Characterizing the learning curve in phacoemulsification

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PURPOSE: To characterize how residents learn phacoemulsification and determine which steps of the procedure are most difficult to master.

SETTING: University of Colorado Hospital, Aurora, Colorado, USA.

DESIGN: Comparative case series.

METHODS: Cataract cases were divided into 3 levels of difficulty for comparison. Residents were given a grade for each step of the procedure by the attending surgeon. Main outcome measures were total case time and a proficiency grade. Independent variables were level of resident experience and degree of difficulty. Case times of attending cases were collected for comparison.

RESULTS: Nine residents were evaluated by 4 attending surgeons while performing 324 cases of phacoemulsification. Case times of 319 attending cases were used for comparison. The easiest-to-learn steps (highest scores versus level of experience) included intraocular lens insertion, ophthalmic viscosurgical device removal, hydrodissection, and nucleus sculpting. Wound integrity, nucleus disassembly and removal, cortex removal, and capsulorhexis had the lowest scores versus level of experience. Resident case times decreased significantly with experience, approaching average case times for attendings.

CONCLUSIONS: For this study, *competency* was defined as the ability of the resident to perform a case in a reasonable time without intervention or complication. Using this definition, competency was achieved when case experience exceeded 75 cataract surgeries.

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Cataract surgery is one of the most common surgical procedures performed in the United States. Although complications of surgery are infrequent, they can be devastating in terms of their economic cost and impact on patients.

Teaching cataract surgery while maintaining a high degree of patient safety remains an ongoing challenge. Most studies[1–5] have focused on outcomes as a measure of how residents compare with their more experienced colleagues in the performance of surgery. Although important, these studies do little in determining how many cases residents have to perform to become competent; nor are they informative in terms of which steps of the procedure are most difficult to learn. Randleman et al.[6] studied the resident learning curve with respect to phacoemulsification efficiency, visual outcomes, and occurrence of complications. However, theirs was a retrospective study that did not consider total case time and did not break down the procedure into individual steps.

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We attempted to address these issues by prospectively giving residents a performance grade on each step of cataract surgery while tracking intraoperative complications and case time. The goal was to determine which steps were the most difficult to learn and at what level of experience on average residents could competently perform cataract surgery. For this study, *competency* was defined as the ability of a resident to perform a case in a reasonable time without intervention or complication. Using attending surgeons for comparison, we examined differences between attending surgeons and residents to attempt to quantify competency. We also assigned a rank order of degree of difficulty for individual steps in cataract surgery.

MATERIALS AND METHODS

The Institutional Review Board, University of Colorado at Denver Health Science Center, approved this study. A study form was developed and reviewed by the attending surgeons for data collection (Figure 1). Data included the attending and resident performing the case; case times (incision to patch); resident's previous experience, measured as a 5-level ordinal variable based on number of cases performed; whether a block was used; degree of difficulty of the case assigned by the attending; and a proficiency score for each step of the procedure. The procedure was divided into the following steps: paracentesis and wound construction, capsulorhexis, hydrodissection, nucleus sculpting, nucleus disassembly and removal, cortex removal, intraocular lens (IOL) insertion, ophthalmic viscosurgical device removal, and wound integrity. Proficiency scores were based on whether each step could be performed successfully without assistance (3), with minimal assistance (2), or with extensive assistance by the attending (1). Mean item proficiency was used in the analyses to make scores comparable between cases in which a block was used and those in which no block was used. Degree of difficulty was based on whether the case was judged by the supervising attending surgeon to be straightforward (1) or to have 1 or more factors (eg, hard nucleus, lack of red reflex, small pupil, anatomic factors such as a deep-set eye, or behavioral factors) making the case more difficult. If at least 1 factor was present, a degree of difficulty of 2 was assigned. If 2 or more factors were present, a score of 3 was assigned. Case times and complications, such as capsule tear or vitreous loss, were noted for residents. For comparison, case times of surgeries completed without complication were collected for 4 attending surgeons of varying postgraduate experience.

Data were analyzed using SPSS software (version 17, SPSS, Inc.). Descriptive statistics were calculated for all variables. Several 2-way factorial analyses of variance (ANOVA) were estimated to examine whether performance (ie, time, complications, proficiency) differed for combinations of 2 independent variables (eg, use of a block, level of difficulty, previous experience). These analyses permit the examination of interactions between the independent variables: for instance, that some combination of use of a block and prior experience may result in different case times. Differences in time were compared using 2×2 factorial ANOVAs with block (block versus no block) and level of training (surgeons' versus residents'). To examine residents' performance as their experience increased, three 2×5 factorial ANOVAs were estimated with use of block and resident's previous experience (divided into 5 groups) as the independent variables and case time, number of complications, and mean item proficiency score each as the dependent variable in one analysis.

Two analyses were conducted to assess the difficulty level of the surgical steps involved. First, the percentage of residents reaching a given level of proficiency for each surgical step was determined. The effect of block and previous experience on ratings of degree of difficulty was estimated using ordinal logistic regression. A 0.05 criterion of statistical significance was used for all tests. To assess whether other characteristics of the surgery were associated with competency, a binary logistic regression analysis was implemented. Using the criterion of performing a case without complication or intervention within 1 standard deviation (SD) of attending time, performance was classified as competent or not and use of a block, degree of difficulty, and previous experience were entered simultaneously as predictors of competence.

RESULTS

The study evaluated 643 operations, 319 performed by attending surgeons (mean patient age 68.8 years) and 324 performed by residents (mean patient age 70.5 years). Resident cases were predominantly men (90.1%) because most were performed at an affiliated Veterans Administration Hospital. Attending cases were split equally between male and female patients. Demographic data were not available for 34 resident cases.

All resident cataract cases were performed using a standard technique with a clear corneal incision and predominantly divide-and-conquer method for nucleus removal. Some residents used a stop-and-chop technique as their experience increased. Table 1 shows the case characteristics for attending surgeons and residents. Serious complications (resident cases only) included capsule tear, vitreous loss, or both. There were no cases of dropped nucleus. Attending surgeons used a block significantly less often than residents ($t = 3.80$, $P \leq .001$) and completed cases in significantly less time than residents ($F_{(1,\ 632)} = 302.68$, $P < .001$). Despite these differences, a chi-square analysis indicated no significant differences in the degree of difficulty of cases between attending surgeons and residents.

The 2×5 factorial ANOVA used to determine the effects on time indicated significant main effects for block ($F_{(1,\ 317)} = 11.29$, $P < .001$) and for previous experience ($F_{(4,\ 312)} = 24.79$, $P < .001$); however, the interaction between use of a block and previous experience was not significant ($F_{(4,\ 324)} = 2.24$, $P < .065$). The main effect for block indicated that the residents' mean time of 41.63 minutes when no block was used was significantly lower than the mean time of 48.81 minutes when a block was used. Use of the Scheffe procedure to compare the marginal means for previous experience indicated that residents who had

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