Determinants of Resident Competence in Mastoidectomy: Role of Interest and Deliberate Practice

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Objectives/Hypothesis: This study explores the influence of selected factors on achievement of competency in mastoid surgery.

Methods: The longitudinal performance of 15 residents was evaluated using the mastoidectomy task-based checklist (TBC). The influence of surgical experience, resident interest, and training factors (course attendance, voluntary use of simulation laboratory) was also examined and compared for the acquisition of distinct levels of technical skill difficulty (cortical mastoidectomy vs. facial recess).

Results: Ninety-six observations made during the first otology rotation were analyzed. Cortical mastoidectomy tasks showed positive associations with cumulated case numbers (OR 1.13, CI 1.04–1.23, P = .003) and interest in otology (OR 3.86, CI 1.21–12.27, P = .022). Facial recess tasks showed a larger positive association with interest in otology (OR 10.38, CI 2.25–47.94, P = .003), and negative association with extra time spent in laboratory practice (OR .05, CI 0.011–0.23, P = .000).

Conclusions: Learning trajectory for cortical mastoidectomy and facial recess may be influenced by different factors. Interest in otology, in particular, may have a moderating effect on the acquisition of more complex skills in mastoid surgery. A negative association between self-directed laboratory simulation and performance may reflect the impact of assessment-guided feedback in promoting deliberate practice. Further investigations are suggested to explore the interactions between individual trainee differences, educational models, and learning outcomes.

Key Words: Learning curve, mastoidectomy, otolaryngology, surgical competency, skill acquisition, OSATS, surgical learning.

Level of Evidence: N/A.

INTRODUCTION

The Accreditation Council for Graduate Medical Education (ACGME) Outcome Project mandates that residency programs should use resident performance data as a guide to program improvement. Starting in July 2013, the Next Accreditation System of the ACGME will require biannual reporting of resident outcome data.¹ It is therefore incumbent upon residency programs to quantify the performance of each trainee and establish a protocol for early remediation, while possibly providing rapidly advancing trainees with additional learning opportunities.

As an integral component of the Johns Hopkins Assessment of technical skills in Ear Nose and Throat (ASCENT) project, we have pilot tested an Objective Structured Assessment of Technical Skills (OSATS) tool for mastoidectomy surgery in the temporal bone laboratory.² The checklist was subsequently found to be reliable and valid in the operating room (OR) setting.³ Moreover, we deconstructed the mastoidectomy procedure into three learning milestones, each with distinct difficulty levels demanding more experience to achieve competence.⁴ Whereas the first two milestones constitute the cortical portion of the mastoidectomy procedure and ensure that preliminary surgical skills are mastered, the third milestone—the opening of the facial recess—demands advanced technical skills and precise visuospatial ability in order to preserve both facial and chorda tympani nerves. Competency in the more advanced milestone may indicate a minimal level of technical ability required for the safe and effective performance of mastoidectomy surgery in most cases of chronic ear disease by a newly graduated otolaryngologist.

To understand surgical skill development, it is important to examine how individual learner factors, as well as the learning environment, influence the performance trajectory. According to Bandura’s social learning⁵ and social cognitive theories,⁶ behavioral (e.g., performance), personal, and environmental factors have reciprocal relationships in a triadic learning model. To understand their associations with mastoidectomy...
performance outcomes, we explored the influence of selected factors in each of the three dimensions. Regarding individual learner characteristics, we investigated the impact of interest, which a number of studies show to be associated with learning processes and outcomes.7,8 Regarding the learning environment, we investigated the impact of 1) attendance of a formal temporal bone course, 2) case experience in the operating room, and 3) self-directed practice on cadaveric material in the temporal bone laboratory. This study’s conceptual model is shown in Figure 1. Understanding the factors that influence the trajectory of technical learning and the acquisition of surgical competence would be useful in identifying effective and efficient educational strategies in graduate medical education.

MATERIALS AND METHODS

Participants

Institutional review board (IRB) approval was obtained. Fifteen residents from the Johns Hopkins Department of Otolaryngology–Head and Neck Surgery (OHNS) were prospectively evaluated for performance of mastoidectomy surgery over a 4-year time frame (2008–2011). Surgical skills in the operating room were assessed by faculty using the OSATS mastoidectomy tool during the second clinical postgraduate year (PGY 2 or PGY 3). Uniformity in selection of residents at this stage ensured the consistency for experience. A survey was also administered to residents to determine their interest in otology and mastoid surgery, their participation in the annual temporal bone course, as well as self-directed practice on cadaveric specimens in the temporal bone laboratory (Appendix A). The timing of the survey was retrospective; it was administered to residents after they had completed their otology rotation. This also ensured that the evaluators were blinded to the participants. The following inclusion criteria were used: 1) Second clinical year (PGY-2 or PGY-3) residents with minimal previous experience in mastoidectomy surgery; and 2) residents with documentation of mastoidectomy evaluations within the first 20 days of their otology rotation, permitting the construction and evaluation of performance learning curves starting early in mastoidectomy training.

Instrument

The evaluations were based on a previously validated task-based checklist (TBC) for the assessment of mastoidectomy skills in the OR.3 The TBC consisted of five key mastoidectomy tasks: 1) initial bone cuts, 2) defining anatomic limits, 3) open antrum, 4) thin posterior external auditory canal (EAC) cortex, and 5) open facial recess (Appendix B). Each item on the checklist was scored on a 5-point Likert scale. The average score across all items was calculated for each evaluation. Competency in performing the mastoidectomy procedure was established at level 3 or higher. Each resident was assessed in the operating room by four to five otology faculty members.

Separate analyses were performed for cortical mastoidectomy alone (i.e., milestones 1 and 2; items 1a–4c) and facial recess (i.e., milestone 3; items 5a–5c). The cumulative number of mastoidectomy procedures performed in the operating room as primary surgeon was obtained from recorded case logs. Participation at the level of resident surgeon required performance of over half of the mastoidectomy procedure. Attendance of the temporal bone course was acquired from available records. Attendance prior to evaluation was computed by noting the cumulative number of days spent in the temporal bone laboratory. Competency in performing the mastoidectomy procedure was established at level 3 or higher. Each resident was assessed in the operating room by four to five otology faculty members.

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Survey Design
A modified Delphi technique was employed to obtain the opinion of a panel of experts on each of the survey questions. Each item on the survey was scored on a 5-point Likert scale. The option exploring interest level ranged from 1 (minimally interested) to 5 (exceptionally interested). The options exploring extra time spent at the temporal bone laboratory ranged from 1 (do not spend extra time) to 5 (> 6 hours per week of extra time spent at the temporal bone laboratory) (Appendix A). The survey was sent to OHNS residents via a survey website (www.surveymonkey.com).

Statistical Analysis
Logistic regression analysis was performed by operationally determined competency (Average TBC score ≥ 3) as a dichotomous dependent variable (0 = unmet, 1 = met competent). Attendance of the temporal bone course, interest in otology, and amount of extra time spent in the temporal bone laboratory were treated as multiple independent variables. Interest in otology was treated as a dichotomous variable by clustering interest level 4 and 5 as a “more interested group” and interest level 1, 2, and 3 as a “less interested group” (resident less interested in otology = 0, resident more interested in otology = 1). Time spent at the temporal bone laboratory was also treated as a dichotomous variable (no extra time spent in the laboratory = 0, some extra time spent in the laboratory = 1). The analysis was performed separately for average TBC scores with and without the task facial recess.

As the time of case-based assessment data was not equally spaced, to smooth visual presentations of learning curves we conducted locally weighted scatterplot smoothing regression (LOWESS) analyses. The mastoidectomy procedures performed over time were treated as longitudinal data (number of cases). The average TBC scores were constructed as the ratio of the sum of the available items on the completed evaluation form over the number of nonmissing items. Interrater reliability for various faculty members was examined for consistency and absolute agreement using a two-way random effects model because different raters reviewed cases randomly. Statistical analysis was performed using STATA 11.0 (College Station, TX) and IBM SPSS 20 (Armonk, NY). Statistical significance was established with a P-value of ≤ 0.05.

RESULTS
Ninety-six evaluations were obtained of 15 residents over a 4-year time frame. The demographic details and evaluation characteristics are presented in Table I. Four expert otologists evaluated 96 mastoidectomy cases performed in the OR by five female (40%) and 10 (60%) male residents. As different raters observed different cases, reliability coefficients of TBC for internal consistency and agreement were Spearman-Brown Coefficient .763 and Intraclass Correlation Coefficient Average Measures .867 for two-way random effects. Thirty-five percent of the evaluations were obtained during PGY-2; and 65% of the evaluations were obtained during PGY-3. Competence was not achieved in 48% of evaluations (i.e., Likert score ≤ 3) but was shown in 52% of evaluations. Five residents (33%) reported less interest in otology, while 10 residents (67%) reported higher interest.

The average TBC score was modeled as a function of the number of cases performed. The trend was examined as a function of interest and separately analyzed for cortical mastoidectomy and facial recess tasks. Figure 2 illustrates how a declared interest in otology influences the learning curve for competency in mastoidectomy. The more interested group demonstrated early accelerated gains in performance compared to the less interested group. With additional OR experience, however, both groups achieved similar rates of competence. A larger and more sustained discrepancy in rates of competence between interested and less interested trainees was found for the facial recess procedure.

The temporal bone course is conducted annually for OHNS residents at our institution. Participation in the course is mandatory for all residents. An average of 20 residents from Post Graduate Year (PGY)–1 to PGY-5 participated in the course. Optional additional opportunities to work in the temporal bone laboratory are also available to each resident. A logistic regression model was used to explore the role of case experience gained in the operating room, attendance of the annual departmental temporal bone course, interest in otology, and additional time spent in the temporal bone laboratory on the achievement of competency (Table II). The probability of attaining competency was predicted by the number of OR cases as resident surgeon (each case performed in the OR increased the odds of being competent in cortical mastoidectomy and facial recess by 1.13 and 1.05, respectively) and interest in otology (more interested residents had odds ratio of 3.86 and 10.38 of being competent in cortical mastoidectomy and facial recess, respectively). Attendance of the temporal bone course did not predict competency in cortical mastoidectomy and facial recess (odds ratio 0.96 and 0.98, respectively).
Extra time spent in self-directed practice in the temporal bone laboratory was associated with a reduced probability of achieving competency during this junior level rotation, particularly for facial recess tasks for which this relationship was statistically significant (odds ratio 0.52 for cortical mastoidectomy; 0.05 for facial recess).

**DISCUSSION**

This study sheds light on the chronology of surgical skill acquisition and the interplay between various factors that may influence trainee performance. Using a triadic reciprocal model of social cognitive theory, we aimed to explore the role of learning environment and personal attributes on surgical skill development. We found that personal attributes exerted substantial influence on surgical performance. Motivated residents required less surgical practice to achieve competency, particularly for the challenging task of navigating the facial recess anatomy. Although a complex interaction of factors is likely to contribute to surgical learning, this study showed that interest in the subject, paired with actual hands-on clinical practice, considerably influenced the magnitude of performance growth.

This study explored three environmental factors that may influence mastoidectomy skill acquisition: 1) the number of cases, 2) attendance of in-house temporal bone courses, and 3) extra time spent in the laboratory. Surprisingly, there was a negative association between the probability of achieving competency and the amount of extra time voluntarily spent in the laboratory setting. This may imply that residents in need of remediation are more likely to be assigned, or voluntarily choose, to use the temporal bone laboratory as a learning resource. This may reflect the benefits of detailed feedback and directions for specific practice that is likely associated with formal skills assessment. High fidelity simulators that better simulate more challenging anatomy such as the contracted mastoid may advance skills faster than the dissection of normal temporal bones in the laboratory setting. The apparent lack of an effect of temporal bone course attendance on performance is likely due to the relatively low rate of non-attendance.

This study is consistent with previous reports in finding an association between interest and performance. Feldman et al. demonstrated that learning curves for performance on laparoscopic surgery differed significantly among trainees interested in laparoscopic surgery when compared to the trainees that lacked interest in this modality. Interest in the specialty or procedure may be an important motivator in the early achievement of higher skill levels, particularly in more complex procedures (Table II, Fig. 2). Selection of trainees for fellowship training, for example, may be based on their demonstration of shorter learning curves and greater interest in the subject matter. An apparent plateau in the learning curve for initial milestones (item 1a–4c) for more interested residents might be an artifact of fewer evaluations conducted in this group as the rotation progressed. The faculty evaluators might have felt that these residents have achieved required competence and may therefore be less likely to evaluate them for initial milestones (Fig. 2B). Conversely, evaluations of less interested residents may have been more sustained. The
resulting in deliberate practice that constitutes the sequential targeted monitoring of skills growth, formative feedback, and goal-oriented learning and that is reflected in favorable performance outcomes. This holistic approach toward achievement of competence is an integral part of the training curriculum within our residency program.

The development of interest in the subject matter and other sources of learner motivation also need to be further examined. Preexisting interest may be based on an attraction to microsurgery and the clinical problems being addressed, or due to previous favorable experiences. Alternatively, interest or learner motivation may be generated or enhanced by early successes and favorable interactions with surgical teachers and patients. In this instance, trainees may approach their learning of mastoid surgery with enhanced motivation for a variety of reasons, of which early interest may be one of many. Mitchell et al. revealed various factors that predicted performance of trainees in health care settings. The authors grouped these factors into three categories: educational infrastructure, health-care resources, and individual physician characteristics. The individual physician characteristics constituted the learning style, the cognitive capacity, the self-learning habits, the self-learning expectations, the personality type, and the motivation to learn. Based on other reports, individual factors that may also influence surgical performance include: confidence, visual-spatial organization, stress tolerance, and psychomotor abilities. The current study did not attempt to identify the origins of interest or distinguish interest from other sources of self-motivated learning. A further study of these factors may identify a greater role of the environment, including interactions with educators in the development of intrinsic interest and motivation by learners.

Dissection of the facial recess is an essential skill set that gives surgical access to the mesotympanum to establish mastoid ventilation, to access middle ear lesions for removal, or to place middle ear or cochlear prostheses. The recess forms a triangular anatomical territory bordered by facial nerve medially, chorda tympani laterally, and fossa incudis superiorly. A comprehensive understanding of the spatial orientation of key anatomical landmarks, in addition to a superior ability in detecting changing anatomy and responding to it, are essential prerequisites to the successful and safe achievement of this procedure. Indeed, accomplishment of advanced milestones such as the facial recess dissection demands both clinical acumen and superior technical dexterity, and it ensures that the trainee is deemed competent and poised for safe and effective surgical performance after graduation.

We previously reported that the first milestone (initial bone cuts and defining tegmen was achieved after a mean of 6 ± 4.3 cases); the second milestone (sharpening posterior EAC to revealing short process of incus to thinning of posterior EAC cortex) after 9 ± 6.7 cases; and the third milestone, which includes performance of facial recess (removal of infralabyrinthine bone to identifying middle ear anatomy) was achieved at 13 ± 6.4 cases. Carr reported program directors' opinions regarding the number of key head and neck procedures required to deem a candidate competent. The program directors were of the opinion that trainees achieve competency for mastoidectomy at the PGY-4 level after performing approximately 8 to 10 procedures, which is within the order of magnitude of experience associated with competency in cortical mastoidectomy within our training program. Results of the present study show that during this junior rotation, performance of facial recess tasks strongly depend on individual interest in otology (OR = 10.38, P = 0.003) and may therefore present a modifiable opportunity to improve performance outcomes for overall mastoidectomy.

Several limitations of this study should be considered: 1) The study was based on a convenient sample. To address this, all data meeting the inclusion criteria was included. 2) There were confounders like aptitude, anxiety, stress, and fatigue, which are known to influence surgical performance. These factors were overlooked in this study. However, the studied setting and situation
did not differ from usual practice. 3) The retrospective evaluation of interest does not rule out the influence of performance on this variable. A prospective evaluation of interest, along with other motivational factors, will be needed to establish a cause-effect relationship between interest and performance. 4) An evaluator bias may exist during the course of evaluation, but this effect is likely to be small since each resident was evaluated by an average of three to four faculty members. Pooling evaluations over multiple time points and computing two-way random effects of intraclass reliability coefficients may have limited this bias. 5) This was a single institutional study with limited sample size and number of evaluations. An ideal study design would be to include a larger pool of residents that would look at surgical performance over an expanded time period and that could explore the role of various factors that potentially influence technical performance. Expanding this study across other head and neck surgical procedures is also warranted.

Evidence from the present study, nevertheless, supports preliminary findings that are relevant to building a model of surgical learning. Such a model will contribute to our understanding about the trajectories of technical skill development. In the wake of stringent accountability to society, growing demands of residency training, and the ACGME work-hour mandate, these findings and their further elucidation may assist in the development of more effective and efficient teaching strategies that incorporate the cultivation of intrinsic motivation.

CONCLUSION

This study supports an interaction between learning environments, personal attributes of the learner, and surgical performance. The effect of experience on growth in surgical performance and the acquisition of competence were greatest for the more demanding facial recess procedure than the cortical mastoidectomy. An affinity for otology and mastoid surgery was associated with a steeper learning curve. The use of simulation facilities by residents with more developed skill growth was a reflection of a successful remediation curriculum that effectively mitigates technical deficiencies in our trainees. Further exploration of learning trajectories of trainees may guide remediation and intervention strategies that may lead to faster achievement of surgical competency.

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BIBLIOGRAPHY