# The First National Institutes of Health Institutional Training Program in Emergency Care Research: Productivity and Outcomes

Craig D. Newgard, MD, MPH*; Cynthia D. Morris, PhD, MPH; Lindsey Smith, MPP; Jennifer N. B. Cook, GCPH; Donald M. Yealy, MD; Sean Collins, MD, MS; James F. Holmes, MD, MPH; Nathan Kuppermann, MD, MPH; Lynne D. Richardson, MD; Stephen Kimmel, MD, MSCE; Lance B. Becker, MD; Jane D. Scott, ScD, MSN; Robert A. Lowe, MD, MPH; Clifton W. Callaway, MD, PhD; L. Kris Gowen, PhD, EdM; Jill Baren, MD, MS; Alan B. Storrow, MD; Nicole Vasilevsky, PhD; Marijane White, MSLIS; Adrienne Zell, PhD

*Corresponding Author. E-mail: newgardc@ohsu.edu, Twitter: @newgardc.

**Study objective:** We assess the productivity, outcomes, and experiences of participants in the National Institutes of Health/National Heart, Lung, and Blood Institute–funded K12 institutional research training programs in emergency care research.

**Methods:** We used a mixed-methods study design to evaluate the 6 K12 programs, including 2 surveys, participant interviews, scholar publications, grant submissions, and funded grants. The training program lasted from July 1, 2011, through June 30, 2017. We tracked scholars for a minimum of 3 years and up to 5 years, beginning with date of entry into the program. We interviewed program participants by telephone using open-ended prompts.

**Results:** There were 94 participants, including 43 faculty scholars, 13 principal investigators, 30 non–principal investigator primary mentors, and 8 program administrators. The survey had a 74% overall response rate, including 95% of scholars. On entry to the program, scholars were aged a median of 37 years (interquartile range [IQR] 34 to 40 years), with 16 women (37%), and represented 11 disciplines. Of the 43 scholars, 40 (93%) submitted a career development award or research project grant during or after the program; 26 (60%) have secured independent funding as of August 1, 2017. Starting with date of entry into the program, the median time to grant submission was 19 months (IQR 11 to 27 months) and time to funding was 33 months (IQR 27 to 39 months). Cumulative median publications per scholar increased from 7 (IQR 4 to 15.5) at program entry to 21 (IQR 11 to 33.5) in the first post-K12 year. We conducted 57 semistructured interviews and identified 7 primary themes.

**Conclusion:** This training program produced 43 interdisciplinary investigators in emergency care research, with demonstrated productivity in grant funding and publications. [Ann Emerg Med. 2018;■:1-12.]

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## INTRODUCTION

### Background

In 2011, 6 sites across the United States received funding to start emergency care research training programs from the National Heart, Lung, and Blood Institute (NHLBI) of the National Institutes of Health (NIH).[1] Several key events set the stage for this training program, including 3 coordinated reports from the Institute of Medicine Committee on the future of emergency care in the US health system, detailing major deficits in emergency care and a lack of trained researchers[2-4]; development of the NIH Task Force on Research in Emergency Medicine to increase NIH support for emergency care research; a series of federal roundtables detailing crucial questions and gaps in emergency care research[5-7]; and advocacy at the federal level by an appointed group of senior emergency medicine investigators from the American College of Emergency Physicians and the Society for Academic Emergency Medicine.

### Importance

As a result, the NHLBI invested $21.6 million in 6 K12 training programs to catalyze the field of emergency care research through formal training of interdisciplinary investigators. This was the first wide-scale federal investment in emergency care research training of clinician-scientists. By design, the program was interdisciplinary,

**Editor's Capsule Summary**

*What is already known on this topic*

Federal funding for emergency medicine research was virtually nonexistent but has increased in recent years.

*What question this study addressed*

What was the effect of the 2011 multisite National Heart, Lung, and Blood Institute (NHLBI) training grant program on research productivity and career advancement for participating emergency care investigators?

*What this study adds to our knowledge*

Forty-three scholars (24 emergency medicine) across 6 sites received 3-year funding from National Institutes of Health (NIH)/NHLBI training awards. Ninety-three percent applied for funding during the program period; 60% were successful. Publication and citation rates suggest substantial academic success among program participants.

*How this is relevant to clinical practice*

Emergency care research capacity and output appear responsive to a training program that included salary support and mentorship from NIH-funded investigators.

with clinician-scientists from all specialties eligible to apply. Several programs were co-led by interdisciplinary teams of principal investigators. The 6 sites chose to work collaboratively, forming a partnership of networked sites using common advertising platforms for scholar recruitment, coordinated dates for applications and offers, common recruitment mechanisms, and an annual K12 meeting at the NIH for all participants. Primary goals for scholars in the program were to submit and secure individual career development awards (such as K23 or K08 awards) or federal research project grants (such as R01 or R21 awards), and to generate peer-reviewed research publications in emergency care.

### Goals of This Investigation

We assessed the productivity and outcomes of all scholars, the influence of the program on emergency care research, and experiences from program participants in the NIH/NHLBI K12 Program in Emergency Care Research. We quantified scholar productivity and outcomes through grant applications and awards, peer-reviewed research publications, collaborative science (measured through social network analysis), and post-K12 career paths. We describe program experiences by using qualitative analysis of interviews with scholars, mentors, and principal investigators.

## MATERIALS AND METHODS

### Study Design

This was a mixed-methods study, including 2 surveys, publicly available data resources, and participant interviews. Each participant provided consent before involvement, and the Oregon Health & Science University institutional review board approved the study.

### Setting

We studied all 6 sites participating in the K12 Program for Emergency Care Research (in alphabetical order): Icahn School of Medicine at Mount Sinai (New York, NY); Oregon Health & Science University (Portland, OR); University of California, Davis Medical Center (Sacramento, CA); University of Pennsylvania (Philadelphia, PA); University of Pittsburgh (Pittsburgh, PA); and Vanderbilt University Medical Center (Nashville, TN).

### Selection of Participants

We included all K12 scholars, principal investigators, primary mentors, and program administrators affiliated with the program sites throughout the duration of the program, from July 1, 2011, through June 30, 2017 (including a 1-year no-cost extension at all 6 sites). The first cohort of scholars entered the program July 1, 2012, and most scholars had completed training by June 30, 2017 (one scholar finished November 8, 2017, because of a later start date). All sites recruited a minimum of 3 cohorts of scholars, generally with 2 scholars per cohort (the target was 6 scholars per site). The program provided up to 3 years of support for each scholar, including salary support for 75% protected time for research, comprehensive mentorship, formal research didactic training, funds to support research expenses, and funds to support education and related travel. The program also included annual collaborative meetings at the NIH.

### Methods of Measurement

We developed an electronic survey through REDCap (Vanderbilt, Nashville, TN) for all program participants. We pilot-tested and refined the survey at one site and then sent it out electronically to all program participants across the 6 sites, including up to 3 reminders over 3 months. Survey variables included demographics (age, sex, race, and ethnicity), dates in the K12 program, clinical training background, primary academic appointment, current work location, proportion of post-K12 time spent on research

(scholars), and grant applications submitted during the K12 period. We sent a subsequent survey to principal investigators and program administrators focused exclusively on scholar career development award and research project grant submissions to verify and update these data. To measure federally funded grants for program participants during and after the K12 program, we determined participant NIH identifications and located all grants for these individuals as principal investigator or coprincipal investigator from the publicly available NIH ExPORTER data set. For federal research grants from non-NIH sources, we generated a list of participant names (including name variations) and then matched this list against the Federal RePORTER data set. We used survey responses to validate identified awards and to ensure awards were not missed because of name variations. We matched submitted grants (survey) to funded grants (NIH ExPORTER and Federal RePORTER), using principal investigator name and grant title. We included all submitted and funded grant applications through August 1, 2017.

To assess peer-reviewed publications, we determined Scopus identifications for all scholars, principal investigators, and mentors. We reviewed Scopus identifications for accuracy and reported duplicate identifications to Scopus for deduplication, and then used these identifications to locate all peer-reviewed journal publications (those containing an International Standard Serial Number) for program participants, including journal type. We defined emergency medicine journals as those classified within the emergency medicine Web of Science journal schema. We organized scholar publications by date of publication (as listed in Scopus and generated by the publisher), aligned with scholar time in the program, to assess time-based productivity pre-K12, during each year in the program, and up to 1 year post-K12. To further assess scientific productivity, we used the Relative Citation Ratio as a bibliometric measure appropriate for this multidisciplinary cohort[8] and used by the NIH to measure publication productivity and impact. The Relative Citation Ratio is a freely accessible, article-level metric that is field normalized and benchmarked to a peer comparison group, providing an article-level and field-independent measure of influential articles.[8] The Relative Citation Ratio benchmarking process is arranged so that the mean article has a score of 1.0, with higher numbers indicating greater impact.[8] We calculated Relative Citation Ratio scores by inputting PMID portfolios of interest into iCite.[9] To generate overall publication counts and Relative Citation Ratio scores, we used a publication cutoff date of June 15, 2017, whereas August 1, 2017, was used for publications included in the social network analysis (these analyses required different software programs and different analysts, resulting in slightly different publication cutoff dates.)

## Outcome Measures

To measure scholar productivity and outcomes, we tracked submitted and funded individual career development awards (eg, K08, K23, multiyear foundation grants), federal research project grants (eg, R01, R21), and peer-reviewed research publications available in public data sources. National foundation career development grants that provided a level of research and salary support similar to that of federal career development awards were included in the analysis to account for the variety of funding pathways pursued by scholars. To focus the analysis on scholar-initiated grants, we considered only grants with scholars listed as principal investigator or coprincipal investigator.

We developed a series of open-ended prompts to assess the K12 program, the mentor-mentee experience, scholar training, collaboration, grant development, scientific productivity, factors influencing success, challenges, and other integral aspects of the program (Appendix E1, available online at http://www.annemergmed.com). We refined the prompts before conducting the interviews, with separate sets of prompts crafted for scholars, principal investigators, mentors, and program administrators. After agreeing to participate, each respondent had a 30- to 60-minute structured telephone interview, with notes taken by the interviewer. Because of resource constraints, we did not record and transcribe interviews. We organized and uploaded all notes to the qualitative software Dedoose (version 10.6.15; SocioCultural Research Consultants, Los Angeles, CA).

## Primary Data Analysis

We used descriptive statistics to characterize scholars. We analyzed the quantity, type, and timing of all scholar grant submissions, funded grants, and publications in relation to scholar time in the K12 program. Using date restrictions, we generated baseline scholar publication productivity on entry to the program and then compared publication output for each subsequent year. We tracked all scholar publications and generated the Relative Citation Ratio metric using publicly available databases. To identify and track grants, we used information from site-level surveys and public databases. For the scholar survey, we excluded questions when fewer than 50% of respondents answered. We used medians, interquartile range (IQR), and proportions where appropriate.

To illustrate and quantify the amount of collaboration in the program, we used social network analysis,[10] a method for mapping and measuring relationships between people within and outside of an organization (eg, the K12 program) to identify knowledge flows and collaborations.[10,11] This aspect of the analysis focused on scholar publications among networks of authors affiliated with the K12 program, during scholar time in the program. We also assessed collaborations within and external to individual K12 sites.

For the qualitative analysis, we used qualitative and evaluation experts not affiliated with the training program. The evaluation team developed a coding framework based on the protocol questions (protocol coding, a priori coding) and concepts recorded throughout the interviews (process coding, derived from the data). They then refined codes under each theme, generating a total of 74 themes (primary and subthemes) and codes.[12] The team developed definitions for each theme and code, with all uploaded into a codebook. To ensure coding reliability, the evaluation team used a group process to analyze interviews before completing the coding for transcripts. Then we assigned each interview a primary and secondary coder, and ensured interviewers did not code their own interviews. We selected illustrative quotes for each theme, edited for brevity and relevance. Qualitative processes were reviewed with the Consolidated Criteria for Reporting Qualitative Research checklist[13] (Appendix E2, available online at http://www.annemergmed.com).

## RESULTS

### Characteristics of Study Subjects

Among the 6 program sites, there were 94 total participants, including 43 interdisciplinary faculty scholars, 13 principal investigators (including coprincipal investigators and principal investigator transitions), 8 program administrators, and 30 non–principal investigator primary mentors (9 principal investigators served as primary mentors for 22 scholars). Scholars represented 11 unique disciplines, including emergency medicine, pediatric emergency medicine, adult critical care, pediatric critical care, cardiology, trauma surgery, pediatric allergy and immunology, nursing, epidemiology, comparative pathology, and physiology/biophysics. Two sites trained 6 scholars each, 1 site trained 7 scholars, and 3 sites trained 8 scholars. Of the 94 total participants, 70 completed the survey (74% overall response rate), including 41 of 43 scholars (95% scholar response rate). In Table 1, we characterize scholar demographics, training background, time spent in the program, and post-K12 work activities. Because of the restriction of 6 years of total K award salary support (institutional or individual), a portion of scholars

**Table 1.** Characteristics of scholars participating in the K12 Program for Emergency Care Research (n=43).

| | |
|---|---|
| **Demographics on Entry to the K12 Program** | |
| Median age on starting the program (IQR), y* | 37 (34–40) |
| **Age categories, No. (%), y*** | |
| 25–29 | 0 |
| 30–34 | 4 (11) |
| 35–39 | 21 (58) |
| 40–44 | 7 (19) |
| 45–49 | 2 (6) |
| ≥50 | 2 (6) |
| Women | 16 (37) |
| **Race/ethnicity, No. (%)*†** | |
| White | 19 (51) |
| Asian | 10 (27) |
| Black | 4 (11) |
| Other | 1 (3) |
| Hispanic/Latino | 3 (8) |
| **Specialty/training, No. (%)** | |
| Emergency medicine‡ | 18 (42) |
| Pediatric emergency medicine | 6 (14) |
| Adult critical care/pulmonary | 5 (12) |
| Cardiology | 5 (12) |
| Pediatric critical care | 2 (5) |
| Trauma surgery and surgical critical care | 2 (5) |
| Pediatric allergy and immunology | 1 (2) |
| PhD, nursing science | 1 (2) |
| PhD, epidemiology | 1 (2) |
| PhD, comparative pathology | 1 (2) |
| PhD, clinical research, physiology and biophysics | 1 (2) |
| **Postgraduate degree(s), No. (%)** | |
| MD only | 5 (12) |
| MD+masters | 30 (70) |
| MD-PhD | 4 (9) |
| PhD+masters | 4 (9) |
| **Training time** | |
| Median time in K12 program (IQR), mo | 24 (24–36) |
| **Post-K12*** | |
| **Post-K12 practice setting, No. (%)*** | |
| Academic | 34 (94) |
| Community or private practice | 2 (6) |
| Federal | 0 |
| Other | 0 |
| Change in practice location from K12 institution, No. (%)* | 2 (5) |
| Median, current effort dedicated to research, % (IQR)* | 75 (30–75) |

*These data were available only from scholar survey responses; numbers and estimates are based on observed values.
†Race and ethnicity were captured as a "check all" question and so appear combined. There were no scholars who checked more than one box.
‡Two emergency physicians also had fellowship training in critical care (and are not counted in the adult critical care/pulmonary group).

purposefully left the K12 program after 24 months to preserve 4 years of eligibility for an individual K award.

## Main Results

Of the 43 scholars, 40 (93%) submitted a career development award or research project grant application as principal investigator during or after the K12 training program. As of August 1, 2017, these submissions included (using the denominator of all 43 scholars) 27 (63%) NIH K applications, 11 (26%) non-NIH career development award applications (eg, Patient Centered Outcomes Research Institute [PCORI] and national foundations), 13 (30%) NIH research project grant applications, and 6 (14%) non-NIH research project grant applications (eg, Department of Defense, US Department of Agriculture). Measured from each scholar's start in the program, the median time to submit the first career development award or federal research project grant application was 19 months (IQR 11 to 27 months) (Figure 1). Two scholars submitted career development awards before the start of the K12 program (one 3.5 months before and another 1 month before).

As of August 1, 2017, 26 scholars (60%) have secured independent grant funding (Figure 2). Nineteen of 43 scholars (44%) have received a career development award and 8 (19%) have received a federal research project grant since starting the program; one scholar received both career development award and research project grant funding. Of the 26 scholars securing independent grant funding, 8 (31%) received funding during their tenure in the program and 18 (69%) obtained funding after completing the program. Nineteen of 31 scholars (61%) applying for career development awards succeeded, as did 8 of 16 scholars (50%) submitting research project grant applications. Eight of 31 scholars (26%) applying for career development awards submitted applications to multiple organizations (NIH, Veterans Affairs, and national foundations) and 8 of 16 scholars (50%) applying for research project grants submitted to multiple organizations (NIH, Department of Defense, and PCORI). The median time to secure funding, measured from date of entry into the program, was 33 months (IQR 27 to 39 months) (Figure 1). The median time to funding from award submission was 17 months (IQR 13 to 21 months).

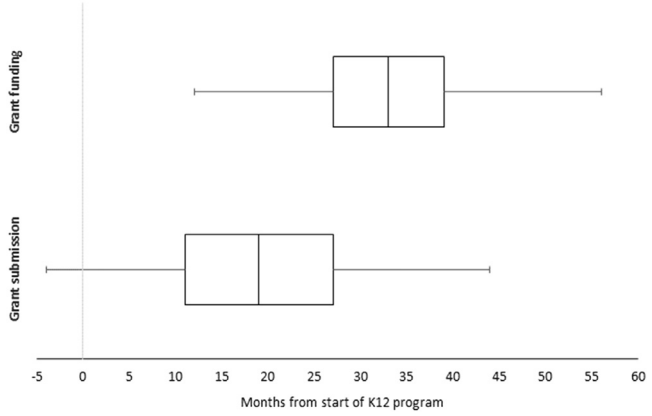


**Figure 1.** Time to grant submission and independent funding among K12 scholars, represented as median, IQR, and total range. We defined scholar grants as any multiyear career development award (eg, K08, K23, national multiyear foundation awards) or any federal research project grants (eg, R01, R21) with the scholar as principal investigator or coprincipal investigator. Two scholars submitted career development grants before matriculation in the K12 program, so the range for submission begins at 4 months before they started the program. Of the 43 scholars, 40 submitted a career development or research project grant application and 26 scholars received independent research funding.

In Table 2, we compare scholars who did (n=26) and did not (n=17) achieve independent research funding during or after the program period. Scholars entering the program with advanced research degrees had more frequent success securing independent funding, as did scholars publishing a greater number of articles during the program (median 22 versus 12). Funded scholars also submitted grant applications earlier in their K12 tenure than those who had not yet achieved independent funding (median 14 versus 27 months). Among the 26 funded scholars, 21 awards (81%) were from the NIH, 3 (12%) were non-NIH federal awards (Department of Defense and US Department of Agriculture), and 2 (8%) were national foundation awards (Robert Wood Johnson Foundation and American Heart Association).

The median per-scholar number of peer-reviewed publications before matriculation in the K12 program was 7 (IQR 4 to 15.5; range 0 to 81). The median cumulative per-scholar number of publications measured from date of entry into the program year was 9 (IQR 5.5 to 18; range 0 to 83) in year 1, 13 (IQR 7 to 25; range 0 to 91) in year 2, 17 (IQR 8.5 to 29.5; range 0 to 99) in year 3, and 21 (IQR 11 to 33.5; range 1 to 104) in the first post-K12 year. The cumulative number of publications per scholar increased over time among all cohorts (Figure 3). The median scholar Relative Citation Ratio before program entry was 0.69, which increased to 1.0 among the post-K12 portfolio of scholar publications ($P<.001$ for comparison), indicating increasing publication impact over time.

We used social network analysis of scholar publications to evaluate patterns of scholar collaboration within and across the K12 sites (Figure 4). Among the 669 scholar


**Figure 2.** Time to independent funding for individual K12 scholars, beginning with matriculation into the program (n=43). K grants or equivalent awards denote multiyear career development awards with the scholar as principal investigator, including federal awards (eg, K08, K23) and foundation awards (eg, Robert Wood Johnson Foundation, American Heart Foundation). Research project grants represent any federal research project grant (including Department of Defense, Veterans Affairs, and other federal granting organizations). The one scholar with a research project grant awarded before a career development award grant was awarded an R03 (classed as a research project grant by NIH) before being awarded a K23.

publications generated during the program, 200 (29.9%) involved K12 collaborations within a scholar's home institution and 37 (5.5%) involved collaborations with K12 participants outside of their primary institution. Nineteen publications (2.8%) were with other K12 scholars and 218 (32.6%) were with K12 mentors. Most scholar publications (n=432; 64.6%) were with non-K12 authors. Of the 669 publications, 239 (36%) appeared in emergency medicine journals. Of the 200 journals publishing K12 scholar work (Appendix E3, available online at http://www.annemergmed.com), the median impact factor was 2.75 (IQR 1.78 to 5.13; range 0.14 to 72.41). When categorized by emergency medicine versus non–emergency medicine journals, the median impact factor was 1.34 (IQR 1.03 to 2.27; range 0.30 to 5.35) and 3.05 (IQR 1.93 to 5.23; range 0.14 to 72.41), respectively.

We conducted 57 semistructured interviews with 32 scholars, 21 mentors and principal investigators, and 4 program administrators. We aggregated mentor and principal investigator responses for analysis because many principal investigators served as mentors. We identified 7 primary themes, which are discussed below and detailed in Table 3.

The opportunities and benefits of the K12 program were a primary theme, including appreciation for collaborations and networks built through participation in the program. Additional scholar benefits included protected time and funding for research, with reduction in clinical duties. Mentors reported growth in their emergency care research programs as a benefit. Scholars cited development of research skills, relevant course work, and protected time as key factors in facilitating collaborative research. The annual K12 program meeting at NIH was consistently mentioned as an

**Table 2.** Comparison of scholars based on achievement of independent research funding (n=43).

| Characteristics | Achieved Independent Funding, n=26* | Did Not Achieve Independent Funding, n=17 |
|---|---|---|
| **On entry into the K12** | | |
| Median age (IQR), y† | 37 (34–40) | 38 (36–39) |
| Median pre-K12 publications (IQR) | 8 (5–18) | 6 (4–9) |
| Specialty, adult or pediatric emergency medicine (%) | 15 (58) | 9 (53) |
| Non–emergency medicine (%) | 11 (42) | 8 (47) |
| MD only (%) | 1 (4) | 4 (24) |
| MD+masters (%) | 19 (73) | 11 (65) |
| MD+PhD (%) | 4 (15) | 0 |
| PhD only (%) | 2 (8) | 2 (12) |
| **During K12** | | |
| Median publications after 3 y (IQR) | 22 (10–34) | 12 (7–19) |
| Submitted grant for independent funding (%) | 26 (100) | 14 (82) |
| Median time to submission of first grant for independent funding (IQR), mo | 14 (8–20) | 27 (21–33) |

*These counts represent the first funded award for scholars.
†Data were available only from scholar survey responses for these variables; numbers and estimates are based on observed values.

important opportunity for networking. Several respondents mentioned the receipt of new research funding as an important outcome of program collaborations.

Many described the program as facilitating increased recognition and legitimacy for the field of emergency care. Respondents mentioned broad knowledge acquisition about emergency care, trends in emergency care, and opportunities to learn unique skills about conducting research in the emergency setting. Respondents generally agreed that the knowledge and skills obtained by scholars will move the field of emergency care research forward. Individuals with an emergency medicine background had more optimistic views than non–emergency medicine participants about future funding for emergency care research. Although many believed it was too early to measure the full influence of the program, most respondents were enthusiastic and optimistic about the scientific influence of the program on the field.

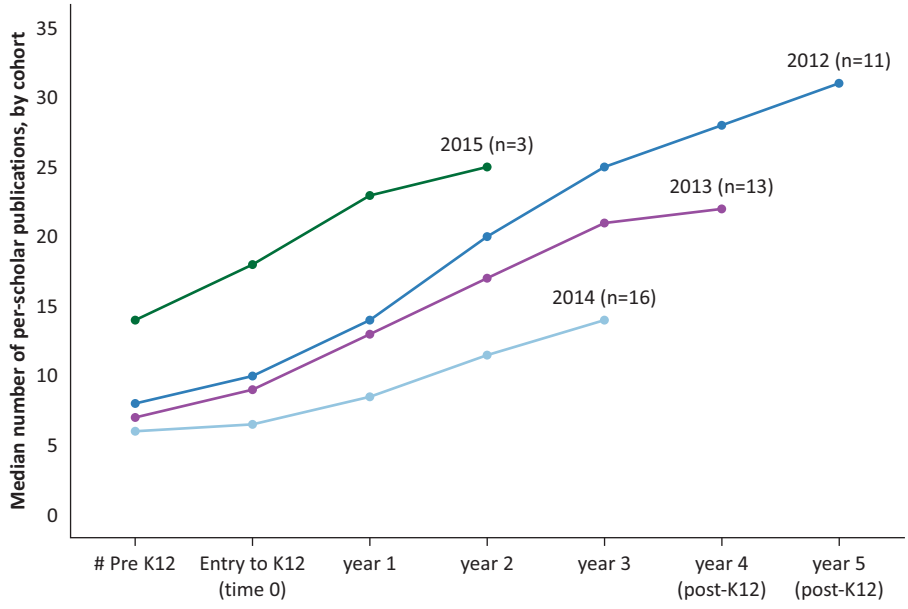


**Figure 3.** Median cumulative per-scholar publications over time, by cohort year (n=43 scholars).

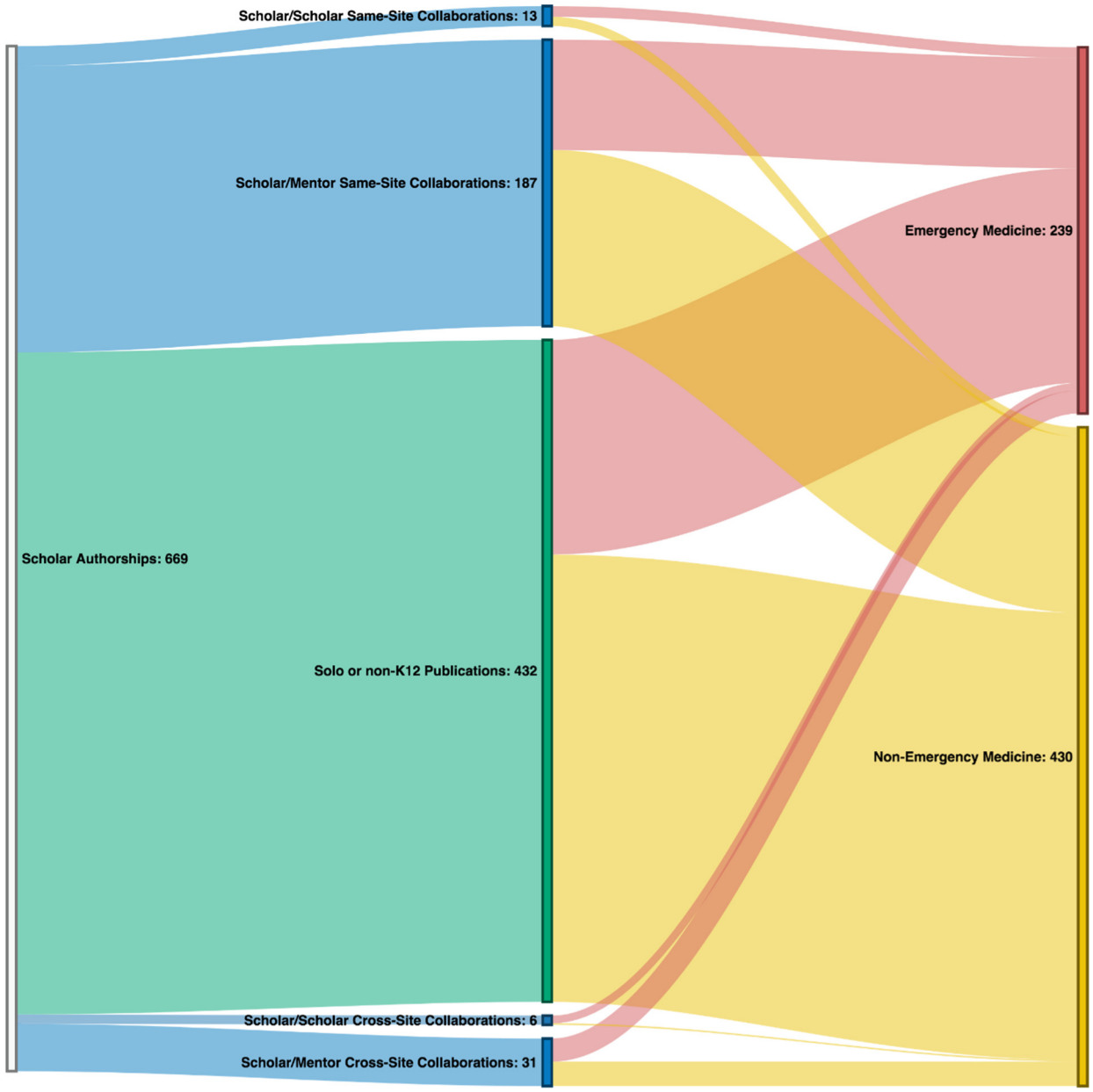


**Figure 4.** Scholar collaboration with K12 participants (left panel) and resulting journal types (right panel) for 669 total publications from 43 scholars. The left panel (blue/green) depicts scholar collaborations with other K12 program participants and the right panel (red/yellow) represents the resulting journal type (emergency medicine versus non–emergency medicine, based on the Web of Science journal categorization).

Respondents believed the most prevalent success measures were grant funding and publications, especially K- and R-level funding. Other measures included "staying in research," academic advancement, and associated research degrees. Some respondents mentioned alternative publication metrics ("alt-metrics"), indicators of commercialization success, and the acquisition of non-NIH funding. These latter metrics were more likely to be mentioned by scholars than by mentors or principal investigators. Several respondents included broader definitions of success, including becoming a mentor themselves, contributing importantly to the field, and affecting the health of patients.

Respondents were asked about barriers to success, with primary themes split into time and "other" barriers. Time-related barriers were mentioned most frequently and included timeframe of the program (too short to achieve independence), clinical versus research balance, not enough time with mentors (including scheduling challenges), time to write grants and obtain new

**Table 3.** Qualitative themes, subthemes, and representative quotes from K12 program participants.

| THEME | SUBTHEMES (HIGHEST PREVALENCE) | SUBTHEMES (LESS PREVALENCE) | QUOTE |
|---|---|---|---|
| OPPORTUNITIES AND BENEFITS | Collaborations and networks, protected time, research skills | Funding, course work, multiple mentors, NIH scholar meeting | "The main one is, it allowed me to have protected time away from my clinical duties to focus on research and go back and get a degree in [name of field]. That would not have been possible without the K12. It opened a lot of doors for me; it bolstered a lot of my methodological skills and gave me the skill set and credibility to submit a K08 on the first go-round." |
| SUCCESS OF K12 PROGRAM | Produces researchers, diversifies the field, produces collaborations | Award rate is high, "too early to tell" | "I think it's vital when it comes to moving the field forward. Emergency care doesn't get a lot of attention, so it needs a program like this. Institutional grants are essential in order to get people going. It gives people access to the collaborations to advance their projects and have the research grow. The connections made in this program are vital." |
| BARRIERS AND CHALLENGES: TIME | Timeframe of program, clinical-research balance, time with mentors | Work-life balance, time to write grants/ obtain funding | "The clinical/research breakdown can be difficult to navigate. Time management. Making sure your skills stay sharp clinically as you do research." |
| BARRIERS AND CHALLENGES: ALL | Funding, mentor match/turnover, research skill acquisition | Mentor expertise, mentor relationship, multiple mentors | "There were not always optimal matches for our scholars. I saw several scholars…[whose] progress has been slower than I would have liked because it was hard to find mentors who had the content, methodological, and mentor-experience expertise to really work with the scholars as much as they needed." |
| COLLABORATION AND NETWORKING | Research skill building and course work, time to build relationships, mentors facilitated collaboration | Cross-discipline research opportunities, NIH meeting for scholars, research-focused environment | "My mentors helped me establish collaborations I wouldn't have had otherwise. That gave me national-level access to senior mentors and exposure to NIH at an early stage. It allowed me to network with people. Without the K12 it would have taken longer." |
| EMERGENCY MEDICINE | Broadened view of emergency medicine, new emergency medicine research skills, emergency medicine to non–emergency medicine collaborations | Emergency medicine field gained status, increased intra-field collaboration | "I think the [emergency medicine] folks are always going to be [emergency medicine] researchers, but what this program has done is develop emergency researchers out of people who aren't trained directly in [emergency medicine] and we have different views and different approaches." |
| SUCCESS MEASURES FOR YOUNG INVESTIGATORS | Funding, publications, stay in research | K/R funding specifically, academic advancement, alt-metrics | "Papers and grants are the standard, retention in academics, the flavor of the job, the impact of the work, look at what some of these people are doing, advanced care planning, new metric for trauma quality; this will be impactful." |

funding, and work-life balance. Work-life balance was mentioned more frequently by scholars. Other common responses included concerns about continued funding, the challenges of securing funding, and matching and managing multiple mentors with appropriate expertise.

## LIMITATIONS

There was no direct comparison group for K12 scholars, so it was difficult to assess what the scientific productivity would have been for these scholars without the K12 program. However, compared with published NIH funding rates for K and research project grant grants, the success of these scholars was high.[14] Also, the time tracking scholars was generally limited to 3 to 4 years (the tenure of the program and 1 year afterward for most scholars), which may not be long enough to assess the full influence and success of scholars. Our scholar sample size was modest, limiting definitive conclusions from our results and comparison of scholars by receipt of grant funding.

Our survey response rate was high but still incomplete, which restricted analyses that required these data. For publications and federally funded grants, we had 100% capture based on publicly available data sources. We had complete data on scholar career development award and research project grant submissions based on a follow-up site survey targeted to principal investigators and program administrators. However, grant submissions were not independently verifiable with public data. Also, we limited our grant tracking to submissions and awards with scholars listed as principal investigator, which excluded awards with scholars as co-investigator because it is not possible to track co-investigator time with publicly available data sources. This limitation likely underestimated scholar funding from federal grants and their contribution to "team science" on projects led by another principal investigator.

For the analysis, it was important to separate publications by date of publication, aligned with the date each scholar started the program. This allowed assessment of scholar-level publications on entry to the program and cumulative productivity over time. However, we were unable to assess the proportion of scholar first- and last-author publications, or the category of "original research" publications. The proportion of articles indexed in PubMed and available for Relative Citation Ratio analysis (75%) provided an indirect estimate of the proportion of original research publications.

Finally, the evaluation team that collected the data for this study, conducted interviews, and analyzed the data (quantitative and qualitative) was not directly affiliated with the K12 program. This arrangement was by design to minimize conflicts of interest and potential biases in favor of the program. However, members of the evaluation team are employed at Oregon Health & Science University and have previous collaborated with one member of the site's K12 leadership, which could have introduced bias to the analysis.

## DISCUSSION

Conducting research in the emergency care setting has unique features and challenges not observed in other scientific domains. Research processes related to study design, enrollment, informed consent, inclusion criteria, data collection, patient tracking, ethical considerations, logistics, and analytics can be unique and distinct from those of other disciplines. Our findings suggest that a federally supported national effort to train interdisciplinary investigators in a specific domain can be accomplished, with high rates of grant submissions, grant funding, and scientific productivity. These results offer important insights and benchmarks for future institutional research training programs.

Scholars in this program had high success with independent grant awards compared with publicly available award rates. Sixty-one percent of scholars who applied for career development awards were funded compared with 37% of K08 or K23 applications across all NIH institutes in 2016.[14] For research project grant applications, 50% of scholars were successful compared with an NIH research project grant funding rate of 17%.[14] Scholar research project grant funding rates were better than the overall success rate of 23% for emergency care research project grants submitted between 2011 and 2014.[15] The NIH tracks "success rate" by grant submission (the same application submitted multiple times during the same fiscal year is counted only once),[16] rather than by applicant. In our study, we tracked scholar-based success rates and combined career development awards and research project grants across multiple federal and nonfederal organizations; these differences should be considered when the above success rates are compared. Although research has quantified the success of emergency medicine K awardees in obtaining subsequent federal funding,[17] our results are not directly comparable because scholars represented many disciplines, the goals of K12 programs differ from individual K awards, and we defined grant success by receipt of either career development award or research project grant funding. It was also not possible to compare these scholars with those in other NIH K12 programs because the focus and goals of each K12 program often differ.

Scholars in the emergency care K12 programs were unique in that many entered with advanced research degrees, following completion of their specialty and subspecialty training, and with very focused research interests. These scholar characteristics, including being farther along in their research careers, may have resulted in higher success rates

than would otherwise be expected. However, there has been a steady increase in the average age of NIH R01 first-time awardees since 1980,[18] suggesting that these scholars may be on a trajectory similar to that of other members of the scientific workforce. Nonetheless, our findings demonstrate that comprehensive resources and mentorship can catalyze federal grant submissions and funding. We also quantify time to grant submission and funding among scholars; we are not aware of previous research that has tracked these intervals among early-stage investigators.

The volume and influence of scholar science progressed throughout the program. The number of publications per scholar and rigor of scholar science (measured through Relative Citation Ratio scores) increased during and after the K12 program. Although early, these results demonstrate measurable increases in the volume, quality, and influence of science generated during a dedicated research training program. As indicated in the qualitative findings, skill development, comprehensive mentorship, protected time, and collaboration were important ingredients of this success.

Time was a common theme in the qualitative results, with scholars frequently noting that there was insufficient time to meet the expected benchmark of transitioning to independent research funding within the duration of K12 support. Insufficient protected time has been noted as a barrier to conducting research among emergency medicine junior faculty.[19] This qualitative theme is supported by the finding that only one third of scholars who ultimately obtained independent research funding did so during their tenure in the program. However, some scholars intentionally ceased the K12 at 2 years to preserve an additional 4 years of individual K funding, as evidenced through the median time in the program. Effectively balancing the many demands on one's time as a clinician-scientist is integral to this career path.

Collaboration was another primary theme in the qualitative results. Because emergency care is an interdisciplinary science, research collaboration is critical, including the ability to work with investigators from many disciplines and institutions. Emergency care is a natural fit for cross-disciplinary team science because the field involves many specialties working together to care for patients across a continuum of time and place. The program provided opportunities for collaboration that may not have been explored by or otherwise available to scholars. Resulting publications further reflect and illustrate the concept of collaboration, with more than one third being collaborations with other K12 scholars and mentors. We believe that collaboration between emergency care investigators across multiple disciplines is key to advancing the science of emergency care.

Defining and measuring success are important for any training program. The traditional definition of success in research is achieving independent federal research funding. We used a similar metric, including both career development awards and research project grant awards. According to this metric, 60% of K12 scholars have succeeded to date. However, in the qualitative results, we found that some participants supported a wider definition of success. A related programmatic issue is predicting which scholars are likely to be successful, particularly when they are selected for a training program. In our modest sample, individuals entering with advanced research degrees, demonstrating greater research productivity, and submitting grant applications earlier in the program were more likely to secure independent funding. Although previous research has noted that having R01-funded investigators in one's department is an independent predictor of success with federal career development awards,[19] every scholar matriculating into the K12 program had mentors with R-level funding. All scholars also had similar protected time and research resources. Why some scholars reached the goal of independent funding and others did not remains incompletely explained by our results. One possible explanation is that a 3-year period may be insufficient to determine the success of early career investigators (we are aware of 2 scholars who have secured individual K awards since the close of our surveillance period; a longer surveillance period for scholars would reflect a higher success rate). The demands of course work toward an advanced research degree (for scholars matriculating without such a degree) or focus on topic areas that do not easily fit into federal research funding priorities may also extend the timeline. Yet success with federal research funding may also rely heavily on an innate sense of perseverance and drive, a concept that has been termed "grit,"[20] more than any single measure of training, number of publications, or demographics.

This NIH/NHLBI-funded research training program produced a substantial number of interdisciplinary investigators in emergency care research, with demonstrated productivity in grant funding and publications. Targeted scientific training investment in an interdisciplinary research field can produce high levels of grant funding rates, scientific productivity, and scientific influence.

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*Author affiliations:* From the Center for Policy and Research in Emergency Medicine, Department of Emergency Medicine (Newgard, Cook, Lowe), Department of Medical Informatics and Clinical Epidemiology (Morris, Lowe), Oregon Clinical and Translational Research Institute (Morris, Smith, Gowen, Zell), and the Ontology Development Group, Library (Vasilevsky, White), Oregon Health & Science University, Portland, OR; the Department

of Emergency Medicine, University of Pittsburgh, Pittsburgh, PA (Yealy, Callaway); the Department of Emergency Medicine, Vanderbilt University Medical Center, Nashville, TN (Collins, Storrow); the Department of Emergency Medicine, UC Davis Health, Sacramento, CA (Holmes, Kuppermann); the Department of Emergency Medicine, Department of Population Health Science & Policy, Icahn School of Medicine at Mount Sinai, New York, NY (Richardson); the Departments of Medicine and of Biostatistics, Epidemiology and Informatics (Kimmel) and the Department of Emergency Medicine (Baren), University of Pennsylvania, Philadelphia, PA; the Department of Emergency Medicine, Zucker School of Medicine at Hofsra Northwell, Manhasset, NY (Becker); and the Division of Cardiovascular Sciences, National Heart, Lung, and Blood Institute, Bethesda, MD (Scott).

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