Published in final edited form as:

J Am Coll Surg. 2018 April ; 226(4): 474–481. doi:10.1016/j.jamcollsurg.2017.12.047.

Surgeon Scientists Are Disproportionately Affected by Declining NIH Funding Rates

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Abstract

Background—Obtaining National Institutes of Health (NIH) funding over the last 10 years has become increasingly difficult due to a decrease in the number of research grants funded and an increase in the number of NIH applications.

Study Design—NIH funding amounts and success rates were compared for all disciplines using data from NIH, FASEB, and Blue Ridge Medical Institute. Next, all NIH grants (2006–16) with surgeons as principal investigators were identified using NIH RePORTER and a grant impact score was calculated for each grant based on the publications' impact factor per funding amount. Linear regression and one-way ANOVA were used for analysis.

Results—The number of NIH grant applications has increased by 18.7% ($p=0.0009$), while the number of funded grants ($p < 0.0001$) and R01s ($p < 0.0001$) across the NIH has decreased by 6.7% and 17.0%, respectively. The mean success rate of funded grants with surgeons as principal investigators (16.4%) has been significantly lower than the mean NIH funding rate (19.2%) ($p = 0.011$). Despite receiving only 831 R01's during this time period, surgeon scientists were highly productive with an average grant impact score of 4.9 per \$100,000, which increased over the last 10 years (0.15 ± 0.05 /year, $p=0.02$). Additionally, the rate of conversion of surgeon scientist mentored K awards to R01's from 2007–12 was 46%.

Conclusions—Despite the declining funding over the last 10 years, surgeon scientists have demonstrated increasing productivity measured by impactful publications and higher success rates in converting early investigator awards to R01s.

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Disclaimer: This work is the opinion of the authors and does not necessarily represent the views of the National Institutes of Health. Presented at the Southern Surgical Association 129th Annual Meeting, Hot Springs, VA, December 2017.

Keywords

Surgeon-scientist; NIH; Funding; Grants; R01; K-Award

Introduction

Historically, surgeons have made invaluable contributions to medicine and, in turn, to science. Landmark discoveries have led to surgeons winning the Nobel Prize: 1909 Theodor Kocher (physiology, pathology, and surgery of the thyroid gland), 1912 Alexis Carrel (blood vessel repair and organ transplantation), 1949 António Egas Moniz (shared with Walter Hess) (the discovery of prefrontal leucotomy), and 1990 Joseph Murray (shared with E. Donnall Thomas) (organ and cell transplantation in the treatment of human diseases) (1). Despite these groundbreaking contributions by surgeons in the past, the number of highly impactful publications by surgeons currently may be declining. Specifically, an analysis of *The New England Journal of Medicine* demonstrated a significant decline in publications related to surgical disciplines over the last 50 years (2).

The NIH has been supportive of investigations that can improve our understanding of human disease and potentially provide novel therapies. However, NIH funding has become increasingly difficult to obtain. The majority of NIH funding has been slated for extramural Research Project Grants (RPGs), of which R01s are a major component. R01s are a type of grant that is generally accepted “to support a discrete, specified, circumscribed project” (3). For meaningful contributions to science, funding at the R01 level is typically required to support a successful research laboratory. Moreover, the NIH has supported mentored K awards to help develop physician-scientist developing into independent investigators (i.e. attaining an R01).

Although surgeons are capable of performing high quality research, fewer surgeons are performing research than in the past. A few potential reasons for this decline include: 1) increasing clinical demand, 2) difficulty in obtaining NIH funding, and 3) belief that research may not be part of their role (4, 5). With this in mind, we hypothesized that surgeons have been disproportionately affected by declining NIH funding rates. Furthermore, we evaluated the overall publication productivity of funded surgeons. Finally, we evaluated the success of surgeons to convert K-awards into R01-equivalent funding.

Methods

Collection of R01 Grant Information

The National Institutes of Health Research Portfolio Online Reporting Tools Expenditures and Results (NIH RePORTER) was queried to collect grant information of Surgery department R01 grants ending in years 2006 to 2016 (6). The NIH RePORTER is a database established by the National Institutes of Health that publishes project information, funding records, project descriptions, citations of papers funded by grants, and patent information from the U.S. Patent and Trademark Office. A Python (Python Software Foundation, Wilmington, DE) (PyCharm Edu Version 1.01, Jet Brains (Prague, Czech Republic)) script

was written to extract the following information from each grant: grant identifier number, title, principal investigator, type of grant, awardee organization, awardee department grant start/end dates, awarding NIH institute, total funding amount, number of publications, PMID of each publication, and the journal of each publication. The Python script utilized three publically available software packages (Phantom JS, Selenium Webdriver, and Beautiful Soup) to assist with data extraction.

NIH Departmental Funding Information

The Blue Ridge Medical Institute (Horse Shoe, NC) was queried for funding information for Internal Medicine and Surgery departments from 2006 to 2016 (7). Total NIH funding information was obtained from the National Institutes of Health Office of Budget (8).

Grant Success Rates

Grant success rates were collected from a report by the Federation of American Societies for Experimental Biology (FASEB) (9). The data for the report was extracted from the NIH Office of Extramural Research NIH FY 2016 Budget summary. From this report, the number and success rates of Research Project Grants (RPG) and R01 applications were collected. Research Project Grant (RPG) success rates for Internal Medicine and Surgery departments specifically were collected from Table #208 of the NIH RePORT (10). The following grants are categorized as RPGs: DP1, DP2, DP3, DP4, DP5, P01, P42, PN1, PM1, R00, R01, R03, R15, R21, R22, R23, R29, R33, R34, R35, R36, R37, R50, R55, R56, R61, RC1, RC2, RC3, RC4, RF1, RL1, RL2, RL9, RM1, UA5, UC1, UC2, UC3, UC4, UC7, UF1, UG3, UH2, UH3, UH5, UM1, UM2, U01, U19, and U34.

Collection of Awardee Information

Information on grant awardees was collected including: academic division, degrees, and current university. The majority of information was obtained from faculty webpages of respective surgeons. If an awardee is currently in private practice, publicly available information online was utilized to collect awardee information.

Calculation of Grant Impact Metric

A Grant Impact score was calculated for each R01 grant. First, an impact factor was assigned for each paper resulting from a particular R01 grant according to Journal of Citation Reports (2016 Journal Citation Reports® (Clarivate Analytics, 2017) Philadelphia, PA) (11). The sum of the impact factors for papers in each grant was divided by \$100,000 to calculate the final Grant Impact. This calculation is similar to one used by Danthi et al. in determining grant impact (12).

K Award to R Award Conversion Rate

K-level awards to principal investigators in Surgery departments were queried in NIH RePORTER between the years of 2007 and 2012 (6). The principal investigators of these awards were searched in NIH RePORTER for subsequent grants. A funded R01 or equivalent award was considered to be a successful transition from K to R award.

Statistics

Funding rates by specialty and Grant Impact by division were analyzed by one-way Analysis of Variance (one-way ANOVA). Changing funding levels, success rates, and impact scores over time were analyzed by linear regression. All analysis was performed and figures were generated using GraphPad Prism Version 7.0a for Macintosh (Copyright © GraphPad Software, La Jolla California USA)

Results

Current NIH Funding

In 2016, the National Institutes of Health (NIH) had a budget of \$32.3 billion, an increase of nearly \$4 billion compared to \$28.5 Billion in 2006 (Figure 1A; $p = 0.028$) (8). Total NIH funding has significantly increased at a rate of \$213 million per year. Funding for all Internal Medicine faculty (including medical subspecialties) from the NIH has remained relatively stable at \$3.2 billion per year over the last 10 years with a slight increase of \$5 million per year (Figure 1B; $p = 0.694$) (7). NIH funding to surgeons, on the other hand, has significantly declined from a peak of \$314 million (2007) to \$292 million (2016) at a rate of a \$3 million decrease per year (Figure 1C; $p = 0.044$) (7).

The number of RPG (any R or larger award) applications has increased significantly from 2006 to 2016 (45,688 to 54,220; $p < 0.00009$, Figure 2B). However, the number of R01 applications has been relatively unchanged over the last decade (Figure 2B; 29,097 to 30,106; $p = 0.131$). Despite a rising number of applications, the total number of Research Project Grants, funded by the NIH has significantly declined by 6.7% over the past decade from 36,812 in 2006 to 34,329 in 2016 (Figure 2A; $p < 0.0001$). Further, the number of funded R01s, the most common Research Project Grant, also significantly declined by 17.0% from 29,123 in 2006 to 24,171 in 2016 (Figure 2A; $p < 0.0001$) (9). Finally, the success rates for RPG (19.3%) and R01 (20.4%) applications have significantly declined (RPG: 0.35% decrease per year [high: 21.8% (2008), low: 16.8 % (2013)], $p = 0.020$; R01: 0.43% decrease per year [high: 23.6% (2007), low: 17.5% (2013)], $p = 0.019$; Figure 2B)(9).

The RPG funding success rates have declined across the entire NIH ($p = 0.020$) (Figure 3). By one-way Analysis of Variance, over the past decade, surgeon-scientists (16.4%) have significantly lower RPG application funding success rates compared colleagues in Internal Medicine specialties (20.7%; $p = 0.0001$) and compared to all NIH RPG applicants (19.2%; $p = 0.011$).

Productivity by Surgeon-Scientists

Surgeon-scientists' grant productivity was evaluated. A Grant Impact (see Methods) per \$100,000 was calculated for each of the 831 surgery R01s ending between 2006 and 2016. Grants awarded to surgeons have an improving trend of Grant Impact per \$100,000 awarded, indicating greater publication impact (Figure 4A). Over this period, Grant Impact increased by 0.15 per year for R01s awarded to Surgery faculty ($p = 0.019$). Mentored K-award to R-award conversion rates have increased from 2007 to 2012 by 2.57% per year. Conversion rates of K-awards to R-awards by year of K-award completion are shown (Figure 4A). K-

award to R-award conversion rates were evaluated only till 2012 due to a lag time in applying for and obtaining R-award funding after K-award project completion.

Next, grant holders with an MD degree or MD/PhD degrees (n=463, assumed to be Surgeons) were evaluated separately from all Surgery department grant awardees, which included PhD scientists (Figure 4B). MD surgeon-scientists have an increasing trend of Grant Impact Per \$100,000 from 2006 to 2016. Surgeon-scientists have increased Grant Impact Per \$100,000 by 0.099 per year ($p = 0.3046$).

Grant Impact and Grant Funding Rates By Surgical Specialty

Divisional data on each principal investigator of Surgery R01s was collected (Figure 5A). Surgical Oncology (n = 93), Cardiac/Thoracic (n = 89), and Transplant (n = 74) divisions had the highest number of grant awards. Based on this data, the Grant Impact per \$100,000 was calculated for each division (Figure 5B). Funded orthopedic surgeons had the highest Grant Impact per \$100,000 (10.43), while the lowest Grant Impact score was for funded Breast Surgeons (1.63). Orthopedic Surgery PIs were significantly more impactful than General Surgery (3.73; $p = 0.005$), Urology (3.37; $p = 0.011$), Vascular Surgery (2.69; $p = 0.001$), and Burn/Shock Trauma (1.72; $p = 0.044$) PIs. Cardiothoracic Surgery (6.55) principal investigator R01s were significantly more impactful than Vascular Surgery R01s (2.69; $p = 0.016$).

Next, the average funding amount per grant was examined by surgical specialty (Figure 5C). Acute Care Surgery received the greatest funding amount per grant awarded (\$4.9 million $\pm$ 1.78), while Breast Surgery received the lowest funding per grant (\$1.2 million $\pm$ 0.16). Acute care surgery received significantly more funding per grant compared to Transplant Surgery (\$2.3 million $\pm$ 0.20; $p = 0.015$), Cardiothoracic Surgery (\$2.3 million $\pm$ 0.20; $p = 0.0194$), Otolaryngology (\$2.15 million $\pm$ 0.34; $p = 0.031$), Pediatric Surgery (\$2.04 million $\pm$ 0.25; $p = 0.018$), Neurosurgery (\$2.0 million $\pm$ 0.20; $p = 0.005$), Surgical Oncology (\$2.0 million $\pm$ 0.16; 0.004), Surgery Research/Surgical Sciences (\$2.0 million $\pm$ 0.28; $p = 0.0075$), Urology (\$2.0 million $\pm$ 0.25; $p = 0.010$), Endocrine (\$1.7 million $\pm$ 0.43; $p = 0.042$), and Surgery Critical Care (\$1.2 million $\pm$ 0.36; $p = 0.016$).

Discussion

As the main funding source for scientific research in the US, the budget, priorities, and funding levels of the NIH are important factors to understand. The present study focused on changes in NIH funding over the past 10 years, specifically in regards to funding to surgeon-scientists and surgeon-initiated grants. The present analysis found that the level of total NIH funding has increased and funding to Internal Medicine faculty has remained stable over the last 10 years, whereas the level of funding given to surgeons has declined (Figure 1). The number of applications for Research Project Grants and R01 grants has increased (Figure 2B) while the success rate and number of funded grants for both categories of grants has significantly declined (Figure 2A, Figure 2B). The funding success rates for Internal Medicine and Surgery departments have remained stable (20.7% $p = 0.111$; 16.4% $p = 0.425$). However, Surgery departments have a significantly lower funding success rates than either Internal Medicine (20.7%; $p = 0.0001$) or the NIH in its entirety (19.2%; $p = 0.011$).

by one-way ANOVA (Figure 3). Despite this low funding rate, over the last 10 years, funded surgery faculty have significantly increased in Grant Impact per \$100,000 as well as in converting K-awards to R-awards (Figure 4A). When looking at MD surgeon-scientists only, the Grant Impact Per \$100,000 has also increased over the last ten years (Figure 4B). Finally, we demonstrate the breakdown by surgical specialty for grant funding and productivity.

While total NIH funding has increased in the last 10 years (2006–2016), the amount of funding to Surgery departments has declined. This decline may be explained by the fact that surgeons face increasing pressure by hospital administrators to spend their time on patient care, which is more financially beneficial to the hospital system. With an increasing clinical load, surgeons are often faced with tough decisions regarding work-life balance. Building a clinical practice along with running a research laboratory can be burdensome to young surgeons (5, 13). Additionally, it is important for academic surgeons' careers to publish papers early on in their career (14). Often times, clinical research projects may be less labor intensive and potentially less costly than translational/ bench research investigations, which may entice young surgeons to focus their academic efforts on performing clinical projects. In accordance with our findings, Mann et al. have reported the number of NIH grants applications by surgeons has been declining (15). With a declining number of applications and a lower funding success rate, surgical research is decreasing at an alarming level even though our data suggests R01-funded surgeons are performing increasingly well with respect to grant publication impact. Similar to Jones et al., we advocate for departmental support and mentorship for young surgeon-scientists to write NIH grant applications and start research laboratories (16). In addition to strong clinical mentorship at the beginning of a career, strong research mentorship is crucial to help surgeons learn how to develop their scientific interests, write grants, and obtain NIH funding (17, 18).

While the number of applications by surgeons and the surgeon funding rates are discouraging, surgeon K-award to R-award conversion rates have been trending upward (Figure 4A). K-awards are "Mentored Clinical Scientist Research Career Development Awards" created for clinicians to establish basic science research laboratories and prospective clinical investigation under the guidance of a senior mentor. The Thoracic Surgery Foundation for Research and Education and Society for Vascular Surgery Foundation have established additional mentorship and advocacy for young surgeons to apply for K-awards (19, 20). These societies have established joint-programs with the National Heart Lung and Blood Institute (NHLBI) to promote surgeon K-award funding. These societies and programs have successfully allowed for K-awardees to transition to R01-level funding (19, 20). One solution to a decreasing number of surgeon-scientists is to establish more programs such as these to help increase applications for K-awards. Many surgeons find the thought of establishing basic science laboratories and applying for R01 funding to be daunting (5). Easing young surgeons into the gargantuan task of starting a basic science laboratory via K-awards may decrease the barriers to entry and increase the number of surgeons who pursue basic science research. Unfortunately, surgeons are currently applying for very few K08 awards (21). Strong research mentorship is necessary in order for surgeons to successfully obtain K-awards. Hospital administrators and Surgery

departmental leaders need to encourage young surgeons to apply for these awards by providing research space, mentorship, and protected research time.

A recent editorial proposed that surgeon-scientists who perform research are affected by an increasing clinical demand which has not affected other physician-scientists in a similar fashion (4). Surgeons generate large amounts of revenue for surgery departments/ hospitals and “policymakers must stop seeing surgeons as easy sources of revenue” (4). Patient care is advanced by surgical research and therefore the two are inevitably linked. Some potential ways we can support surgical research would involve closer alignment with the NIH. Examples could include: 1) special allowances for surgeons to offset the costs for departments in regard to K awards which may lead to an increased number of K award applications, 2) greater surgeon participation on NIH study sections to advocate for surgeon PIs, 3) RFAs specifically focusing on surgical research to encourage surgical grant applications, and 4) making the application process less burdensome via departmental support or by simplifying the application may solicit a higher number of grant applications from surgeons.

The results of the present study are limited by a few factors. We only evaluated NIH R01 grants in this study as this is the major type of grant used for running academic research laboratories in the United States. We are unable to study non-NIH funding sources such as industry grants, American Heart Association grants, and American Cancer Society grants as data on these funding mechanisms are less publically available. Second, the Grant Impact of non-surgeons such as internists, pathologists, and anesthesiologists were not evaluated and compared in our study as this would be an inordinate number of investigators and grants. The number of R01 applications (and resubmission) by surgeons over this time was not evaluated. Any surgeons as co-investigators or collaborators and their percent effort towards a grant was not analyzed. Additionally, we were limited to studying K-awards only until 2012 to account for the lag time between completing the K-award and obtaining subsequent NIH funding. This K-award to R-award conversion lag time is due to numerous application cycles, hiring of personnel, and delayed publication of manuscripts from K-award research. Finally, we do not have institution-specific information regarding the financial support that surgeons receive during their K-award. The NIH will only pay a maximum of \$100,000 of an investigators salary for 75% of dedicated research effort (22). Often times, surgeons will need to have the remainder of their salary paid by the department. The number of K-award applications may be affected by this problem.

Conclusion

Surgeon funding levels have significantly declined over the past decade in contrast to Internal Medicine and overall NIH funding which have been stable. This decline may be due to low funding rates for surgery grant applications during the past decade. Despite this worrisome trend, surgeons have increased their grant publication impact and sustained a high success rate in converting K-awards to R01-equivalent grants. Potential solutions to declining research funding include protected research time and an emphasis on mentorship. Supporting young surgeons in their research efforts, particularly with respect to K-award submissions, should still remain an important avenue towards these goals. Young-surgeon

scientists need support from academic institutions and the NIH in applying for and successfully obtaining funding in order to increase basic science research and to lead future surgical discoveries that will benefit mankind.

Acknowledgments

Disclosure Information: Nothing to disclose.

Support for this study: This work was supported by the National Institutes of Health [T32 HL07849, UM1 HL088925, T32 GM007267, and T32 GM007055].

Abbreviations

NIH	National Institutes of Health
FASEB	Federation of American Societies For Experimental Biology
RPG	Research Project Grant
NHLBI	National Heart, Lung, and Blood Institute
NIH RePORT	National Institutes of Health Research Portfolio Online Reporting Tools
NIH RePORTER	National Institutes of Health Research Portfolio Online Reporting Tools Expenditures and Results
PMID	PubMed Identifier

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Figure 1.

(A) Total NIH funding. Total NIH funding from 2006 to 2016 is shown in \$Millions. Total NIH funding has significantly increased by \$212.7 million per year ($p = 0.028$). (B) Internal medicine funding. Internal medicine departmental funding from 2006 to 2016 is shown in \$Millions. Internal medicine funding has increased by \$4.93 million per year ($p = 0.6942$). (C) Surgery department funding. Surgery department funding from 2006 to 2016 is shown in \$Millions. Surgery department funding has decreased by \$2.79 million per year ($p = 0.044$). Linear regression analysis was performed for statistical significance.

Figure 2.

(A) Number of funded RPGs and R01s. The total number of Research Project Grants (RPG) and R01s funded are shown from 2006 to 2016. Linear regression analysis is significant for both RPGs ($p < 0.0001$) and R01s ($p < 0.0001$). RPGs have declined at about 396 awards per year whereas the number of R01s per year has declined at about 570 awards per year. (B) RPG/R01 Applications and success rates. The number of RPG Applications and R01 applications from 2006 to 2016 are shown in solid symbols and solid linear regression lines. The number of RPG applications has significantly increased by 933 applications per year ($p = 0.001$). The number of R01 applications has increased by 170 per year ($p = 0.131$). The RPG success rates and R01 success rates from 2006 to 2016 are shown in hollow symbols and dotted linear regression lines. The RPG success rate for funded applications has

significantly declined by 0.35% per year ($p = 0.020$). The R01 success rate for funded applications has significantly declined by 0.43% per year ($p = 0.019$). Linear regression analysis was performed for statistical significance.

Figure 3.

Grant application funding success rates. Research Project Grant application funding success rates are shown from 2007 to 2016. Internal medicine funding success rates have declined by 0.35% per year ($p = 0.111$). Surgery department funding success rates have declined by 0.21% per year ($p = 0.425$). All NIH RPG success rates have significantly declined by 0.41% per year ($p = 0.020$). Statistical analysis was performed using linear regression. Comparison of the 3 groups by one-way ANOVA (overall 10-year comparison) results in surgery success rates being significantly lower than internal medicine ($p = 0.0001$) and all NIH RPG success rates (0.011). Internal medicine success rates are not significantly different from All NIH RPG success rates ($p = 0.223$). IM, internal medicine; RPG, Research Project Grant.

Figure 4.

(A) Surgery grant productivity. Surgery department R01 grant impact per \$100,000 (n = 831) is shown in blue. The impact of surgery R01s has increased by 0.15 per \$100,000 from 2006 to 2016 (p = 0.019). Surgery K-award to R01-equivalent award conversion has increased by 2.57% per year from 2007 to 2012 (p = 0.217). (B) MD only surgery. R01 grant impact. principal investigators with an MD were analyzed separately (n = 463). The grant impact per \$100,000 of MD investigators has increased by 0.099 per year (p = 0.305).

Figure 5.

(A) Number of grants awarded by division. The number of grants for which funding information was available is shown. Surgical oncology (n = 93), cardiac/thoracic surgery (n = 89), and transplant surgery (n = 74) had the highest number of grant awards. Acute care surgery (n = 7), surgery critical care, (n = 6) and breast surgery (n = 2) had the lowest number of grant awards. (B) Grant impact of all surgery divisions. The grant impact per \$100,000 for each division is shown. Orthopaedic surgery (10.43) has significantly higher grant impact per \$100,000 compared to general surgery (3.73; p = 0.005), urology (3.37; p =

0.011), vascular surgery (2.69; 0.001), and burn/shock trauma surgery (2.64; $p = 0.438$), using one-way ANOVA. Cardiac and thoracic surgery (6.55) has significantly greater grant impact per \$100,000 compared to vascular surgery (2.69; $p = 0.016$). (C) Funding per grant by division. The funding per grant in \$Million is shown for each division. Acute care surgery (\$4.9 million) is significantly greater than cardiac and thoracic surgery (\$2.3 million; $p = 0.019$), transplant surgery (\$2.3 million; $p = 0.015$), otolaryngology (\$2.2 million; $p = 0.031$), pediatric surgery (\$2.0 million; $p = 0.018$), surgical oncology (\$2.0 million; $p = 0.004$), urology (\$2.0 million; $p = 0.010$), surgical research/surgical sciences (\$2.0 million; $p = 0.008$), neurosurgery (\$2.0 million; $p = 0.005$), endocrine surgery (\$1.7 million; $p = 0.042$), and surgery critical care (\$1.2 million; $p = 0.016$). Statistical comparison was performed using one-way ANOVA. $*p < 0.05$ and $**p < 0.01$ in comparison to acute care surgery.