from academic-private collaborations, and 4.5% from academic-government collaborations (Table 1).

Over two-thirds (67.0%) of all publications originated in the United States, with most from the Northeast region (22.2%), followed by the South (18.8%), Midwest (16.9%), and West (9.1%) regions. Europe accounted for 12.5% of publications, followed closely by Asia (12.4%), Canada and Mexico (4.5%), Australia (1.8%), South America (1.7%), and Africa (0.2%; Table 2).

Institutional Collaboration and NIH Funding

The number of publications arising from institutional collaborations (academic-private and academic-government) increased from 47 in 2012 to 110 in 2016 ($P = 0.020$; Fig. 1). The annual proportion of institutional collaborations also increased, from 9.8% in 2012 to 18.7% by 2016 ($P = 0.038$; Fig. 2). This increase in institutional collaboration was due to increases in both academic-private and academic-government partnerships as they individually increased from 6.4% to 13.1% and 3.3% to 5.6% in the same time frame, respectively.

Table 1. Institutional Characteristics

| | Publications by Institutional Type (%) | | | | | Total |
|---------------------|--|------------|------------|------------|------------|--------------|
| | 2012 | 2013 | 2014 | 2015 | 2016 | |
| Academic | 395 (82.1) | 423 (79.1) | 390 (79.8) | 372 (74.0) | 447 (76.2) | 2,027 (78.1) |
| Private | 39 (8.1) | 30 (5.6) | 27 (5.5) | 27 (5.4) | 29 (4.9) | 152 (5.9) |
| Academic/private | 31 (6.4) | 53 (9.9) | 53 (10.8) | 81 (16.1) | 77 (13.1) | 295 (11.4) |
| Academic/government | 16 (3.3) | 27 (5.1) | 19 (3.9) | 21 (4.2) | 33 (5.6) | 116 (4.5) |
| Government | 0 (0.0) | 2 (0.4) | 0 (0.0) | 2 (0.4) | 1 (0.2) | 5 (0.2) |
| Total | 481 | 535 | 489 | 503 | 587 | 2,595 |

Table 2. Regional Characteristics

| | Publications by Region (%) | | | | | Total |
|---------------|----------------------------|------|------|------|------|------------|
| | 2012 | 2013 | 2014 | 2015 | 2016 | |
| Africa | 1 | 1 | 1 | 0 | 1 | 4 (0.2) |
| Asia | 42 | 72 | 64 | 62 | 81 | 321 (12.4) |
| Australia | 7 | 15 | 8 | 7 | 9 | 46 (1.8) |
| Canada/Mexico | 21 | 30 | 26 | 24 | 17 | 118 (4.5) |
| Europe | 64 | 72 | 49 | 55 | 84 | 324 (12.5) |
| Midwest | 82 | 81 | 88 | 95 | 92 | 438 (16.9) |
| Northeast | 110 | 106 | 107 | 119 | 135 | 577 (22.2) |
| South | 101 | 101 | 99 | 84 | 104 | 489 (18.8) |
| S. America | 12 | 8 | 4 | 10 | 9 | 43 (1.7) |
| West | 41 | 49 | 43 | 47 | 55 | 235 (9.1) |
| Total | 481 | 535 | 489 | 503 | 587 | 2,595 |

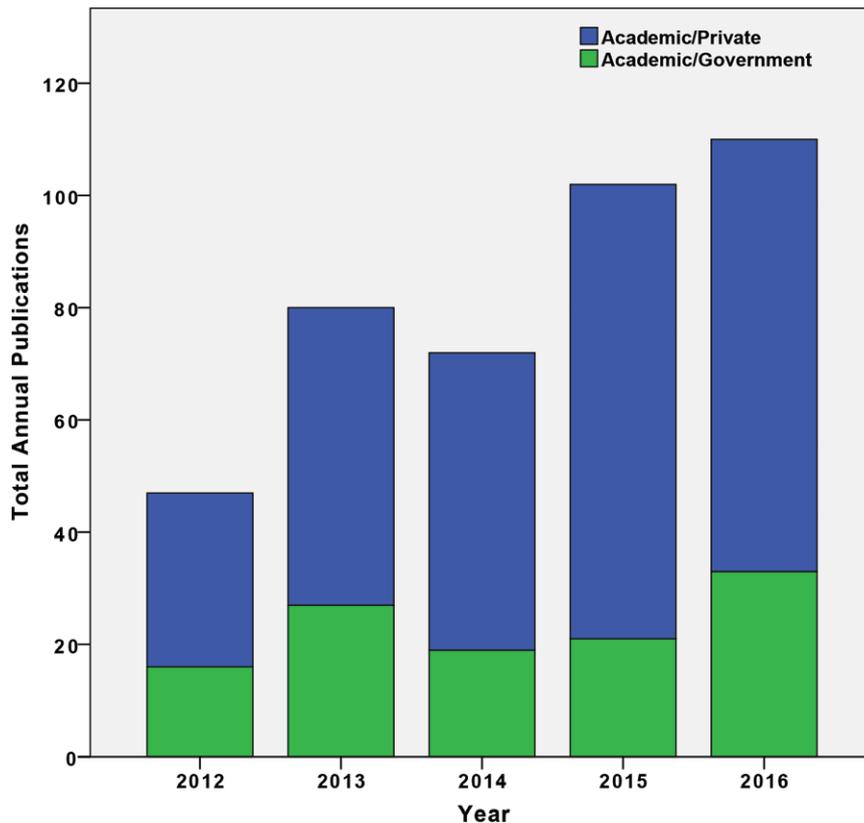


Fig. 1. Number of academic and private/government collaborative publications by year. There is an increasing trend of institutional collaborations in the last 5 years ($P = 0.020$).

Over the study period, NIH funding decreased from \$33.4 billion in 2012 to \$31.3 billion in 2016, with a nadir of \$30.7 billion in 2015 (Fig. 2). As NIH funding decreased, the annual percentage of academic-only pub-

lications decreased ($P = 0.025$), with a concomitant increase in institutional collaborations ($P = 0.0053$; Fig. 3). This increase appeared to be largely due to academic-private partnerships ($P = 0.011$), whereas academic-govern-

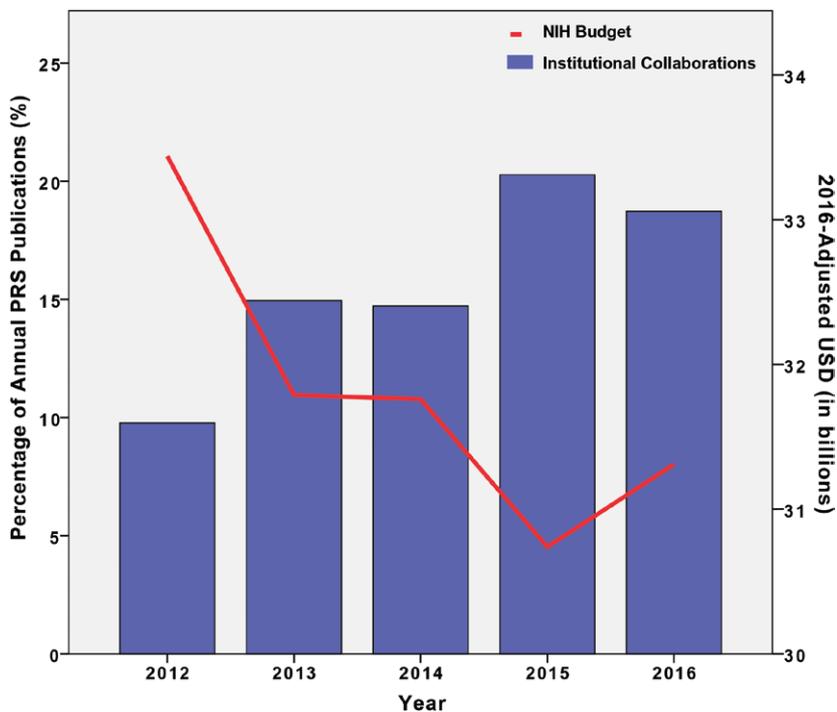


Fig. 2. Percentage of academic and private/government collaborative publications with NIH budget by year. There is an increasing proportion of PRS publications originating from institutional-type collaborations in the last 5 years ($P = 0.038$) during concomitant NIH funding challenges.

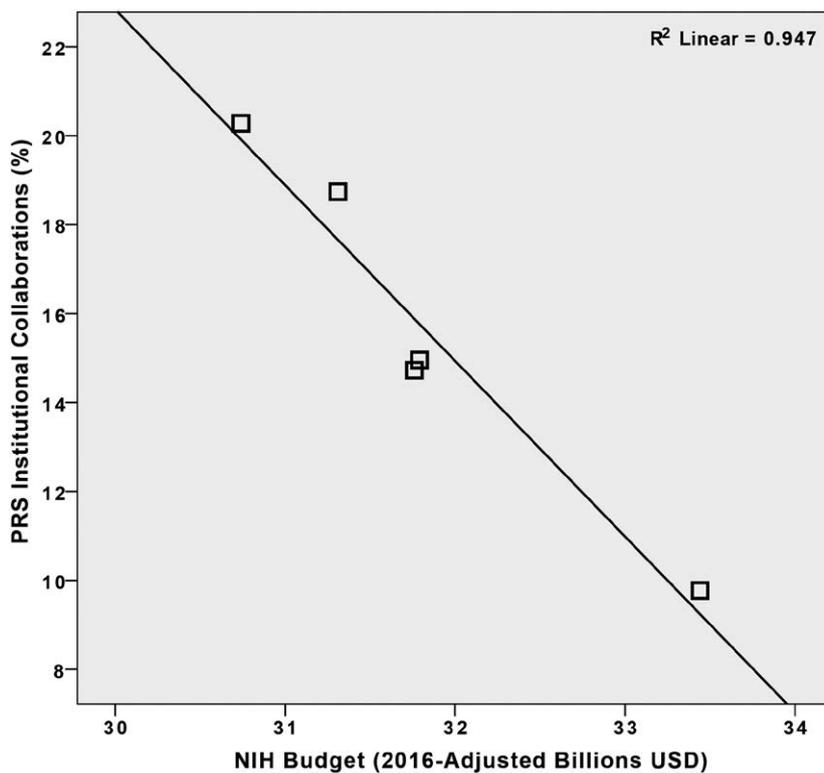


Fig. 3. NIH budget and percentage of collaborations. There is a significant inverse correlation between the annual percentage of PRS publications originating from institutional-type collaborations and available NIH funding ($P = 0.0053$).

ment research partnership increases were not significant ($P = 0.32$).

Regional Publication Trends

Research publication output can also be analyzed by geographic region as a proportional contribution to all PRS publications in the study period. The United States accounts for the majority of all publications in PRS over the study period, with significant contributions from Europe and Asia (Fig. 4).

When the regional data were analyzed by specific year to discern any research productivity trends over time for specific regions, most regions demonstrated fairly constant relative annual research productivity, with the exception of Asia and the South region (Fig. 5). Relative contribution to PRS publications appeared to increase over the study period in Asia, while seeming to decrease in the South region. However, these trends were not statistically significant ($P = 0.20$ and $P = 0.12$, respectively).

Regional Institutional Collaborations

When regional publications were examined according to institutional collaborations, there appeared to be certain outliers (Fig. 6). Chi-square analysis of each region according to its institutional collaborations found Asia [X^2 (3, $N = 320$) = 17.7, $P = 0.00051$], Europe [X^2 (3, $N = 323$) = 53.3, $P = 0.00001$], Northeast [X^2 (3, $N = 577$) = 15.1, $P = 0.0018$], South [X^2 (3, $N = 487$) = 15.1, $P = 0.0018$], and the other grouping [X^2 (3, $N = 211$) = 19.7, $P = 0.00020$] to be significant outliers. In Asia and Europe, 73% and 72% of

this variation arose from significant overrepresentation of academic-government collaborations with nearly double the expected 14.3 and 14.5 academic-government publications, respectively. In the Northeast region, its significant variation arose from decreased numbers of private (13) and academic-government (8) publications than expected (28.6 and 21.9, respectively). Conversely, in the South region and the Other grouping, their outlier status is from increased private enterprise with 43 and 26 observed compared with an expected 28.6 and 12.4, respectively.

DISCUSSION

Amidst the uncertainties of health care reform and the biomedical funding crises, the plastic surgery research community should act with creative foresight to continue advancing the frontiers of plastic and reconstructive surgery. This study analyzes the leading plastic surgery research journal, PRS, from 2012 to 2016 to identify publication trends that may guide future research endeavors. The study period coincided with a tumultuous 5 years that saw implementation of the Affordable Care Act, debt ceiling challenges, government shutdown, and sequestration; all of which resulted in fiscal challenges and the restriction of NIH funding.^{19,20} Although top-down efforts are currently underway to relieve research funding restrictions, this study documents increasing institutional collaborations in research productivity over a recent 5-year period.²¹ There are also many other concurrent forces that may explain these observations.

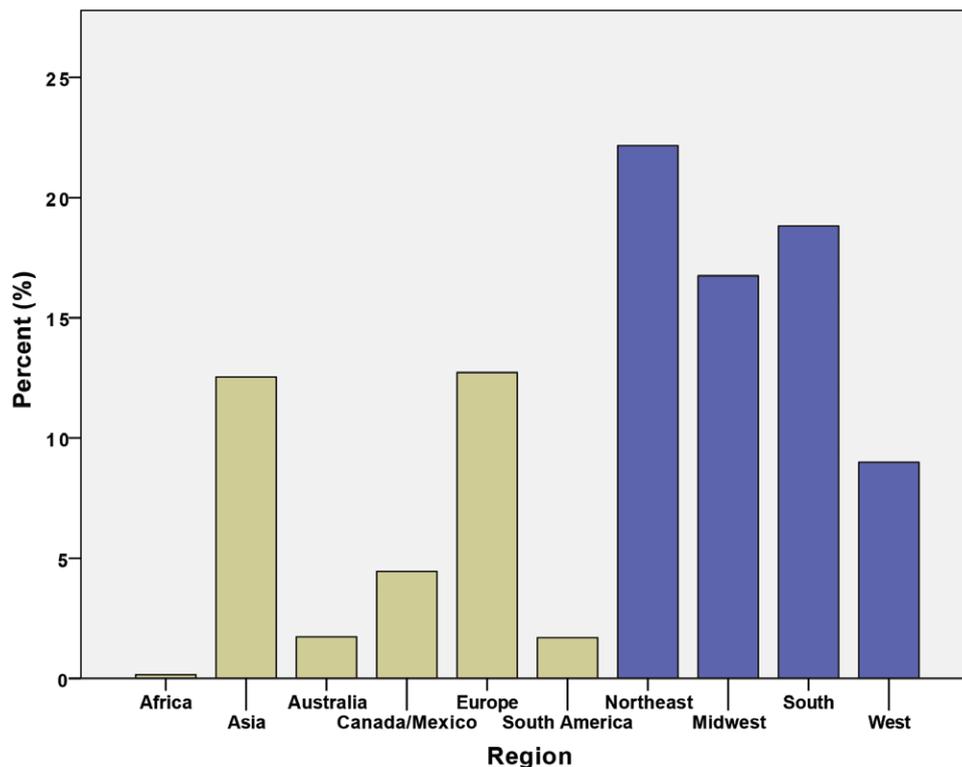


Fig. 4. Regional percentages of total publications. The United States accounts for approximately two-thirds of PRS publications.

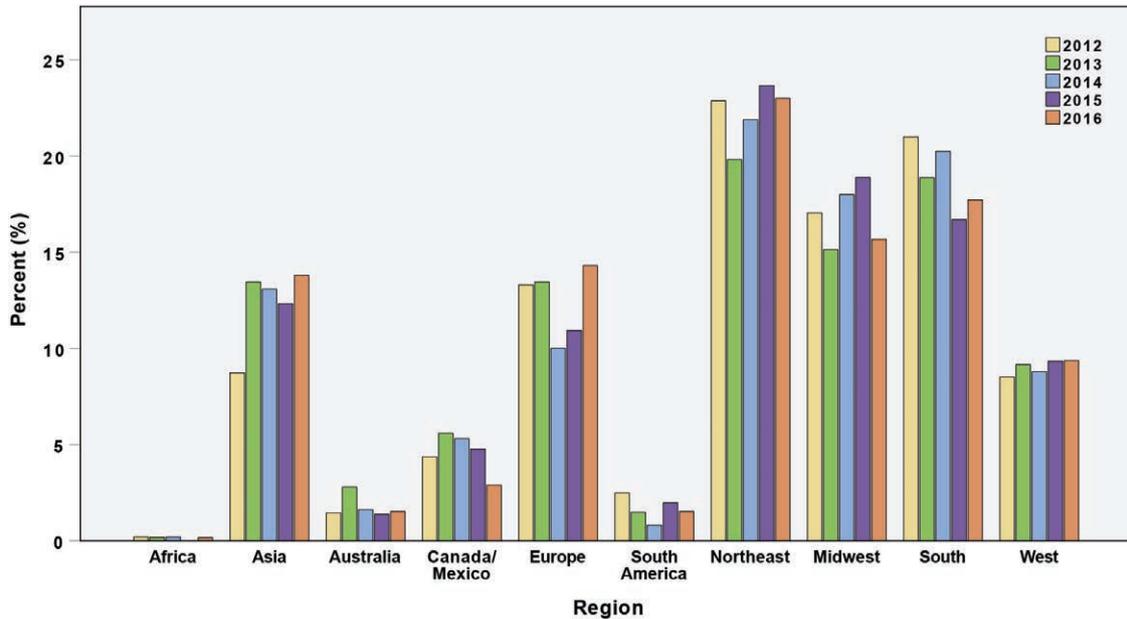


Fig. 5. Regional percentages of annual publications. Each region accounts for a proportion of PRS publication that has remained largely constant over this time period with the potential exceptions of Asia and South region.

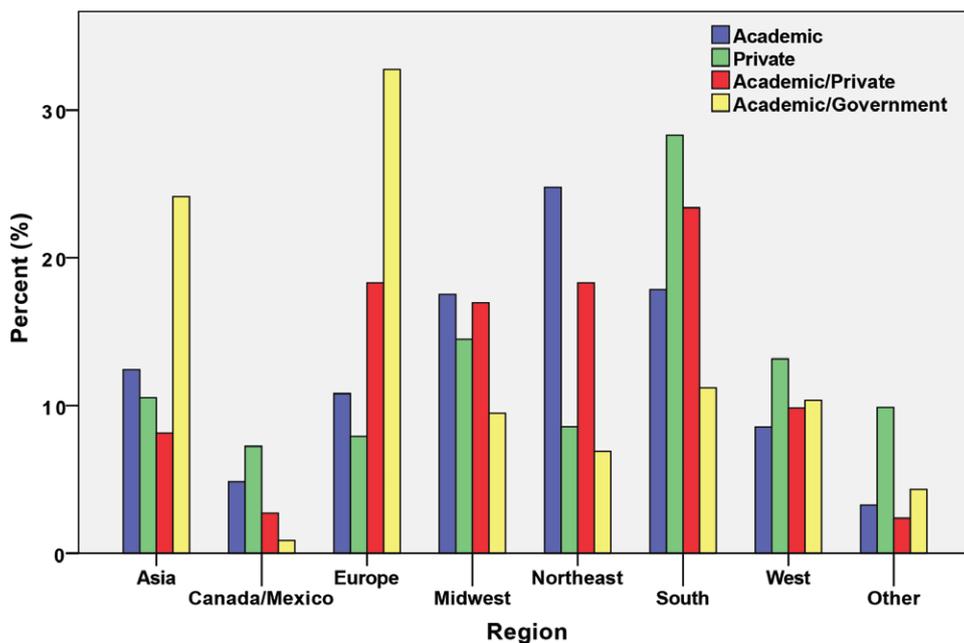


Fig. 6. Institutional collaborations by region. Some regions are associated with a disproportionate amount of publications from specific collaboration types.

Greater institutional collaboration in the setting of funding limitations is no foreign concept, and increased research networks have been observed to facilitate collaboration.^{22,23} For example, partnerships with foreign aid organizations and local hospitals to establish cleft palate repair centers in resource-limited areas have led to favorable patient outcomes and fewer surgical complications.²⁴ Moreover, international collaboration within plastic surgery has been increasing over the years, with 1 analysis showing a growing trend in multinational academic collaborations

from 1972 to 2004.²⁵ Our study demonstrates a strong correlation between an increasing proportion of published articles in PRS and academic collaboration with both private enterprise and government entities. In particular, the chief driver of this associative trend appears to be academic-private partnerships ($P = 0.011$) over academic-government ($P = 0.32$), which is also reflected in the overall literature.²⁶ Although academic-government partnerships may also benefit through the exchange of different ideas and perspectives, government agencies are likely subject

to the same budgetary constraints felt by academic institutions via the NIH.

The strengths of increasing institutional diversity in research endeavors have been well documented. Academic plastic surgeons, especially NIH-funded surgeons, occupy a valuable niche in the research landscape.²⁷ By promoting the open sharing of information, incentive to publish, and freedom from regular profit quotas that can stifle creative risk-taking, academic researchers are at the forefront of innovation in developing novel therapeutics and mechanisms of action.²⁸ However, they may lack the financial resources and large-scale clinical expertise to navigate economic and legal barriers in translating these ideas from lab bench to patient bedside. In turn, commercial entities often possess the financial resources to fund proof-of-principle testing of these theories developed in academic research groups.²⁹ For example, the NIH experience with large clinical trials is now heavily reliant on industry support as private enterprise can harness their existing global network of diverse clinical trial sites instead of laboriously developing their own.³⁰ There are also drawbacks to this sort of partnership, particularly in the form of conflicts of interest.³¹ It is, therefore, crucial that any conflict of interest is declared and that research is conducted with full transparency.

Geographically, this study finds that some regions are predisposed toward certain institutional research collaborations. Both Europe and Asia seem to have a larger than expected representation of academic-government partnerships. There was a predominance of nationalized hospitals collaborating with universities in Europe, such as the National Health Service in the United Kingdom, and a similar prevalence of military-associated hospitals collaborating with universities in Asia. In the United States, the Northeast region is marked by lower-than-expected private-only and academic/government publications, whereas the South region is marked by higher-than-expected private-only publications.

Although this study identifies an association between decreased NIH funding and an increase in institutional collaborations, there are other explanatory models that are likely pertinent. Other economic factors may have played a role in the observed trend of increased academic-private collaborations. As the effects of the great recession abated in the financial markets, the biotechnology sector saw breakthrough growth and buoyant revenue returns from 2010 to 2015.³² Naturally, this rise in financial fortunes saw significant self-reported increases in research and development spending from \$48.6 billion to \$58.8 billion USD from 2011 to 2015 within the biotechnology sector.³³ External academic observers and other accounting firms confirmed these annualized research increases of 14–18%.^{34,35} These gains in research funding were only present on the side of private enterprise, whereas the NIH began to feel the worst effects of the recession and political turmoil.³⁶ Unsurprisingly, the relative abundance of private enterprise funding may explain the increase in academic-private collaborations between 2012 and 2016.

The study period also coincided with a period of increasing interconnectivity facilitated by technological ad-

vances, further decreasing barriers to communication and collaboration.³⁷ Direct initiatives to facilitate this networking between researchers have had notable effects. The International Collaboration on Complex Interventions, aimed at connecting investigators in multiple disciplines from Canada, the United States, the United Kingdom, and Australia, has increased communication, inter-disciplinary citation, and research productivity.³⁸ Concurrently, the field of plastic surgery has seen an acceleration of the use of social media, such as Twitter and other social networks.³⁹ In particular, a recent study analyzing the use of Twitter in plastic surgery found that approximately 20% of posts by plastic surgeons were directly related to plastic surgery research fields (basic science, patient safety, and reconstruction outcomes).⁴⁰ The advent of social media and greater visibility to the overall public and private enterprise may also contribute to increasing institutional collaboration.

There are further limitations intrinsic to analyses of published data. Because we were not able to examine the characteristics of all submitted manuscripts, accepted or rejected, the identified trends do not necessarily represent those of unpublished manuscripts.⁴¹ There is also a potential lag time involved between NIH funding availability and institutional collaboration. Research projects come to fruition at different rates, and collaborations with different institution types may have been initiated well before the year of publication. However, the NIH budget is typically announced long before its applicable fiscal year and thus may mitigate this phenomenon of lag time. Despite these limitations, our study demonstrates a potential increasing associative trend of institutional collaborations in line with decreasing NIH funding, as modeled by publications in PRS.

CONCLUSIONS

Traditional sources of academic research funding have been restricted during the politically and financially tumultuous years included in our study period. Our study demonstrates that academic plastic surgery has increased research collaboration with private enterprise and government institutions concurrently with decreased academic research funding. With no signs of improving access to financial resources from the National Institutes of Health, these findings may encourage academic plastic surgeons to increase the diversity of their research partnerships to further advance the field.

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