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Can Lung Transplant Surgeons Still Be Scientists? High Productivity Despite Competitive Funding

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ABSTRACT

Background: Today's declining federal budget for scientific research is making it consistently more difficult to become federally funded. We hypothesized that even in this difficult era, surgeon-scientists have remained among the most productive and impactful researchers in lung transplantation.

Methods: Grants awarded by the NIH for the study of lung transplantation between 1985 and 2015 were identified by searching NIH RePORTER for 5 lung transplantation research areas. A grant impact metric was calculated for each grant by dividing the sum of impact factors for all associated manuscripts by the total funding for that grant. We used nonparametric univariate analysis to compare grant impact metrics by department.

Results: We identified 109 lung transplantation grants, totaling approximately $300 million, resulting in 2304 papers published in 421 different journals. Surgery has the third highest median grant impact metric (4.2 per $100,000). The department of surgery had a higher median grant impact metric compared to private companies (P <.0001). There was no statistical difference in the grant impact metric compared to all other medical specialties, individual departments with multiple grants, or all basic science departments (all P >.05).

Conclusions: Surgeon-scientists in the field of lung transplantation have received fewer grants and less total funding compared to other researchers but have maintained an equally high level of productivity and impact. The dual-threat academic surgeon-scientist is an important asset to the research community and should continue to be supported by the NIH.

INTRODUCTION

Lung transplantation is a critical treatment option for end-stage lung diseases including chronic obstructive pulmonary disease (COPD), idiopathic pulmonary fibrosis, cystic fibrosis, and others [Hartert 2014]. Lung transplantation has been studied since the early 1900s; however, it was not until 1963 that James Hardy performed the first human lung transplant. [Hardy 1963]. Many researchers including Vladamir P. Demikhov, Bruce Reitz, and Norman Shumway performed initial lung transplants using mammalian animal models [Cooper 1969; Reitz 1982]. In 1986, Joel Cooper and the Toronto Lung Transplant Group performed 2 successful lung transplantations that extended patient survival [Toronto Lung Transplant Group 1986]. Their clinical success was built upon the foundation established in their laboratory [Dark 1986]. Research has been pivotal to the success of lung transplantation. Basic science lung transplantation research has led to numerous advances in the fields of donor selection and procurement, recipient selection, primary graft dysfunction, perioperative problems, surgical techniques and complications, acute cellular rejection, and chronic lung allograft dysfunction [Dilling 2011].

Surgeons face multiple barriers to lung transplantation research including busy clinical practices. Research is very important in the development of an academic surgeon-scientist [Kron 2000]. However, the time required for research needs to be carefully balanced, and that time needs to be protected by the university and department [Kron 2001]. Additionally, the National Institutes of Health's (NIH's) research budget annually is roughly $32.3 billion. Of this sum, surgery departments were funded approximately $280 million in 2016 compared to $3.2 billion for internal medicine researchers [Ranking Tables of NIH Funding 2017]. Mark Evers, MD, past president of the Southern Surgical Association, notes that surgeon-scientists possess key attributes and approaches not found in other researchers such as being "do-ers and having to maintain a high level of both surgical and research skills." He also notes that NIH-funding success rates for surgeons have consistently been lower than for other clinicians [Evers 2015].

This study aims to determine whether surgeons are underfunded compared to other researchers. This is a 2-fold analysis, in which funding levels need to be compared in the setting of productivity. Productivity is an important measure of grant success and is often times directly related to resources and personnel relative to the level of grant funding. To compare productivity levels of different types of researchers, we selected lung transplantation as a field to evaluate owing to the diversity of researchers studying lung transplantation.

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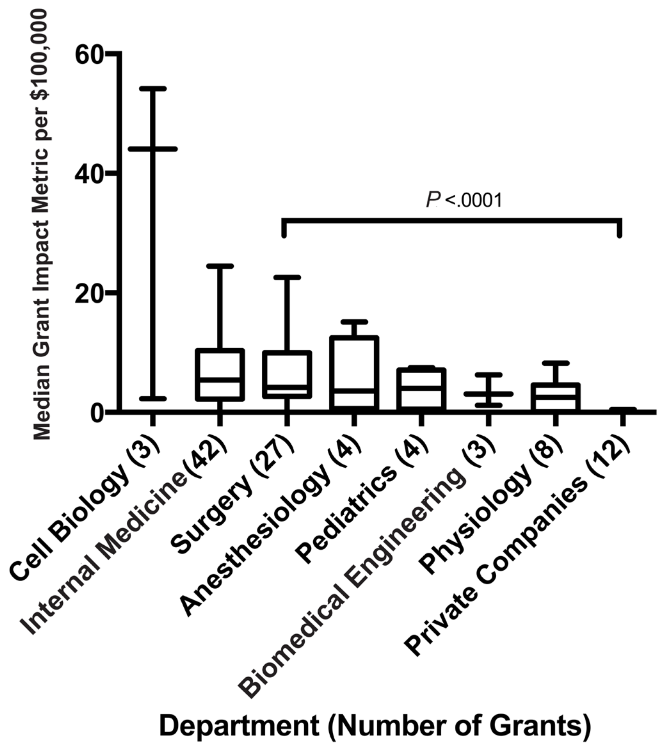

Figure 1. Median grant impact metric of departments studying lung transplantation. The median grant impact metric for departments with 3 or more grants is shown. Surgery departments were significant when compared to private companies in our use of univariate analysis. <<Q6>>

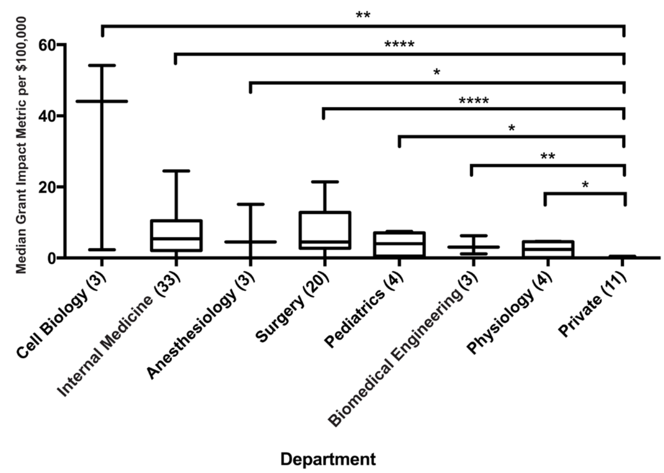

Figure 2. The 2005-2015 median grant impact metric of departments studying lung transplantation. The median grant impact metric for departments with 3 or more grants and grants active between 2005-2015 is shown. All departments were significantly greater than private companies in our use of the Mann-Whitney U test. ****P <.0001, **P <.01, *P <.05. <<Q7>>

Lung transplantation is of interest to surgeons, other clinicians, and basic science researchers. We hypothesized that surgeons maintain a comparable level of productivity to other researchers despite receiving fewer grants and having low grant-funding success rates.

METHODS

Collection of Grant Information

We used the NIH Research Portfolio Online Reporting Tools (RePORT) Expenditures and Results (NIH RePORTER) database to collect information on grants for this study (1985-2015). NIH RePORTER contains project information, funding records, abstracts, full-text articles, and information from the U.S. Patent and Trademark Office. We used the "Text Search" feature to query for grants with the following 5 terms related to lung transplantation: lung preservation, ischemia reperfusion, ex vivo lung perfusion, anti-rejection medication, and airway healing. Grants not related to lung transplantation were excluded by a secondary search for "lung transplant" in the description page of NIH RePORTER. We recorded the following information from each grant: grant number, title, type of grant, principal investigator, awardee organization, state, department, project start date, project end date, years of funding awarded, years of funding received, total amount of funding, NIH awarding institute, NIH study section, number of publications, PMID of each publication, and journal of each publication [NIH RePORTER 2017].

Calculation of Grant Impact Metric

By using the Journal Citation Reports (2014), the impact factor of the journal in which each paper was published was assigned to the 2304 publications. The impact factors from papers in each grant were summed to obtain a total grant impact score. The total grant impact score was then divided by the total funding (per $100,000) for each grant to obtain the grant impact metric." The calculation is

$$\frac{\sum (Impact\ Factors\ of\ Papers)}{Total\ Funding}$$

This calculation is similar to the calculation reported by Kaltman et al [Kaltman 2014]. All grant impact metrics are reported per $100,000.

Statistics

SAS statistical software (SAS 9.4, SAS Institute, Cary, NC, USA) was used to perform nonparametric univariate analysis to compare grant impact metrics by department. All other statistics and figures were generated by using GraphPad Prism version 7.00 for Macintosh (© GraphPad Software, La Jolla, CA, USA).

RESULTS

Departmental Analysis

We collected and analyzed a total of 109 lung transplantation grants from NIH RePORTER by using the following 5

Table 1. Departmental Analysis of Lung Transplantation*

Department†	No. of Grants	No. of Papers	Total Funding	Mean Publications per $1,000,000 (±SD)	Median Grant Impact Metric (IQR)	*P* versus Surgery
Medicine	42	1057	$118,786,097	10.14 (±8.17)	5.4 (2.22-10.1)	.86
Surgery	27	934	$102,543,031	15.38 (±15.93)	4.2 (2.7-10.0)	—
Physiology	8	190	$31,767,840	5.39 (±4.85)	2.5 (0.3-4.5)	.10
Private companies	12	14	$26,662,402	0.14 (±0.33)	0 (0-0)	<.001
Basic science departments‡	16	234	$127,395,570	17.74 (±19.21)	3.5 (1.7-7.2)	.59
Medicine subspecialties§	53	1117	$39,458,068	10.40 (±10.02)	5.0 (2.1-9.8)	.85
Anesthesiology	4	36	$3,886,468	9.83 (±11.44)	3.6 (1.3-9.8)	.58
Cell biology	3	28	$3,009,816	46.51 (±39.75)	44.1 (2.3-54.2)	.20
Pediatrics	4	13	$2,895,507	7.07 (±7.90)	4.0 (1.0-6.7)	.43
Biomedical Engineering	3	11	$2,414,431	7.04 (±8.41)	3.1 (1.2-6.3)	.50

*SD, standard deviation; IQR, interquartile range.

†One biostatistics grant was not included in this table owing to heterogeneity.

‡Basic science departments include: physiology, cell biology, biomedical engineering, microbiology/immunology, pharmacology.

§Medicine subspecialties include: internal medicine, anesthesiology, pediatrics, radiation oncology, dermatology, pharmacy.

search terms: lung preservation, ischemia reperfusion, ex vivo lung perfusion, anti-rejection medication, and airway healing. A grant impact metric and publications per $1 million were calculated for each grant. The grant impact metric is shown in Figure 1 and Table 1 as median with interquartile range, and publications per $1 million is shown in Table 1 as an average ± standard deviation. Surgery departments had 27 grants, 934 papers, $102 million in funding, 15.38 publications per $1 million, and a median grant impact metric of 4.2. Surgeons (with an MD degree) comprise the majority of investigators within surgery department grants (n = 23; median grant impact metric = 4.2: average grant impact metric = 7.25). Of the departments with 4 or more grants, surgery ranked second in median grant impact metric. Internal medicine had 42 grants, 1057 papers, $119 million, 10.14 publications per $1 million, and a grant impact metric of 5.4. Private companies had 12 grants, 14 papers, $26 million, 0.14 publications per $1 million, and a median grant impact metric of 0. The complete departmental breakdown is shown in Table 1 and a box-and-whisker graphical representation is shown in Figure 1. Analysis of recent grants (2005-2015; Figure 2) has revealed similar trends as the entire time period (1985-2015). All departments have significantly greater grant impact metric per $100,000 compared to private companies. There are no significant differences between departments. Cell biology (44.1 [2.3-54.2]), internal medicine (5.408 [2.105-10.48]), anesthesiology (4.5 [0-15.2]), and surgery (4.5 [2.7-12.8]) have the highest median grant impact metric per $100,000 (interquartile range is shown in Figure 2). Internal medicine departments have received relatively consistent funding from the NIH ($3.2 billion per year) since 2006. However, funding for surgery departments has decreased from a peak of $320 million to $280 million in 2016 [Ranking Tables of NIH Funding 2017].

Grant-Type Analysis

Please change to "We categorized and analyzed all 109 lung transplantation grants by grant type (Table 2). The most commonly awarded grant type was an R01 (45), followed by K awards (16). Surgeons received 10 R01s and 5 K awards. The majority of Ruth L. Kirschstein National Research Service Awards (NRSA F30 and F32) were given to surgeons (4 out of 6 total grants). Two of U awards were given to surgeons. Both UM1 (Research Project with Complex Structure Cooperative Agreement) grants were also given to surgery departments. P01 grants were allotted the most funding ($106 million) followed by R01 grants ($99 million). Out of 8 P01 grants, only 2 were awarded to surgery departments.

Institutional Analysis

The University of California San Francisco had the highest number of grants awarded in our study (12) (Table 3). They also had the highest number of papers (486), funding ($25.17 million), and total grant impact metric (192.7). However, the surgery department at University of California San Francisco had no grants for lung transplantation. Contrastingly, the University of Virginia had 6 grants awarded to study lung transplantation with all 6 grants being awarded to its surgery department. Most institutions had a polarized grant profile with either most of the lung transplantation grants being awarded to surgery departments (University of Virginia, Washington University in St. Louis, University of North Carolina at Chapel Hill, and University of Pittsburgh) or almost no grants being awarded to surgery departments (University of California San Francisco, University of Colorado Denver, University of Vermont, Harvard University and affiliated hospitals, Duke University, Stanford University, Johns Hopkins University, University of South Alabama, and

Table 2. Analysis of Grant Types in Lung Transplantation

Grant Type	No. of Grants	No. of Papers	Total Funding, Millions	Median Grant Impact Metric (IQR)*	Surgery Grants
F30, F32	6	16	$0.54	17.8 (0-22.87)	4
K01, K02, K08, K22, K23	15	136	$7.92	7.1 (4.8-14.3)	5
P01	8	719	$106.43	7.1 (2.5-36.6)	2
R01	45	980	$99.24	3.9 (1.9-7.2)	10
R03	1	3	$0.17	7.5 (7.5-7.5)	0
R21, R29	8	38	$3.39	4.8 (1.8-11.6)	1
R37	1	103	$6.39	10.8 (10.8-10.8)	0
R41, R43, R44	12	1	$8.54	0 (0-0)	0
RC2, RC4	2	18	$5.72	1.8 (0.3-3.2)	1
T32	2	166	$6.59	11.99 (6.25-17.74)	1
U01, U19, U54	4	100	$32.85	2.6 (0.9-3.27)	2
UM1	2	1	$6.15	0.06 (0-0.11)	2
Z01, ZIA	2	18	$12.11	1.3 (1.2-1.4)	0

*IQR, interquartile range.

Yale University).

DISCUSSION

In this study we present evidence that surgeon-scientists are just as productive as other scientists studying lung transplantation. We come to this finding after analysis of over 100 lung transplantation grants awarded to numerous departments. First, we calculated a grant impact metric for each grant to assess productivity by using total grant funding and the impact of published papers. Surgery departments were just as productive as all other researchers. Next, we found that funding for surgery departments has declined sharply since 2006, whereas funding for internal medicine departments has remained relatively stable. Although the overall amount of funding to internal medicine departments is 10 times that of surgery departments, the quality of research published by funded lung transplantation investigators is equal. We analyzed the types of grants funded and found that the majority of grants are R01s. Surgery departments have received 10 of 45 lung transplantation R01s and 5 of 15 K awards. Finally, we analyzed the grants from our study by institution and concluded that University of California San Francisco has received the most grants and published the most papers. However, Harvard University (and affiliated hospitals: Brigham and Women's, Boston Children's Hospital, and Massachusetts General Hospital) has received the most funding. The University of Virginia received the highest number of grants awarded to a surgery department.

The number of grants received by physicians has plateaued. However, physicians receive a smaller percentage of grants currently than they have in the past [Garrison 2014]. With this decrease in physician-scientist funding, we hypothesized that surgeon-scientists would still be productive in the field of lung transplantation compared to other physicians and basic scientists. George Gittes, a past president of the Society of University Surgeons, states "the ability of surgeons to apply basic clinical skills to their research efforts has nearly disappeared." He also notes "the complexity of clinical care and particularly clinical surgical care has increased dramatically" [Gittes 2006]. The decrease in overall funding to surgery departments is not apparent in the field of lung transplantation.

Chairs of surgery departments look for the following when they hire potential surgeon-scientists: passion for research, research history, research education/training, and provision of protected time for them. However, they see the following as being hindrances for a surgeon-scientist: inability of the department to support multiple surgeon-scientists, view of the surgeon as an "investment," small institutions, NIH salary caps, and pressure for clinical productivity [Kodadek 2016]. The current belief is that surgery has become too complicated for a scientist and that science has become too complicated for a surgeon [Menger 2012]. To combat this problem, many surgeon-scientists have paired up with basic science researchers to work as a team [Gruber 2008]. This team may consist of the surgeon-scientists and one basic science professor, or a group of research scientists in the laboratory. However, Peter Gruber notes that many times these laboratories do not meet the rigor to publish in top tier journals because of numerous constraints. Gruber suggests that scientists should aim to meet the standards for the top journals and not "lower the bar" for scientific research [Gruber 2008].

Surgery departments were significantly better in regard to median grant impact metric compared to private companies. Interestingly, internal medicine departments receive a greater amount of funding from the NIH compared to surgery departments. This

Table 3. Analysis of Institutions Studying Lung Transplantation

Institution*	No. of Grants	No. of Papers	Sum of Grant Impact Metrics, per $100,000	Total Funding, Millions	Surgery Grants
University of California San Francisco	12	486	192.7	$25.17	0
University of Virginia	6	168	47.4	$13.31	6
Harvard University (and affiliated hospitals: Brigham and Women's, Boston Children's Hospital, and Massachusetts General Hospital)	6	382	47.1	$55.65	2
University of Colorado Denver	5	41	22.3	$9.35	0
University of Vermont	5	79	49.7	$8.89	0
Washington University in St. Louis	4	110	31.5	$8.13	4
Duke University	3	16	7.6	$6.22	0
Johns Hopkins University	3	19	11.88	$2.86	1
Stanford University	4	193	9.4	$16.63	1
University of North Carolina at Chapel Hill	3	6	4.19	$4.42	2
University of Pittsburgh	3	76	8.51	$10.34	2
University of South Alabama	3	7	2.98	$3.71	0
Yale University	3	53	36.81	$6.59	0

*Only institutes with 3 or more grants were analyzed in this table.

suggests that there are fewer surgeon-scientists than internist-scientists applying for and receiving NIH grant funding. Grants given to private companies are used for the development of products that the companies can patent. These grants come in the form of Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs [Ben-Menachem 2006]. This may explain why private companies do not prioritize publishing papers with NIH grant funding.

One F30 was awarded to an MD/PhD candidate and 5 F32 grants were awarded to postdoctoral candidates. Only 2 T32 grants were found. T32 grants in surgery are used for funding protected research time for residents. This finding suggests that there are very few avenues for postdoctoral research for surgeons. Garrison et al. have found that physician-scientists are receiving less postdoctoral training than before [Garrison 2014]. Training grants in thoracic and cardiovascular surgery are vital to providing research training for residents [Narahari 2018a]. However, only 51 T32 training grants were awarded to surgery departments in 2015 compared to about 2000 T32 awards overall [NIH RePORTER 2017].

We anticipated that R01 grants would have received the most funding ($99.2 million) and the greatest number of grants (45). However, P01 grants received the most funding ($106.4 million) compared to all other grant types even though only 8 P01 grants were awarded. Only 2 P01 grants were awarded to surgeons. Ten of the 45 R01 grants were awarded to surgery departments. Surprisingly, F30 and F32 awards had the highest median grant impact metric (17.8). T32 training grants had the second highest median grant impact metric (11.99) followed by R37 grants (10.8). This result can be explained by the fact that trainees on T32 training grants and F30 and F32 NRSA grants are generally supported by other grants for their lab work (R01 or equivalent). However, as evidenced by the high median grant impact metric, individuals receiving NIH funding for training in a laboratory are publishing quite well.

Five institutions had 5 or more lung transplantation grants (Table 3). These institutions are the following: University of California San Francisco, University of Virginia, University of Colorado Denver, University of Vermont, and Harvard University. To our surprise, the University of Virginia had all 6 of its grants in the surgery department. There are a few highly funded centers for lung transplantation research in the United States. Of these well-funded centers, a few institutions have most of their lung transplantation research being performed by surgeon-scientists (Table 3).

Analysis of an NIH report has shown that surgery departments have consistently been funded at a lower percentage compared to the overall funding rate and especially compared to internal medicine departments [Division of Planning E 2016]. Although the lower amount of funding to surgery departments can be explained by fewer grants being submitted and funded, the lower percentage of funding cannot be accounted for. Academic surgeons have many pressures to operate and bring in revenue while they still are expected to run a research group. Recently, Keswani et al have reported that funding for surgeons has declined and determined the many pressures that surgeons face [Keswani 2017]. Here, we report that even though surgeons have external pressures, they are able to publish quality work and the reason for decreased research may be due to lower funding success rates.

We were limited by the data present in NIH RePORTER. The NIH is one of the largest funding agencies in the United States and therefore was chosen for analysis. If principal investigators were MDs in surgery, the percentage of time they spend doing research was not determined. Finally, we utilize a calculation for grant impact metric quite similar to the one used by Michael Lauer (deputy director for Extramural Research, NIH) and colleagues [Kaltman 2014]. Lauer and colleagues use a normalized citation impact for each publication, sum the impacts of all papers derived from a grant, and divide by funding in millions of dollars. A normalized citation impact utilizes publication percentile with regard to citations for each paper. Our formula deviates from theirs slightly by using a journal's impact factor for 2014 rather than a normalized citation impact. However, our grant impact metric calculation is similar otherwise and has now been used in other works. We have also shown the number of publications per $1 million in funding as another metric for viewing productivity. We recognize that our data heavily utilizes the impact factors of journals in 2014 (grant impact metric); however, owing to the lack of availability of other grant productivity metrics, we used this calculation. This calculation has been previously used to evaluate productivity, with the given limitations described above [Narahari 2018b; Narahari 2018c]. Impact factors of journals are calculated by the number of average citations an article in that journal received the previous 2 years. Our grant impact metric calculation assumes that journals with higher impact factors are difficult to publish in and that publishing in a high impact journal correlates to a high level of productivity. Finally, we would like to emphasize that certain specialty journals with low impact factors have a broader clinical impact compared to high-profile journals that have high impact factors. Unfortunately, this type of broad impact through specialty journals cannot be accounted for. Grants to lung transplant surgeons result in a similar level of productivity compared to nonsurgeons, as determined by grant impact metric. The grants funded by the NIH to surgery departments are resulting in an equal level of academic productivity as grants funded by the NIH to other departments. However, the level of funding for surgery departments is much lower than internal medicine departments. Overall funding for surgery departments has declined since 2006, whereas funding for internal medicine departments has been maintained at a similar level [Ranking Tables of NIH Funding 2017]. The success rates of grant funding to surgery departments have also been declining compared to all other researchers [Division of Planning E 2016]. To this end, we have quantified the level of research productivity of academic lung transplantation surgeon-scientists. Funding surgeon-scientists studying lung transplantation is a worthy investment for the NIH, and these surgeons should be funded at a high rate to study this clinically relevant problem.

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