Early- and late-career surgeon deficiencies in complex cases

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It is often challenging to determine a trainee's capacity for independent practice during residency years.¹ Examining coronary artery bypass grafting (CABG) in particular, the authors of a study from England compared outcomes between 1 and 4 years following training and found a substantially improved mortality rate by the third and fourth years.² In a series of mostly primary cardiac operations, the Brigham group examined crossclamp times versus years post-training and demonstrated an increase in efficiency as surgeons gained experience.³ On the other end of the spectrum, Waljee and colleagues⁴ compared operative mortality following CABG in surgeons 41 to 50 years of age versus those older than 60 years of age. Those older than 60 years of age had a higher observed-to-expected (O:E) mortality ratio if they were low-volume or medium-volume surgeons, but if they were high-volume surgeons, the O:E ratios were the same. High-volume surgeons were able to maintain good outcomes.

One's capacity to learn new procedures may also vary with age. Gottlieb-Vedi and associates⁵ studied 36 surgeons in Sweden performing esophagectomy and found that the younger surgeons (younger than 45 years of age) were more apt to learn procedures quicker than the older surgeons (45 years of age and older). Proficiency gain curves look for change points in cumulative sum analysis (ie, CUSUM) at which there is a sustained improvement in outcomes. Proficiency gain was substantially shorter, implying a faster time to achieve the desired outcome, for the younger surgeons in regards to improved R1 resection margin (7 vs 16 cases in the older group), diminished 30-day mortality (18 vs 31 cases), and greater 5-year mortality (13 vs 48 cases).

Next, looking at the congenital cardiac experience, Anderson and coauthors⁶ hypothesized there was a substantial variation in relation to career phase. They reviewed 206

Nonlinear relationship between reoperative cardiac outcomes and surgical experience.

CENTRAL MESSAGE

Surgical experience impacts results with reoperative cardiac surgery. An initial learning curve exists, then outcomes stabilize throughout the mid-career and decline during the most senior years.

See Commentaries on pages 1026 and 1028.

surgeons at 91 centers who performed 62,581 index operations with an 11.5% major morbidity or mortality rate. They compared early career surgeons (less than 15 years in practice), to mid-career (15-24), senior (25-34), and very senior (35 or greater) surgeons. Mid-career and senior surgeons had similar outcomes to early career surgeons, but very senior surgeons started to have an increase in their O:E ratio of 1.24, which was significant compared with the other career phase groups ($P = .028$), irrespective of provider volumes.

WHAT ABOUT REOPERATIVE CARDIAC SURGERY?

Reoperative cardiac surgery is more difficult and carries greater risk of technical complications than a primary operation.⁷ Roselli and colleagues⁸ at the Cleveland Clinic examined outcomes with reoperative surgery and found that predictors of an intraoperative adverse event included increased number of reoperations, history of radiation therapy, elevated bilirubin, tricuspid valve operation, and

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previous non-CABG surgery, but they did not examine surgeon-specific factors. A recent study from Washington University School of Medicine examined the impact of surgeon-specific factors in reoperative cardiac surgery with the following hypothesis: surgical experience impacts outcomes with an initial learning curve and a nonlinear relationship demonstrating a decline in outcomes in advanced years.⁹

During a 33-year period, 2314 patients underwent reoperative cardiac surgery that included either a CABG or valve. The study included 34 surgeons in practice between 1 and 39 years. The overall mortality rate was 11%, and the post-operative complications were as expected for any large series of complex reoperations. Importantly, only 71% of these patients were eligible for calculation of a Society of Thoracic Surgeons Predicted Risk of Mortality due to the complicated nature of these procedures, so a new risk prediction model was developed to accurately and reproducibly risk stratify patients and determine an O:E ratio.

Multivariate logistic regression analysis yielded 10 independent risk factors to predict operative death including, in decreasing order of significance: (1) preoperative shock (odds ratio, 5.5); (2) chronic renal disease (3.7); (3) combined CABG/valve procedure (2.2); (4) age older than 80 years (2.1); (5) New York Heart Association class III or IV (2.0); (6) tricuspid operation (1.8); (7) greater than 1 reoperation (1.7); (8) mitral operation (1.5); (9) history of myocardial infarction (1.5); and (10) peripheral vascular disease (1.4). These 10 independent risk factors were entered into the standard formula for predicted probability to calculate a mortality risk for each patient.

Analysis of the risk-adjusted CUSUM curve for survival following reoperative cardiac surgery identified 4 distinct change-points: (1) year 5—outcomes first began to stabilize; (2) year 9—outcomes started to become better than expected; (3) year 18—outcomes were at their best; and (4) year 29—outcomes began to decline. This facilitated identification of 5 career phases including early career (less than 5 years), early-mid career (5-8 years), mid-career (9-17 years), mid-late career (18-28 years), and late career (greater than 28 years). Mid-late career and mid-career surgeons tended to average more reoperations per year (17.4 and 11.6, respectively) than early-mid (9.7), late (8.2), or early (6.0) career surgeons. The standardized mortality ratio (SMR) was greatest in the late-career phase (1.53, $P = .032$) and the early-career phase (1.29, $P = .059$) (Table 1). SMR was lowest during the mid-career phase at 0.78 ($P = .034$). SMR was not significantly different than 1.0 at early-mid career (0.95, $P = .724$) and mid-late career (1.05, $P = .735$). The polynomial fit for SMR versus years in practice identified a nonlinear relationship (Figure 1). In summary, these data support a nonlinear relationship between patient outcomes and surgeon experience with complex reoperative cardiac surgery. There was evidence of a

TABLE 1. SMR versus years in practice for 5 distinct career stages

Years in practice	Cases	SMR	P Value
0-4	331	1.29 (0.99-1.70)	.059
5-8	427	0.95 (0.71-1.26)	.724
9-17	834	0.78 (0.62-0.98)	.034
18-28	558	1.05 (0.81-1.36)	.735
≥29	164	1.53 (1.03-2.26)	.032

Based on data from Moon and colleagues.⁹ SMR, Standardized mortality ratio.

learning curve during the first 4 years, then outcomes improved and ultimately stabilized throughout the mid-career. During the most senior years, there was a decline in outcomes.

The Brigham group demonstrated with a series that included mostly primary operations that CABG results were similar among surgeon age groups whereas results with valve operations were better in the senior surgeon group, most of whom had been practice 30 years.³ Waljee and Greenfield¹⁰ reported a decline of motor skills and dexterity with age, including stamina. Age does not impair memory encoding, but integration of motor and cognitive tasks can suffer. A straightforward primary procedure involves muscle memory with limited variability. In contrast, cardiac reoperations can introduce extensive variability, which may make outcomes less predictable. Typically, the largest decline in operative activity occurs between 60 and 70 years of age, as was the case in our series.¹¹ Maintaining procedural volumes may counter age-related deterioration in complex operations.⁴ Surgeons who shift their practice to lower complexity or who maintain caseloads for high complexity cases until retirement may best support efforts to preserve outcomes.

It is important to emphasize that these data do not imply that early-career and late-career surgeons should not be performing reoperations. In fact, the early- or late-career surgeon may be the most appropriate member of the team to tackle a complex reoperation, but it requires a protocol-driven approach to maximize outcomes.

RECOMMENDATIONS TO ADDRESS POTENTIAL DEFICIENCIES

The importance of preoperative planning using checklists and huddles, as well as the overall experience of the entire team, cannot be overemphasized.¹² During complex reoperative surgery, surgeons of any career phase should feel comfortable enlisting the assistance of other team members, whether an attending colleague or high-level trainee, to lighten the physical and cognitive strain that accompanies these procedures and strengthen the team. Surgeons should consider performing complex reoperative cases earlier in the day, when they are presumably at their best. In addition, teaming early-career with late-career surgeons may improve results at both ends of the spectrum. This

FIGURE 1. SMR versus years in practice for reoperative cardiac surgery. Nonlinear regression of 5-year running average using Marquardt–Levenberg algorithm. $SMR = 1.387 - (0.0793 * yr) + (0.00275 * yr^2) - (0.00000663 * yr^3)$. Based on data from Moon and colleagues.⁹

relationship provides the mentorship of a senior surgeon to facilitate transference of knowledge and skills and provides the safety net of a second younger cognitive presence to minimize variability.

Even under the best of circumstances, adverse events will occur, but with adequate team planning and surgeon preparation, failure to rescue can remain low for surgeons at any career phase. Interventions to improve the learning curve of a novice surgeon and to balance the skill attrition of a senior surgeon will warrant further study, as will the impact of shifting one's practice to lower complexity versus maintaining caseloads of high complexity with aging.

Conflict of Interest Statement

Dr Moon is a consultant/advisory board member for Medtronic.

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References

1. Moon MR. Technical skills assessment in thoracic surgery education: we won't get fooled again. *J Thorac Cardiovasc Surg.* 2014;148:2497-8.
2. Bridgewater B, Grayson AD, Au J, Hasan R, Dihmis WC, Munsch C, et al. Improving mortality of coronary surgery over first four years of independent

- practice: retrospective examination of prospectively collected data from 15 surgeons. *BMJ.* 2004;329:421. <https://doi.org/10.1136/bmj.38173.577697.55>
3. Burt BM, ElBardissi AW, Huckman RS, Cohn LH, Cavasco MW, Rawn JD, et al. Influence of experience and the surgical learning curve on long-term patient outcomes in cardiac surgery. *J Thorac Cardiovasc Surg.* 2015;150:1061-8.
4. Waljee JF, Greenfield LJ, Dimick JB, Birkmeyer JD. Surgeon age and operative mortality in the United States. *Ann Surg.* 2006;244:353-62.
5. Gottlieb-Vedi E, Mackenzie H, van Workum F, Rosman C, Lagergren P, Markar S, et al. Surgeon volume and surgeon age in relation to proficiency gain curves for prognosis following surgery for esophageal cancer. *Ann Surg Oncol.* 2019;26:497-505.
6. Anderson BR, Wallace AS, Hill KD, Gulack BC, Matsouaka R, Jacobs JP, et al. Association of surgeon age and experience with congenital heart surgery outcomes. *Circ Cardiovasc Qual Outcomes.* 2017;10:e003533. <https://doi.org/10.1161/CIRCOUTCOMES.117.003533>
7. Roselli EE. Reoperative cardiac surgery: challenges and outcomes. *Tex Heart Inst J.* 2011;38:669-71.
8. Roselli EE, Pettersson GB, Blackstone EH, Brizzio ME, Houghtaling PL, Hauck R, et al. Adverse events during reoperative cardiac surgery: frequency, characterization, and rescue. *J Thorac Cardiovasc Surg.* 2008;135:316-23.
9. Moon MR, Henn MC, Maniar HS, Pasque MK, Melby SJ, Kachroo P, et al. Impact of surgical experience on operative mortality after reoperative cardiac surgery. *Ann Thorac Surg.* 2020;110:1909-16.
10. Waljee FF, Greenfield LJ. Aging and surgeon performance. *Adv Surg.* 2007;41:189-98.
11. Greenfield LJ, Proctor MC. Attitudes toward retirement. A survey of the American Surgical Association. *Ann Surg.* 1994;220:382-90.
12. Elbardissi AW, Duclos A, Rawn JD, Orgill DP, Carty MJ. Cumulative team experience matters more than individual surgeon experience in cardiac surgery. *J Thorac Cardiovasc Surg.* 2013;145:328-33.

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