How simulation can be used to ensure optimal training of future surgeons

Fumiya Abe-Nornes[1], Dean Golan[2], Hannah Strat[3], Simran Malik[4], Yin Yin[5]
Center for Healthcare Engineering and Patient Safety, University of Michigan, Ann Arbor, MI

Introduction

Recent studies conducted in the field of surgical competency suggest that the systems in place to train surgical residents may not adequately prepare residents to perform surgeries independently.

Figure 1. Pathway to becoming a doctor

Current Surgical Residency Programs:
- 5-7 years, depending on specialization
- Rotate through different subspecialties/services on a time basis
- Must fulfill minimum case requirements determined by ACGME

Current surgical training method fails to consider the following factors:
- Different residents become competent in procedures at different rates
- Surgical cases arrive in random patterns
- Competency is not a binary metric

Objective

Develop a time-variable, competency-based training model to analyze the effects of training duration, resident skill level, and stochastic procedure distribution on surgical residency competency outcomes

Methods

The model was built using Python with the packages NumPy and Matplotlib with a focus on generalizability.

The model inputs include the following:
- Normal distribution of Procedures Needed per procedure (**Figure 2-1**)
- Poisson distribution of Procedures Completed per procedure (**Figure 2-2**)
- Maximum percent transfer between procedures

The model generates the following:
- Learning curves for each resident and procedure (**Figure 2-3**)
- Transfer curves for each resident and ordered procedure pair (**Figure 2-4**)

The model outputs the following:
- Histogram of percent competency for each procedure
- Percent of residents that achieved competency for each procedure
- Likelihood of residents to achieve competency in multiple procedures

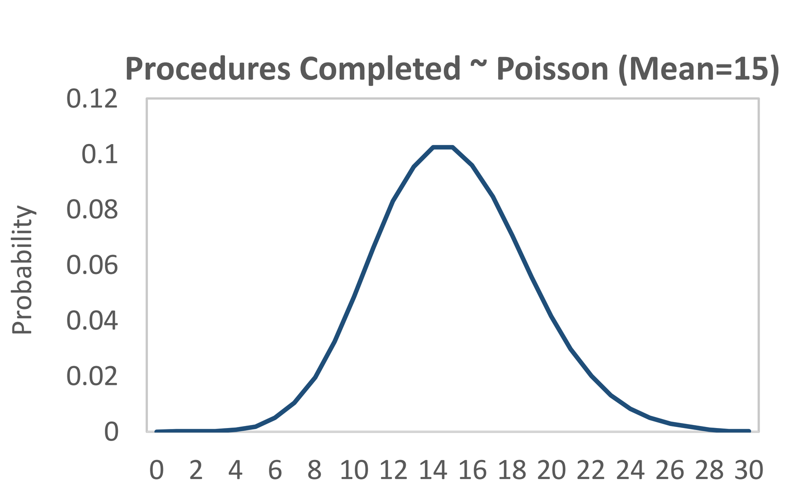

Figure 2-1. Number of Procedures Completed distribution when the average is 15

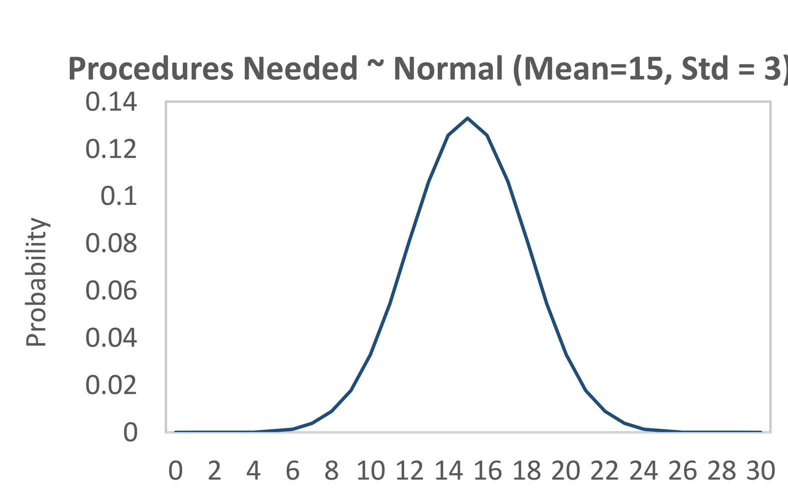

Figure 2-2. Number of Procedures Needed distribution when the average is 15

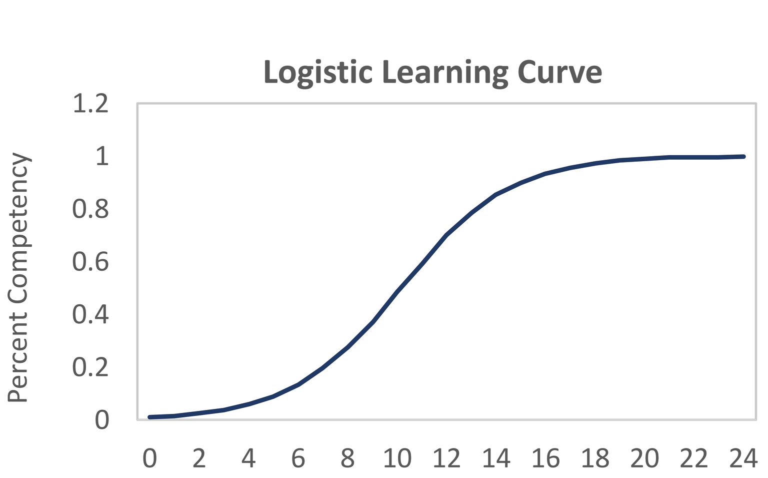

Figure 2-3. Number of Procedures completed in relation to the competency

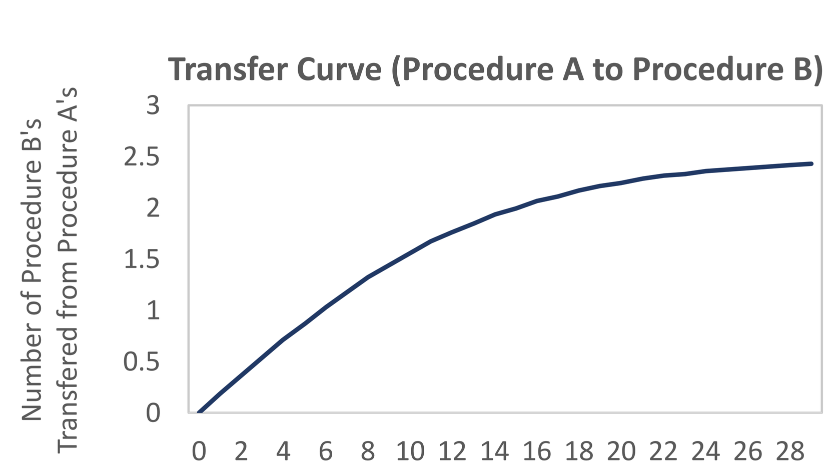

Figure 2-3. Transfer curve when 25 procedures of B needed and 10% of A can be used for B

Results and Discussion

Procedure	Average Procedures Needed	Average Procedures Completed	Maximum Percent of Procedures Completed Via Transfer
A	15	15	30%
B	20	15	30%
C	30	15	30%
D	30	15	45%

Table 1: Summary of inputs into the simulation representing a hypothetical scenario with four procedures. The standard deviation of the Procedures Needed was 3 for all Procedures A-D. This simulation modeled 10,000 residents.

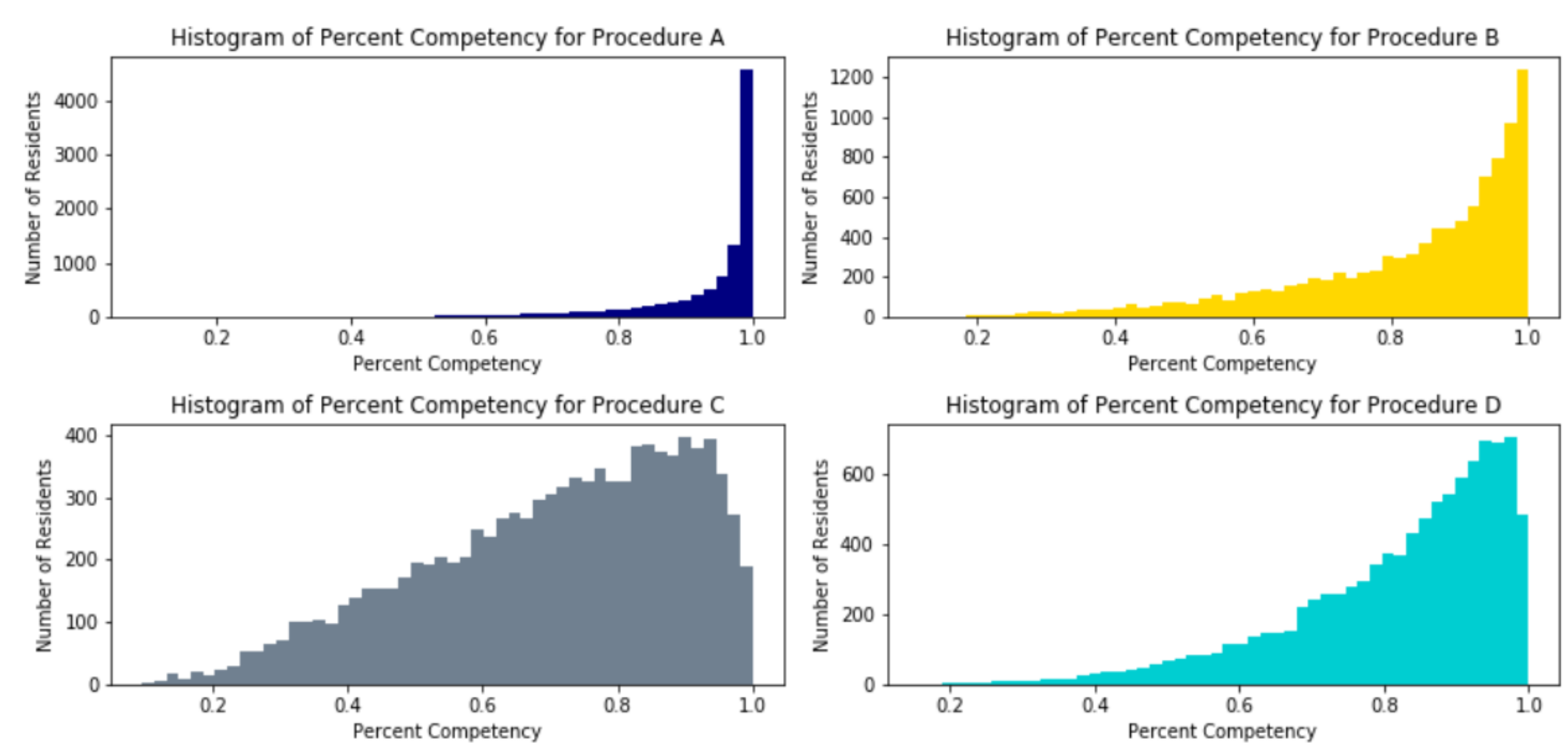

Figure 5: Histograms showing the frequencies of the percent competency achieved by 10,000 simulated residents for Procedures A-D. Inputs for each procedure are shown in Table 1 above.

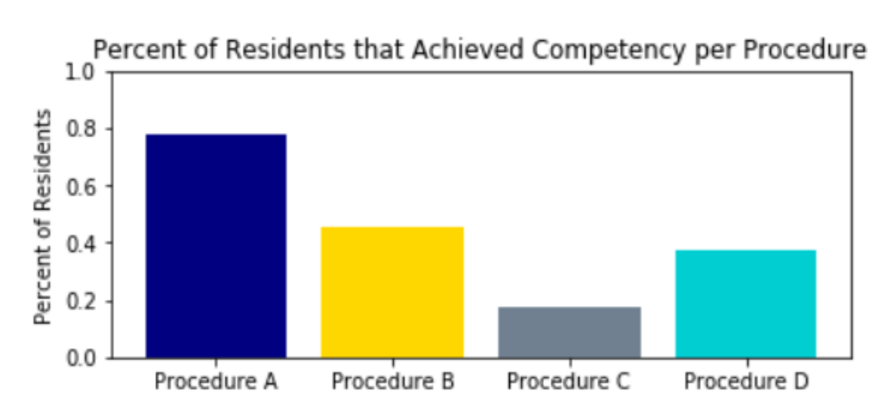

Figure 6: Percent of 10,000 simulated residents that achieved ≥ 90% competency in Procedures A-D

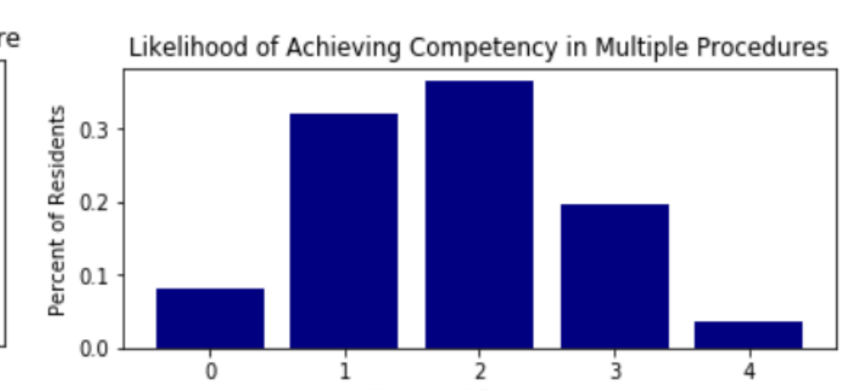

Figure 7: Percent of 10,000 residents that achieved ≥ 90% competency in 0, 1, 2, 3, and 4 procedures

Conclusions and Future Work

The competency of graduating surgical residents is determined by many different factors that are not reflected in current surgical training methods. By utilizing simulation tools, we can better predict the estimated outcomes of a resident training program based on the stochastic nature of procedure occurrences, resident learning curves, and non-binary competency.

In the future, more research on learning curves and transfer rates is necessary to understanding how completion of different cases affects a resident's overall competency in individual procedures. Once learning curves are established for each resident, we can more accurately model programs and outcomes, and determine how programs can be changed in order to improve outcomes.

Future work includes introducing a time variable into the simulation in order to model the amount of time required to achieve 100% competency among all residents. Additionally, an optimization model will be introduced in order to determine how to optimally assign procedures to residents to maximize total competencies.

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