Effectiveness of iterative interventions to increase research productivity in one residency program

Richard Alweis, MD1,2*, Suzanne Wenderoth, MD1,2 and Anthony Donato, MD MHPE1,2

1Department of Medicine, Reading Health System, West Reading, PA, USA; 2Department of Medicine, Sidney Kimmel Medical College at Thomas Jefferson University, Philadelphia, PA, USA

Background: The Accreditation Council for Graduate Medical Education requires residency programs to expose residents to research opportunities.

Objective: The purpose of this study was to assess the impact of a series of iterative interventions to increase scholarly activity in one internal medicine residency.

Methods: Retrospective analysis of the effectiveness of a series of interventions to increase resident and faculty scholarly productivity over a 14-year period was performed using quality improvement methodology. Outcomes measured were accepted regional and national abstracts and PubMed indexed manuscripts of residents and faculty.

Results: Initially, regional meeting abstracts increased and then were supplanted by national meeting abstracts. Sustained gains in manuscript productivity occurred in the eighth year of interventions, increasing from a baseline of 0.01 publications/FTE/year to 1.57 publications/FTE/year in the final year measured. Run chart analysis indicated special cause variation associated with the interventions performed.

Conclusions: Programs attempting to stimulate research production among faculty and residents can choose among many interventions cited in the literature. Since success of any group of interventions is likely additive and may take years to show benefit, measuring outcomes using quality improvement methodology may be an effective way to determine success.

Keywords: increasing research productivity; education; medical; graduate; research

*Correspondence to: Richard Alweis, Department of Medicine, Reading Hospital and Medical Center, 6th Avenue and Spruce Streets, West Reading, PA 19611, USA, Email: richard.alweis@readinghealth.org

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In 1994, the Accreditation Council for Graduate Medical Education began requiring residency training programs to ensure that residents gain experience in research and demonstrate participation in a culture of scholarly inquiry. This requirement evolved into the Practice-Based Learning and Improvement competency in the new outcomes-based educational models in the United States (1). Cited benefits to exposing residents to research experience include increased satisfaction with residency training (2, 3), improved resident analytical skills and lifelong learning habits (4, 5), better patient care (5), increased likelihood of pursuing a career in academics (6–8), increased likelihood of becoming a clinician investigator (9), and as an asset to fellowship candidacy (10). However, significant barriers to resident research have been described, including a lack of resident and faculty time to perform research (11–14), absence of a research curriculum (14–16), availability of funding (14, 17), and availability of mentors (14, 18). Independent academic medical centers note more difficulty exposing residents to research (17, 18), have fewer experienced research faculty (19), and are more likely to be cited for a lack of research by residency review committees (17, 18).

Various multi-faceted interventions have been attempted to improve research productivity, including requiring resident research (13, 17, 20–26), granting protected time (11, 13, 17, 20–23), providing biostatistical and research support personnel (11, 13, 24, 27), appointing a residency research director (RRD) (11, 13, 17, 20, 25, 27–29), assigning mentors (17, 20–25, 27), and offering incentives such as presentation opportunities, awards (13, 24), and funding (17, 20, 27). Financial incentive plans, including performance-based (30–34) as well as salary-at-risk (30, 33, 35) formulations have also been implemented. Most interventions were used in combination, and the effects of any single intervention on specific outcomes across the literature have not been reviewed.
The purpose of this study was to assess the impact of a series of iterative interventions to increase scholarly activity as measured by accepted peer-reviewed abstracts and PubMed indexed manuscripts.

**Methods**

**Setting and participants**
This study was performed at a university-affiliated, community-based internal medicine residency program in the northeastern United States over a period of 14 academic years. In academic year 2001–02, the program employed 6 faculty and 27 residents, growing over the subsequent 13 years to 11 faculty and 41 residents by academic year 2013–14. Following a citation by the RRC-IM in 2001 for lack of resident exposure to research, the residency enacted a series of measures to improve resident scholarly activity. The effects of these interventions were studied by retrospective review of peer-reviewed abstracts and PubMed-indexed publications using continuous quality improvement methodology from 2001 to 2015.

**Interventions**
Descriptions of interventions, reasons for interventions, and the timeline are included in Table 1. The first intervention was identifying a RRD from the full-time faculty. Further interventions were selected based on needs assessments generated from faculty and residents on ACGME.

**Table 1.** Timeline of interventions in the research culture development at Reading Health System

| Year      | Initiative                                                                 | Description                                                                                           | Rationale                          |
|-----------|-----------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|-------------------------------------|
| 2002–03   | Named residency research director                                           | Chose director from faculty without additional protected salary or time; served as mentor and evaluator for projects and elective experience | Coordinate and centralize research  |
| 2003–04   | Redesigned journal club                                                     | Focused on study design and critical appraisal, rather than on study outcomes                         | Introduce/reinforce skills          |
| 2004–05   | Created research ‘Wall of Fame’                                             | Framed copies of research posters and first pages of publications displayed on wall of departmental conference room | Celebrate successes                 |
| 2005–06   | Mandated resident scholarly activity                                        | Developed ‘point system’ for scholarly activity for all residents and determined minimum point requirement for graduation | Raise expectations                 |
| 2006–07   | Implemented faculty incentive plan that included research production        | Scholarly activity bonus initiated for full-time faculty worth approximately 5% of base salary         | Counterbalance clinical productivity incentives |
| 2007–08   | Clinical research noon conference series                                     | Three 1-hour sessions annually covering basics of evidence-based medicine and literature search skills | Reinforce research skills           |
| 2008–09   | Hired statistician                                                          | Full-time biostatistician hired by institution and shared across departments                         | Added expertise                     |
| 2010–11   | Formal research curriculum with associated research elective                | Curriculum written by residency research director for resident research elective time                 | Provide protected time and mentorship |
|           | Created mentoring guidelines that included formal review of resident efforts using structured portfolio | In fall of second year, emphasis of residency mentor discussions was re-focused to resident research efforts recorded in personal development portfolio | Reinforce expectations              |
| 2011–12   | ‘How to write a clinical vignette’ seminar                                 | One-hour seminar with focus on choosing topic and writing with clarity; residents in teams all write abstract on same vignette with top rated abstract awarded rights to submit case | Expand research repertoire           |
| 2012–13   | Implemented resident incentive plan                                         | Pay-for-performance bonus using residency discretionary funds; $100 bonus per regional or national abstract and $300 bonus per publication (maximum: $600) | Re-balance resident priorities     |
| 2013–14   | Increase in resident incentive plan                                         | Increased maximum resident bonus to $1,000                                                           | Reward productive residents        |
|           | Resident-initiated ‘How to do a systemic review’ seminar series             | Seven 1-hour seminar sessions during which teams developed, researched, and wrote a systematic review and meta-analysis over the course of 14 weeks | Expand research repertoire          |
surveys, as well post-graduate surveys. Those interventions included formal curricular development, redesign of journal club, and seminars on education topics (vignette writing, evidence-based medicine, and systematic reviews), defining protected time for electives (up to 3 months over 2 years, based on progress from previous work), hiring of a biostatistician, defining research requirements and prioritizing these requirements during mentor meetings, celebrating resident successes with displays of successful work, and with pay-for-performance bonuses for faculty and residents. The scholarly activity component of the faculty incentive plan, in which up to 5% of a faculty member’s base salary would be available as a bonus, was based on a point system developed by the internal medicine faculty. The system assigned points for poster presentations at local, regional, or national levels, as well as for publications (based on journal impact factor). The number of points assigned to each type of academic production and the number of points needed to meet varying levels of bonus targets were negotiated each year with the hospital administration. In addition, a pay-for-performance bonus was added to disburse additional funds into the resident’s discretionary education fund. Residents had previously received $1,500 to use at their discretion for career-related educational or professional needs (e.g., stethoscopes, board review materials). In academic year 2012–03, in addition to these funds, the residents were awarded an additional taxable $100 bonus per regional or national abstract they authored and $300 bonus per publication they authored. The maximum available bonus in the first year of implementation was $600. The following academic year, this maximum was increased to $1,000.

Data analysis

The primary outcome measures for scholarly activity output were accepted peer-reviewed abstracts and PubMed-indexed manuscripts. The unit of analysis was scholarly output per full-time equivalent (FTE) per academic year. One FTE was assigned for all residents in the program and staff, but was prorated for part-time staff and staff that left during an academic year. Scholarly activity outcomes were determined by review of resident files, as well as individual searches of Google Scholar, EMBASE, and PubMed for each author by name. All abstracts and publications were reviewed, and duplicates were deleted. Abstracts were characterized as ‘regional’ or ‘national’ based on the meeting description. Scholarly activity was recorded in an Excel spreadsheet (Microsoft Corporation, Redmond, WA) by a trained research associate. Ten percent of entries were double-coded by one investigator to ensure accuracy of the database. Calculations of publications per FTE faculty and resident were performed within Excel. Run charts were then created using the Institute for Healthcare Improvement (IHI) run chart tool (IHI, Cambridge, MA). The center line was created using the mean of the PubMed indexed publications per FTE in the years leading up to the first intervention. In order to compare our results, we reviewed the literature for scholarly activity interventions in the literature, categorizing their specific interventions as well as their publications, measured by reported publications per physician per year averaged over the length of the study. Publication counts were confirmed by direct communication with corresponding authors when necessary. The Reading Health System Institutional Review Board exempted this study as quality improvement.

Results

The program had 5.9 FTE faculty members and 27 residents for a total of 32.9 FTE in the first year of measurement (2001–02) and grew to 10.55 FTE faculty members and 41 residents for a total of 51.55 FTE by the last year of the study (2014–15). There was an initial increase in regional meeting abstracts in the academic year 2003–04, which was surpassed by national meeting abstracts in 2010–11 but declined thereafter. Sustained gains in manuscript productivity occurred in the eighth year of interventions, increasing from a baseline of 0.01 publications/FTE/year to 1.57 publications/FTE/year in the final year measured (Fig. 1). In academic year 2012–13, 27 out of 32 residents qualified for a scholarly activity bonus and received a total of $9,200. The following year, 31 out of 39 residents qualified and received a total of $16,900. In the final year measured, 30 out of 41 residents qualified and received a total of $21,800.

Our run chart of publications per FTE demonstrated three total runs. A run chart with 14 data points should have between 4 and 11 runs, indicating too few runs which we interpreted as an indication of special cause variation in the data set (36). In addition, both a shift (12 points above centerline, starting in 2003–04) and a trend (six consecutively increasing points from 2009 to 2010 and onward) indicated special cause variation in our data (Fig. 2).

Discussion

In this study, we found that scholarly activity significantly increased over the past 12 years of our outcomes measures, indicating special cause variation (i.e., statistically unlikely to be the result of random fluctuation or chance). We interpret this finding as indicating a positive association between our interventions and research productivity. Due to the time difference between interventions relative to the time cycle of a typical manuscript from idea inception to publication, we could not determine the individual impact of any single one of our interventions. In addition, the effects of any single intervention would be expected to be additive on prior interventions, making it more difficult to determine the relative effect of any single intervention. Given that the order of interventions was chosen based on local needs as determined by the RRD, the effect
of changing that order on scholarly activity cannot be determined. However, given the above limitations, we concluded that the measurement of the impact of scholarly activity programs using quality improvement methods allowed us to definitively determine our overall program’s success. Follow-up ACGME surveys of current and graduating residents (in 2013, 2014, and 2015) and at a site visit (in 2010) no longer cited research exposure as a program deficiency.

Similar to other interventions in the literature to increase scholarly activity, our methods involved multimodal programmatic and financial interventions (Table 2). Although other studies confined their efforts to either faculty or resident groups, we chose interventions intended to influence

Fig. 1. Research output of the residency program.

Fig. 2. PubMed indexed publications per academic year per FTE (faculty and resident data).
| Table 2. Interventions performed to increase scholarly activity in the literature |
| --- |
| **Interventions** | **Time studied (years)** | **Protected time** | **Research requirement** | **Mentors** | **Curriculum** | **Research assistant** | **Research director** | **Bioskistatian** | **IT support** | **Research fund available** | **Opportunities or awards** | **Funding: performance based** | **Funding: salary at risk** | **Specifics of interventions** | **Reported publication outcomes** |
| Interventions on faculty | | | | | | | | | | | | | | | |
| Bertram et al. (27) | GIM faculty | 16 | x | x | x | x | x | x | | | | | Director: 10-20% salary support; co-director: 5-10% support | 334 publications/16 years (0.83 pubs/fac/years) |
| Cramer et al. (35) | Fam med faculty | 3 | | | | | | | | | | | | | Research points increased from 524 to 775 (48% increase) |
| Filler et al. (40) | Staff Pediatrics and administrators | 3 | | | | | | | | | | | | | No difference in research scores; publications not reported |
| Reich et al. (33) | Anesthesia faculty | 1 | | | | | | | | | | | | | No change in publications |
| Sakai et al. (39) | Clinical faculty | 6 | | | | | | | | | | | | | Performance-based incentive, 30% of salary at risk |
| Schweitzer et al. (32) | Medical school faculty | 10 | x | x | x | x | x | x | x | | | | | Productivity-based incentive tied to tenure |
| Tarquino et al. (41) | Physicians in 12 clinical divisions | 2 | | | | | | | | | | | | | Financial incentives |
| Interventions on residents in training | | | | | | | | | | | | | | | |
| Byrnes et al. (22) | IM residents | 3 | x | x | x | x | x | | | | | | | | | 4 months approved elective time with mentor |
| Carek et al. (24) | Fam med residents | 10 | x | x | x | x | x | | | | | | | | | Required curriculum for senior residents: 1 year (0.05 pubs/res/years) |
| Chang and Mills (31) | ENT residents | 8 | | | | | | | | | | | | | 41 publications/14 years |
| Durning et al. (28) | IM residents | 5 | x | x | x | x | | | | | | | | | | Residency research director spent 7 hours/week on projects |
| Fancher et al. (25) | IM residents | 4 | x | x | x | | | | | | | | | | | 2 publications/1 year |

Iterative interventions increase research productivity
| Study          | Time studied (years) | Protected time | Research requirement | Mentors | Curriculum | Research assistant | Research director | Biostatistician | IT support | Research fund available | Opportunities or awards | Funding: performance based | Funding: salary at risk | Specifics of interventions | Reported publication outcomes |
|---------------|----------------------|----------------|----------------------|---------|------------|---------------------|-------------------|----------------|-----------|------------------------|--------------------------|--------------------------|--------------------------|-----------------------------|--------------------------|
| Fischer and Cation (29) | IM residents (n = 24/year) | 6 | x | x | x | x | | | | | x | | | RRD, elective time, mandatory requirement | No publications |
| Hepburn et al. (23) | IM residents (n = 30/year) | 5 | x | x | x | x | x | x | | | | | | | Mandatory res requirement, 2 months dedicated time | 21 publications/5 years (0.14 pubs/res/year) |
| Holmes et al. (26) | EM residents (n = 24/year) | 10 | | | | | | | | | | | | Required research | 36 publications/10 years (0.15 pub/res/year) |
| Kanna et al. (13) | IM residents (n = 64/year) | 2 | x | x | x | x | | x | | | | | | 2-week required rotation; assigned mentor; awards day | 49 publications/2 years (0.29 pubs/res/year) |
| Roane et al. (20) | Psych residents (n = 48/year) | 5 | | x | x | x | | | | | | | | Required research, assigned mentors | 32 publications/5 years (0.13 pubs/res/year) |
| Rotheberg et al. (11) | IM residents (n = 54/year) | 6 | x | x | x | x | | | | | | | | RRD with 0.25 FTE protected Time: biostats and research assistant support | 58 publications/7 years (0.15 pubs/res/year) |
| Vinci et al. (21) | Peds residents (n = 126/year) | 5 | | x | x | x | | | | | | | | Elective 3-month rotation, assigned mentors, 25 hours mandatory curriculum | 15 publications/5 years (0.02 pubs/res/year) |
| Interventions in both faculty and residents | Alweis 2015 | IM residents, faculty (n = 33 - 51/year) | 14 | x | | | | | | | | | | Research electives, incentive plan for faculty and then residents | 176 resident publications/14 years (0.44 pubs/res/year); 21 faculty publications/14 years (0.20 pubs/fac/year) |
both residents and faculty. Similar to other studies, we retrospectively studied the effects of interventions at a single site studied over a prolonged period of time. Most authors chose outcomes measures that included abstracts and publications or publications only, whereas others measured grant funding received, making direct comparisons between studies difficult. No single intervention appears to be uniformly successful, and no specific pattern of multimodal interventions appears to be more effective than another in our review of the literature, suggesting that the optimal solutions at any one facility may be unique to the barriers at that facility. This suggests that a formal needs assessment and rigorous measurements of outcomes may best guide future individual interventions. Pay-for-performance models have existed in the business literature for approximately 100 years but are more recent additions to the American medical culture (37, 38). These models have increased clinical productivity (defined as volume) and ‘time on task’ (37, 39). However, studies of isolated financial incentives directed towards medical education outcomes, including research, have shown conflicting results (30, 31, 40, 41). How large an incentive is needed relative to the other components of compensation to effectively stimulate research is also currently unknown (31, 41–44).

There are several potential limitations to this study. While the number of potential venues for all publications has greatly increased over the time of this study, we limited our outcome measure to only those that were indexed by PubMed to limit the effects that newer open access journals may have had on our results. This may have given us a more conservative estimate of our overall effectiveness than if we had captured all peer-reviewed publications (as all others had done with one exception) (31), but prevented us from potentially overstating the effects of our intervention. The improvement in research productivity as attributed to our interventions is potentially confounded by the growth of the residency faculty and more competitive resident recruitment over the course of the study, although it should be noted that none of the faculty recruited had research backgrounds or protected research time.

Conclusions

Programs attempting to stimulate research production among faculty and residents can choose among many interventions cited in the literature. Since success of any group of interventions may be additive and take years to effect a measurable increase in the outcomes of interest, measuring outcomes using quality improvement methodology may be an effective way to determine success. Whether these efforts lead to future resident research production in fellowship or practice is a matter for further research. The best methodologies to sustain gains in research productivity in the face of rapid turnover of the majority of the participants (i.e., residents) deserve further inquiry.

Conflict of interest and funding

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References

1. ACGME Next Accreditation System Milestones. Available from: http://acgme.org/acgmeweb/tabid/430/ProgramandInstitutionalAccreditation/NextAccreditationSystem/Milestones.aspx [cited 24 February 2014].

2. Takahashi O, Ohde S, Jacobs JL, Tokuda Y, Omata F, Fukui T. Residents’ experience of scholarly activities is associated with higher satisfaction with residency training. J Gen Intern Med 2009; 24(6): 716–20. doi: http://dx.doi.org/10.1007/s11606-009-0970-4

3. Hayward RA, Tawedd F. Data and the internal medicine house officer: Alumni’s views of the educational value of a residency program’s research requirement. J Gen Intern Med 1993; 8(3): 140–2.

4. Goodman NW. Does research make better doctors? Lancet 1994; 343(8888): 59.

5. Abramson M. Improving resident education: What does resident research really have to offer? Trans Sect Otolaryngol Am Acad Ophthalmonol Otolaryngol 1977; 84(6): 984–5.

6. Neacy K, Stern SA, Kim HM, Dronen SC. Resident perception of academic skills training and impact on academic career choice. Acad Emerg Med 2000; 7(12): 1408–15.

7. Sanders AB, Fulginiti JV, Witzke DB. Factors influencing resident career choices in emergency medicine. Ann Emerg Med 1992; 21(1): 47–52.

8. Hillman BJ, Fajardo LL, Witzke DB, Cardenas D, Irion M, Fulginiti JV. Factors influencing radiologists to choose research careers. Invest Radiol 1989; 24(11): 842–8.

9. Rosenberg LE. Young physician-scientists: Internal Medicine’s challenge. Ann Intern Med 2000; 133(10): 831–2.

10. Stain SC, Hiatt JR, Ata A, Ashley SW, Roggin KK, Potts JR, et al. Characteristics of highly ranked applicants to general surgery residency programs. JAMA Surg 2013; 148(5): 413–17. doi: http://dx.doi.org/10.1001/jamasurg.2013.180

11. Rothberg MB, Kleppel R, Friericci JL, Hinckey K. Implementing a resident research program to overcome barriers to resident research. Acad Med 2014; 89(8): 1133–9. doi: http://dx.doi.org/10.1097/ACM.0000000000000281

12. Hellenthal NJ, Ramirez ML, Yap SA, Kurzrock EA. Manuscript publication by urology residents and predictive factors. J Urol 2009; 181(1): 286–8; discussion 286–7. doi: http://dx.doi.org/10.1016/j.juro.2008.09.022

13. Kanna B, Deng C, Erickson SN, Valerio JA, Dimitrov V, Soni A. The research rotation: Competency-based structured and novel approach to research training of internal medicine residents. BMC Med Educ 2006; 6: 52. doi: http://dx.doi.org/10.1186/1472-6920-6-52

14. Rivera JA, Levine RB, Wright SM. Completing a scholarly project during residency training. Perspectives of residents who have been successful. J Gen Intern Med 2005; 20(4): 366–9. doi: http://dx.doi.org/10.1111/j.1525-1497.2005.04157.x

15. Hebert RS, Levine RB, Smith CG, Wright SM. A systematic review of resident research curricula. Acad Med 2003; 78(1): 61–8.
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16. Hamann KL, Fancher TL, Saint S, Henderson MC. Clinical research during internal medicine residency: A practical guide. Am J Med 2006; 119(3): 277–83. doi: http://dx.doi.org/10.1016/j.ajmmed.2005.12.001

17. Levine RB, Hebert RS, Wright SM. Factors associated with citation of internal medicine residency programs for lack of scholarly activity. Teach Learn Med 2005; 17(4): 328–31. doi: http://dx.doi.org/10.1207/s15328015tlm1704_3

18. Algire PC, Anderson WA, Albrecht RR, Poland GA. Resident research in internal medicine training programs. Ann Intern Med 1996; 124(3): 321–8.

19. Youn RA, Dehaven MJ, Passmore C, Baumer JG. Research participation, protected time, and research output by family physicians in family medicine residencies. Fam Med 2006; 38(5): 341–9.

20. Roane DM, Inan E, Haeeri S, Galyonker II. Ensuring research competency in psychiatric residency training. Acad Psychiatr 2009; 33(3): 215–20. doi: http://dx.doi.org/10.1176/appi.ap.33.3.215

21. Vinci RJ, Bauchner H, Finkelstein J, Newby PK, Muret-Wagstaff. A mission-based productivity compensation model for an academic family medicine department. Acad Med 2000; 75(12): 1159–66.

22. Byrne AB, McCormack FX, Diers T, Jazieh A-R. The resident scholar program: A training research opportunity for internal medicine house staff. J Cancer Educ 2007; 22(1): 47–9. doi: http://dx.doi.org/10.1080/0885810701348133

23. Hepburn MJ, Battafurano DF, Enzenauer RJ, Salzberg DJ, Murphy FT, Parisek RA, et al. Increasing resident research in a military internal medicine program. Mil Med 2003; 168(4): 341–5.

24. Carek PJ, Dickerson LM, Diaz VA, Steyer TE. Addressing the scholarly activity requirements for residents: One program’s solution. J Grad Med Educ 2011; 3(3): 379–82. doi: http://dx.doi.org/10.4300/JGME-D-10-00201.1

25. Fancher TL, Wun T, Hotz CS, Henderson MC. Jumpstarting academic careers with a novel intern research rotation: The AIMS rotation. Am J Med 2009; 122(11): 1061–6. doi: http://dx.doi.org/10.1016/j.ajmmed.2009.06.017

26. Holmes JF, Sokolove PE, Panacek EA. Ten-year experience with an emergency medicine resident research project requirement. Acad Emerg Med 2006; 13(5): 575–9. doi: http://dx.doi.org/10.1119/j.aem.2005.12.016

27. Bertram A, Yeh HC, Bass EB, Brancati F, Levine D, Cofrancesco J. How we developed the GIM clinician-educator mentoring and scholarship program to assist faculty with program promotion and scholarly work. Med Teach 2015; 37(2): 131–5. doi: http://dx.doi.org/10.3109/0142159X.2014.91269

28. Durning SJ, Cation LJ, Markert RJ, Pangaro LN. Assessing the reliability and validity of the mini-clinical evaluation exercise for internal medicine residency training. Acad Med 2002; 77(9): 900–4.

29. Fischer JL, Cation LJ. Impact of a residency research program on research activity, faculty involvement, and institutional cost. Teach Learn Med 2005; 17(2): 159–65. doi: http://dx.doi.org/10.1207/s15328015tlm1702_10

30. Sakai T, Hudson M, Davis P, Williams J. Integration of academic and clinical performance-based faculty compensation plans: A system and its impact on an anesthesiology department. Br J Anaesth 2013; 111(4): 636–50. doi: http://dx.doi.org/10.1093/bja/aet150

31. Chang CWD, Mills JC. Effects of a reward system on resident research productivity. JAMA Otolaryngol Head Neck Surg 2013; 139(12): 1285–90. doi: http://dx.doi.org/10.1001/jamaoto.2013.5303

32. Schweitzer L, Sessler DI, Martin NC. The challenge for excellence at the University of Louisville: Implementation and outcomes of research resource investments between 1996 and 2006. Acad Med 2008; 83(6): 560–7. doi: http://dx.doi.org/10.1097/ACM.0b013e3181722d31

33. Reich DL, Galati M, Krol M, Bodian CA, Kahn RA. A mission-based productivity compensation model for an academic anesthesiology department. Anesth Analg 2008; 107(6): 1981–8. doi: http://dx.doi.org/10.1213/ane.0b013e31818ca31c

34. Miller A, Archer J. Impact of workplace based assessment on doctors’ education and performance: A systematic review. BMJ 2010; 341: c5064.

35. Cramer JS, Ramalingam S, Rosenthal TC, Fox CH. Implementing a comprehensive relative-value-based incentive plan in an academic family medicine department. Acad Med 2000; 75(12): 1159–66.

36. Armstrong F. Six sigma – step 2 – measure. 2011. Available from: http://thequalityweb.com/menu.html; http://thequality-web.com/measure3.html [cited 18 November 2014].

37. Long RD, Wilder DA, Betz A, Dutta A. Effects of and preference for pay for performance: An analogue analysis. J Appl Behav Anal 2012; 45(4): 821–6. doi: http://dx.doi.org/10.1901/jaba.2012.45-821

38. Hendrickson MA. Pay for Performance and medical professionalism. Qual Manag Health Care 2008; 17(1): 9–18. doi: http://dx.doi.org/10.1097/QMH.0b013e318189797b

39. Bucklin BR, McGee HM, Dickinson AM. The effects of individual monetary incentives with and without feedback. J Organ Behav Manage 2004; 23(2–3): 65–94. doi: http://dx.doi.org/10.1030/JOBM2004.0000058

40. Filler G, Burkoski V, Tithecott G. Measuring physicians’ productivity: A three-year study to evaluate a new remuneration system. Acad Med 2014; 89(1): 144–52. doi: http://dx.doi.org/10.1097/ACM.000000000000058

41. Tarquiniro GT, Dittus RS, Byrne DW, Kaiser A, Neilson EG. Effects of workplace-based assessment on the clinical activity, research portfolio, and teaching mission and outcomes of research resource investments between 1996 and 2006. Acad Med 2003; 78(7): 690–701.

42. Emery SE, Gregory C. Physician incentives for academic productivity. An analysis of orthopaedic department compensation strategies. J Bone Joint Surg Am 2006; 88(9): 2049–56. doi: http://dx.doi.org/10.2106/JBJS.E.00243

43. Iyengar R, Wang Y, Chow J, Charney DS. An integrated approach to evaluate faculty members’ research performance. Acad Med 2009; 84(11): 1610–16. doi: http://dx.doi.org/10.1097/ACM.0b013e3181b2364

44. Bluth EI. An incentive system for radiologists in an academic environment. J Am Coll Radiol 2007; 4(5): 332–34. doi: http://dx.doi.org/10.1016/j.jacr.2006.12.016