Using Simulation to Predict the Likelihood that Surgical Residents Achieve Procedural Competency

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Outline

- Background
- Current Assumptions
- Version I: Randomness in Procedure Opportunity
- Version II: Randomness in Requirement to Achieve Competency
- Version III: Continuous Learning Curve
- Version IV: Multiple Procedures
- Version V: Transfer of Learning Between Procedures

BACKGROUND

Background

Road to Becoming a Doctor

1. Bachelor's Degree
2. Medical School (4 years)
3. Residency Program (3-5 years)
4. Fellowship to specialize (Optional)

Background

Surgical Residency Programs

- 3-5 years, depending on specialization (general surgery, emergency medicine, neurology, etc)
- Rotate through different subspecialties/services (typically monthly)
- Learning opportunities depend on monthly variations in training experiences

Background

Resident Certification Requirements

- American Board of Medical Specialties (ABMS) sets "educational and professional standards for certifying doctors in medical specialties."
- Include **minimum case requirements** determined by the Accreditation Council for Graduate Medical Education (ACGME)
- Residents are assumed to be competent in a procedure if they have met the minimum case requirements

Background

Resident Certification Requirements cont.

- Assumes every resident achieves competency after the same number of cases for a given procedure
- Assumes each time period provides the same number of cases for a given procedure
- Assumes competency is binary (i.e. a resident is either competent or not competent in a procedure)

Background

One standard for all…

- Certification requirements are standard for all residents
- Do not account for **differences in residents' learning rates**

Distinct residents may need a different number of opportunities to master individual procedures!

Background

One timeline for all…

- Each resident is assigned to the same amount of time on a particular service
- It is assumed that each time period will provide the same number of cases for a given procedure

Due to randomness in case occurrences, not all residents will have the same number of training opportunities in the same time period

Background

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Competency is viewed as **binary**…

- If you perform the minimum case number of a procedure, you are assumed to be fully competent in the procedure
- Otherwise, you do not achieve competency in the procedure

In reality, competency is not all-or-nothing!

Motivation

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- Given the randomness in training opportunities…
- Given the randomness in residents' learning rates for a procedure…
- Given a continuous (not binary) view of competency…

How can we accurately predict the training outcomes of a surgical residency program?

Outline

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Current Assumptions

Current Assumptions

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It is currently assumed that…

- Every resident needs the same number of cases to achieve competency in a procedure
- Every resident receives the same number of cases of a procedure (assuming each time period on service provides the same number of cases for all residents)
- Competency is binary

Current Assumptions

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Example 1

- ACGME requires each resident to perform 15 cases to achieve competency in Procedure A
- It is assumed that each service block will include 17 cases of Procedure A

100% of residents are assumed to achieve competency in the procedure!

Current Assumptions

Example 2

- ACGME requires each resident to perform 15 cases to achieve competency in Procedure A
- It is assumed each service block will include 12 cases of Procedure A

0% of residents are assumed to achieve competency in the procedure!

Outline

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- Current State
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VERSION 1: Randomness in Procedure Opportunity

Version 1

Now, let's remove the assumption that all residents have the same number of cases available to them during their training period.

Version 1

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Instead let's recognize that there is variability in the number of cases available to residents in each given block of time on service

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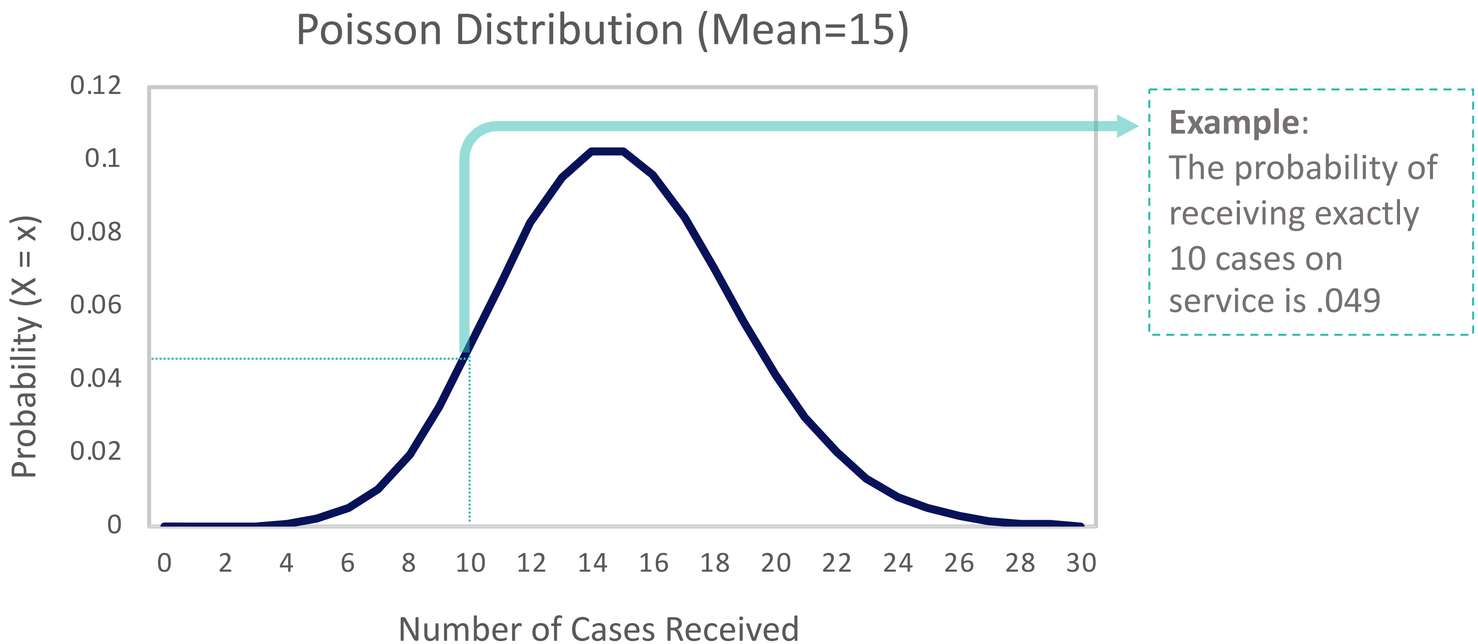
Suppose the number of cases available in each block on service is drawn from a Poisson distribution



This is the probability of receiving *x* cases during your time on service

Version 1

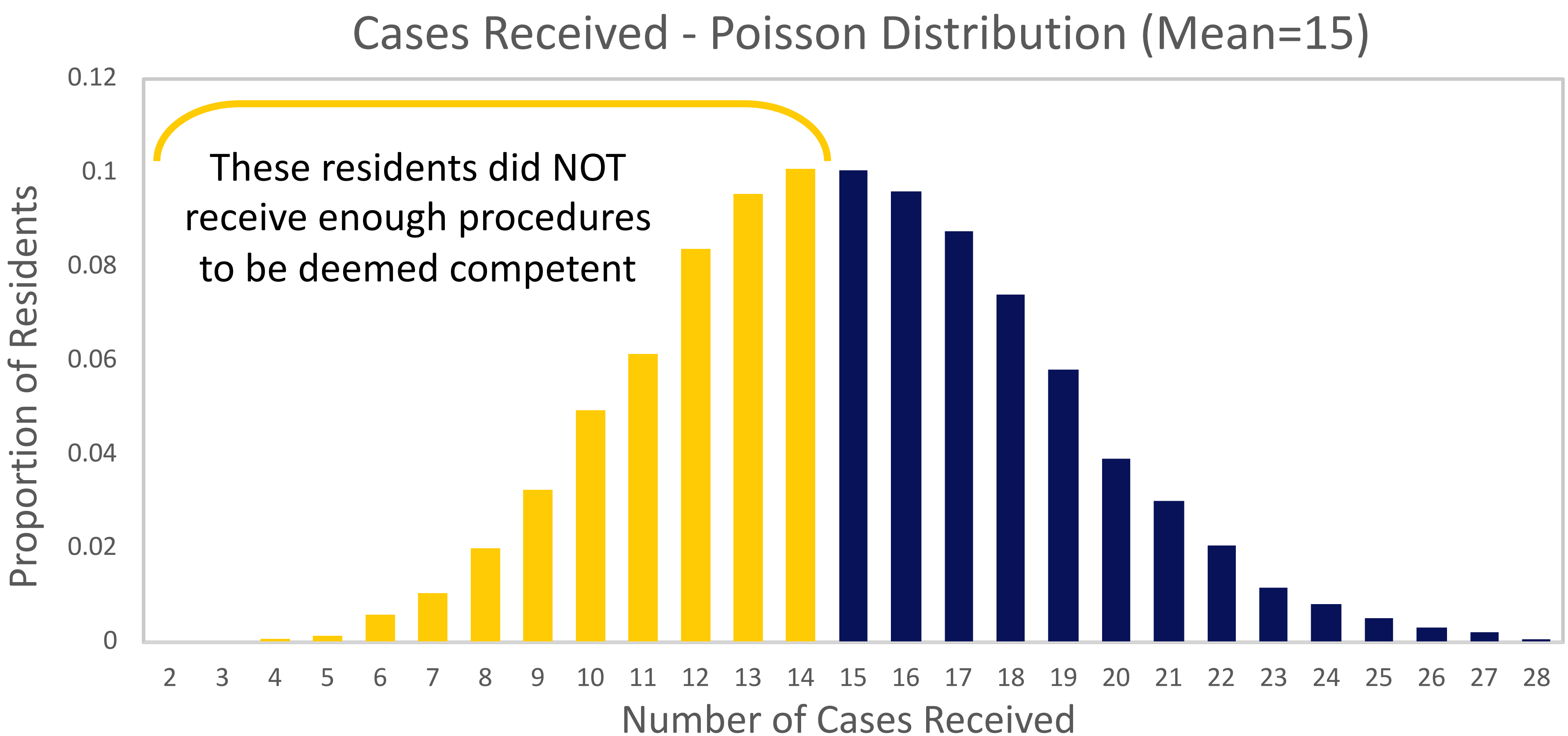
Example 3

- Each resident receives a **random number** of cases based on **Poisson** distribution with mean = 15
- All residents require 15 cases to become competent

Let's see what the results look like for a simulation of 10,000 residents who each require 15 cases:

Version I

46.2% of residents did NOT receive enough cases to achieve competency!



Outline

- Background
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VERSION II: Randomness in Requirement to Achieve Competency

Version II

Now, let's remove the assumption that every resident requires the same number of cases to achieve competency in that procedure

Version II

Instead, let's recognize that there is variability in the number of cases that each resident needs in order to achieve competency in a given procedure

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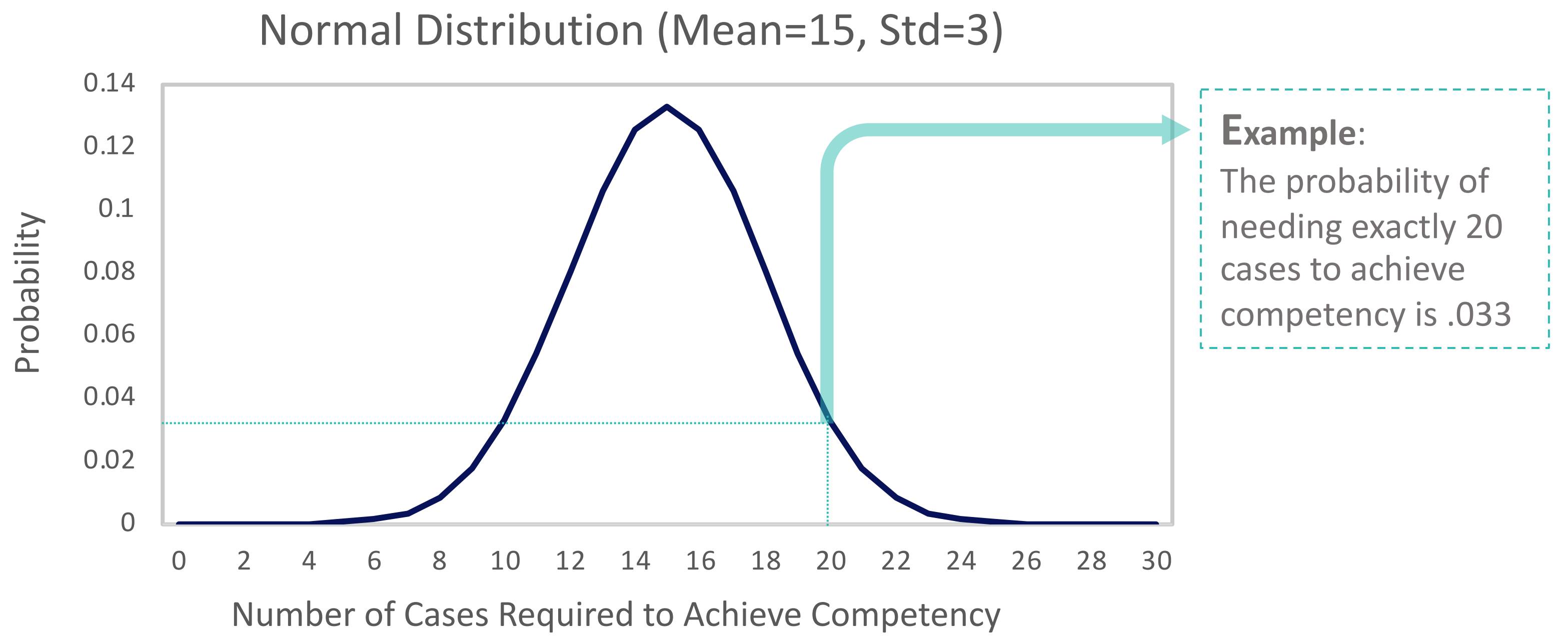
Suppose the number of cases required for a resident to achieve competency in drawn from a Normal Distribution



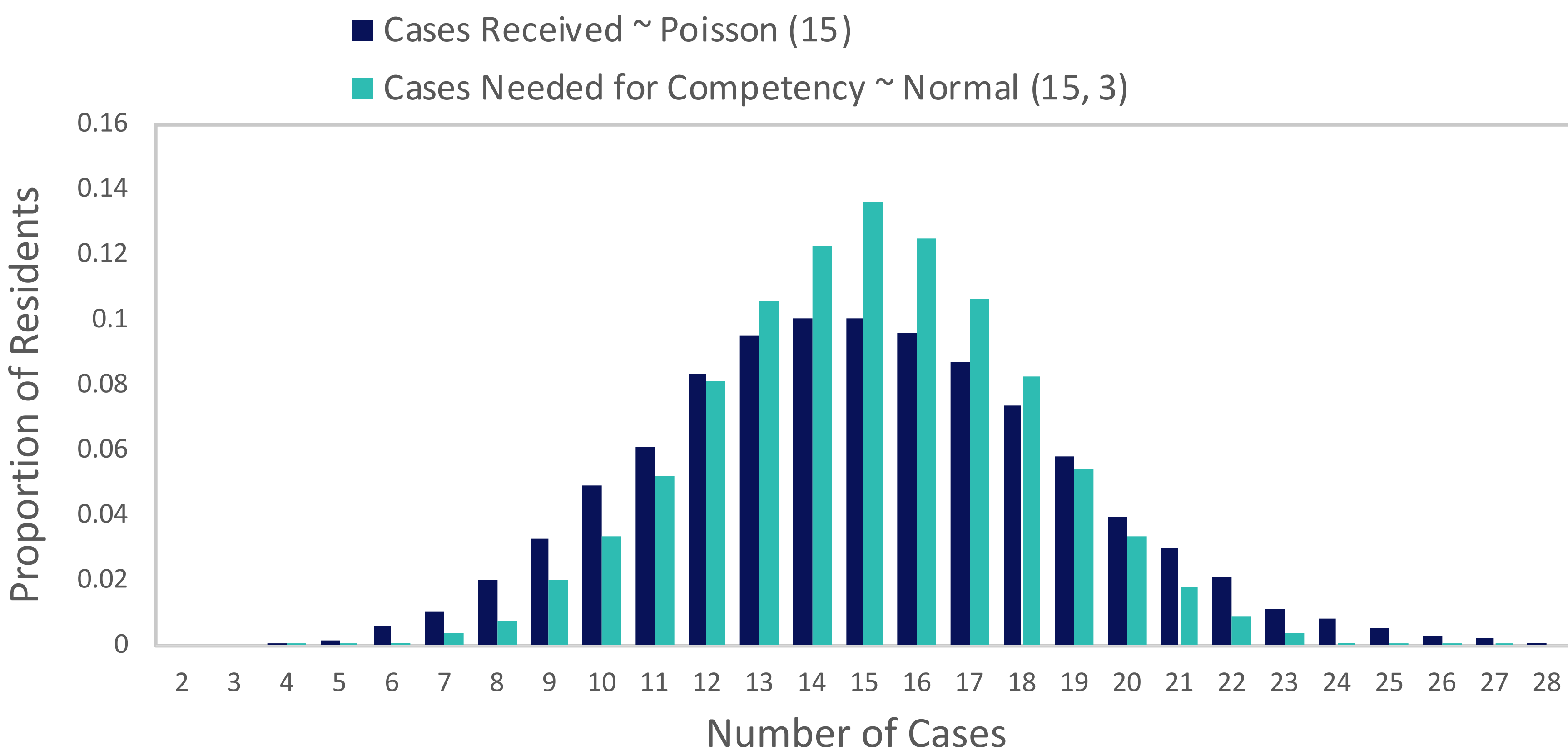
This is the probability of needing *x* number of cases to achieve competency in that procedure

Version II

Example 4

- Each resident receives a random number of cases based on Poisson distribution with mean = 15
- Each resident requires a **random number** of cases to become competent based on **Normal** distribution with mean = 15, std = 3

Comparison of Cases Received with Cases Needed



Outline

- Background
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- Version I: Randomness in Procedure Opportunity
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VERSION III: Continuous Learning Curve

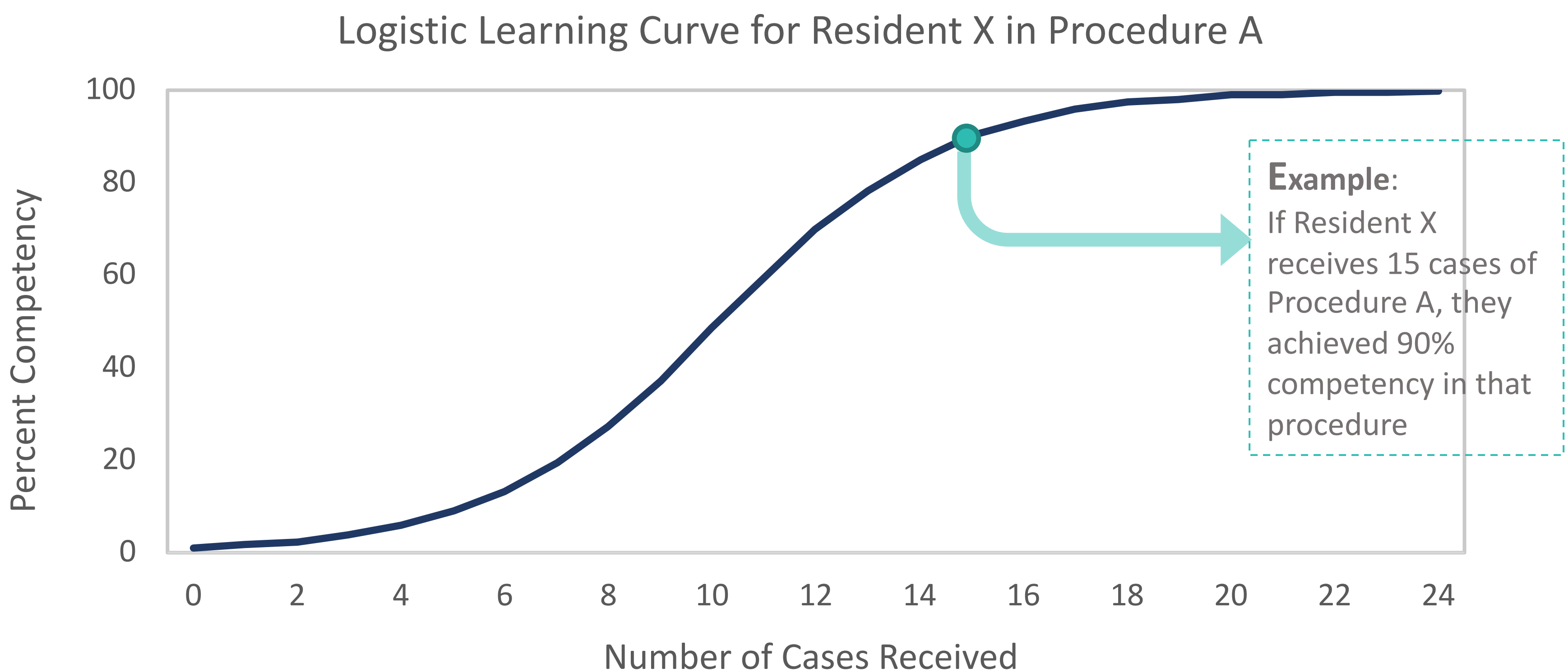
Version III

Now, let's remove the assumption that competency is binary

Version III

Instead, let's take on a **continuous** measure of competency

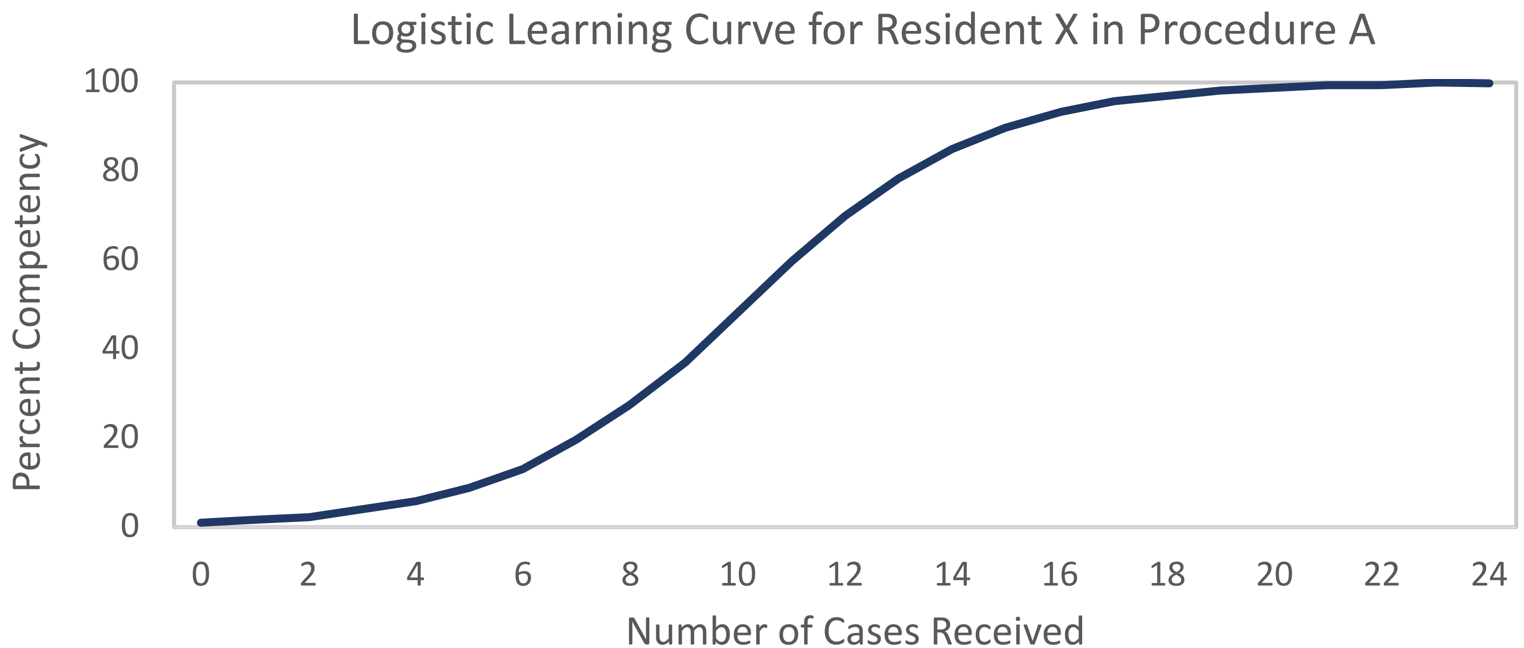
Suppose the learning curve for each resident and each procedure is drawn from a logistic function



Version III

Notice…

- Percent Competency always increases as Number of Cases Received increases
- Never achieve 100% Competency



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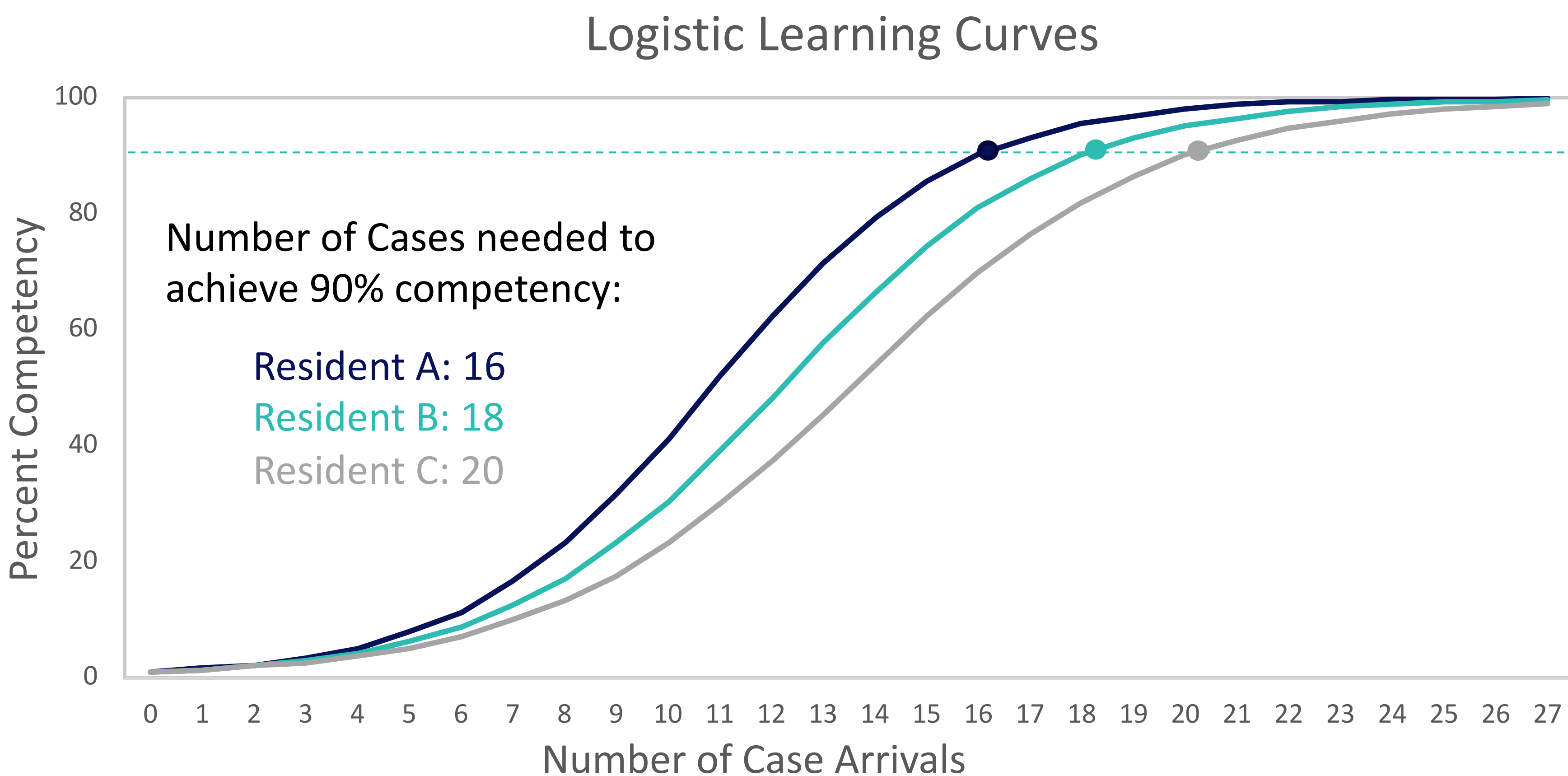
Generation of Logistic Learning Curve

Random number of cases needed to achieve competency → Random number of cases needed to achieve **90% competency**

- Residents assumed to have 1% competency when they have seen 0 cases for a given procedure

Example Continued…



Version III

Advantages of Continuous Learning Curve

- Resident competency is **not binary**
- Competency increases after each case opportunity
- 100% competency is never achieved

Version III

Version III Model Structure

- Simulation with 1000 residents
- One procedure
- Each resident receives a random number of cases (Poisson Distribution)
- Each resident requires random number of cases to achieve 90% competency (Normal distribution)
- Logistic learning curve drawn for each resident and each procedure

Version III

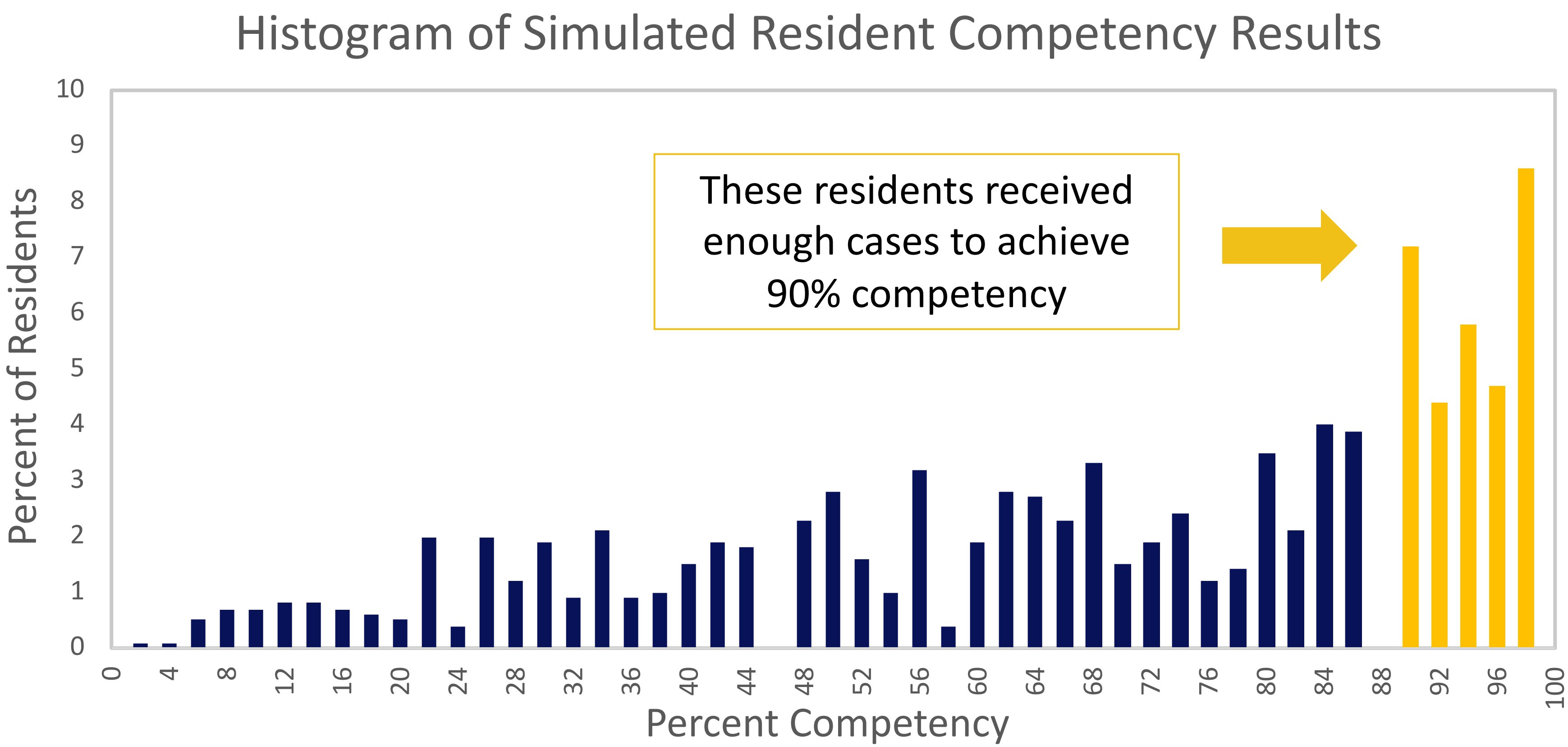
Version III Example

- Each resident receives a random number of cases
  ~ Poisson (mean = 15)
- Each resident requires random number of cases to become 90% competent

  ~ Normal (mean = 18, std = 3)
- Logistic learning curve drawn for each resident and each procedure

Version III

30.7% of residents achieved at least 90% competency in the procedure!



Outline

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VERSION IV: Multiple Procedures

Version IV

Now, let's consider that every resident is working to achieve competency in multiple procedures

Version IV

We will need to define the number of cases completed and number of cases required to achieve competency for each resident and each procedure

Version IV

Example 5

- Simulation with 1000 residents
- 5 procedures
- Each resident receives random number of cases for each procedure
- Each resident requires random number of cases to achieve competency for each procedure
- Logistic learning curve for each resident and each procedure

Version IV

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Example 5 continued…

Mean number of cases received ~ Poisson (mean)

Proc A	Proc B	Proc C	Proc D	Proc E
15	30	40	25	20

Mean number of cases to become 90% competent ~ Normal (mean, std = 3)

Proc A	Proc B	Proc C	Proc D	Proc E
18	32	40	30	18

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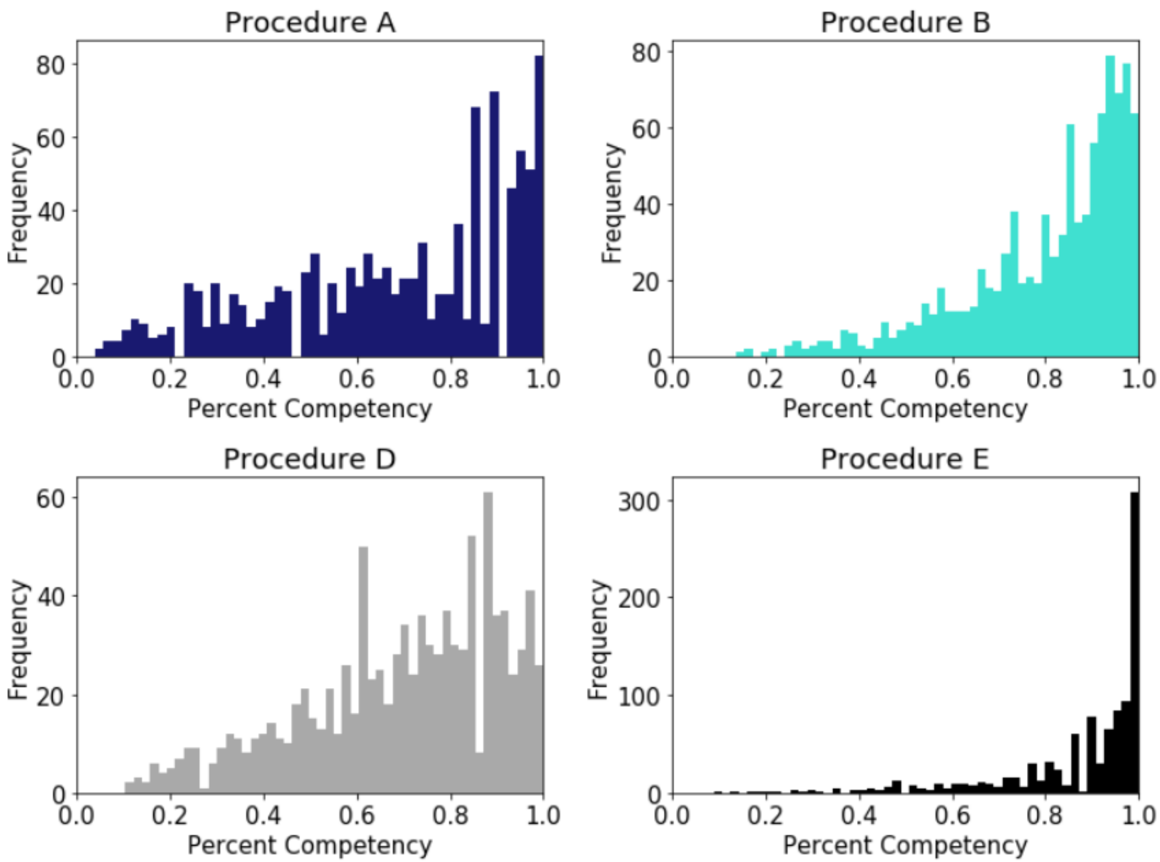
Histograms of Simulated Resident Competency Results for Each Procedure



Notice how Procedure E is the only instance where the average cases received is higher than the average cases needed

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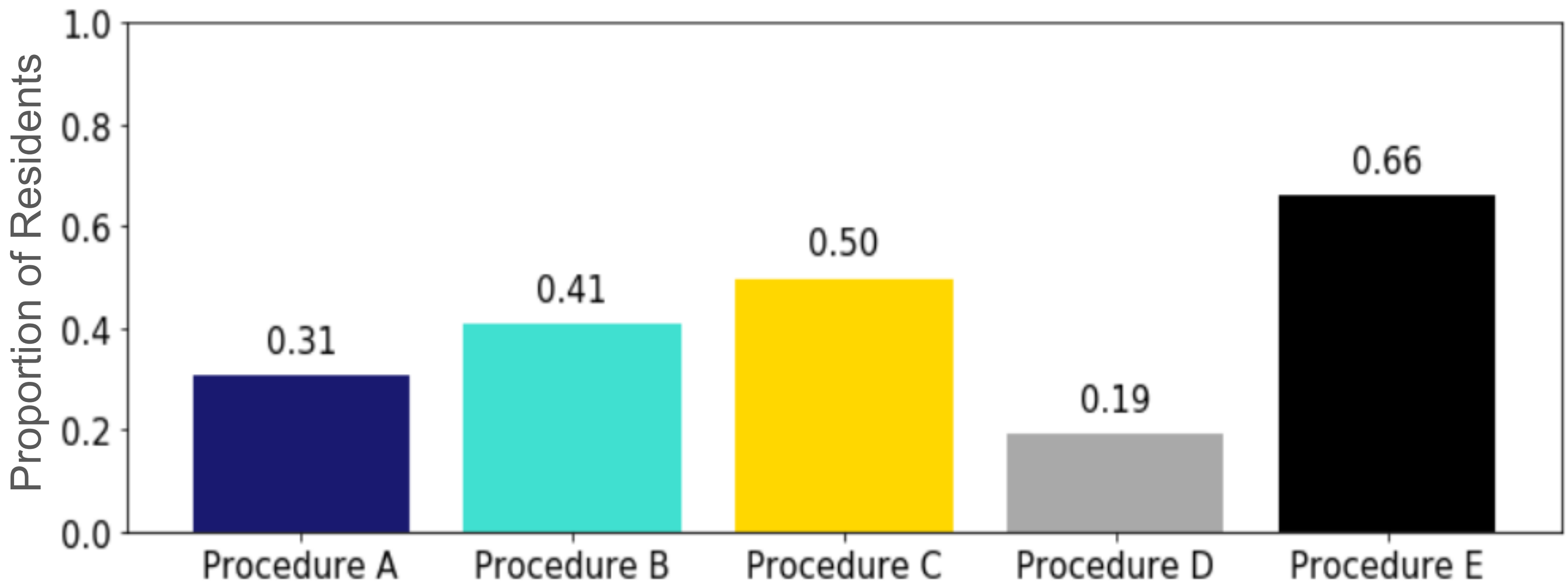
Fraction of Residents that Achieve at least 90% Competency in Each Procedure



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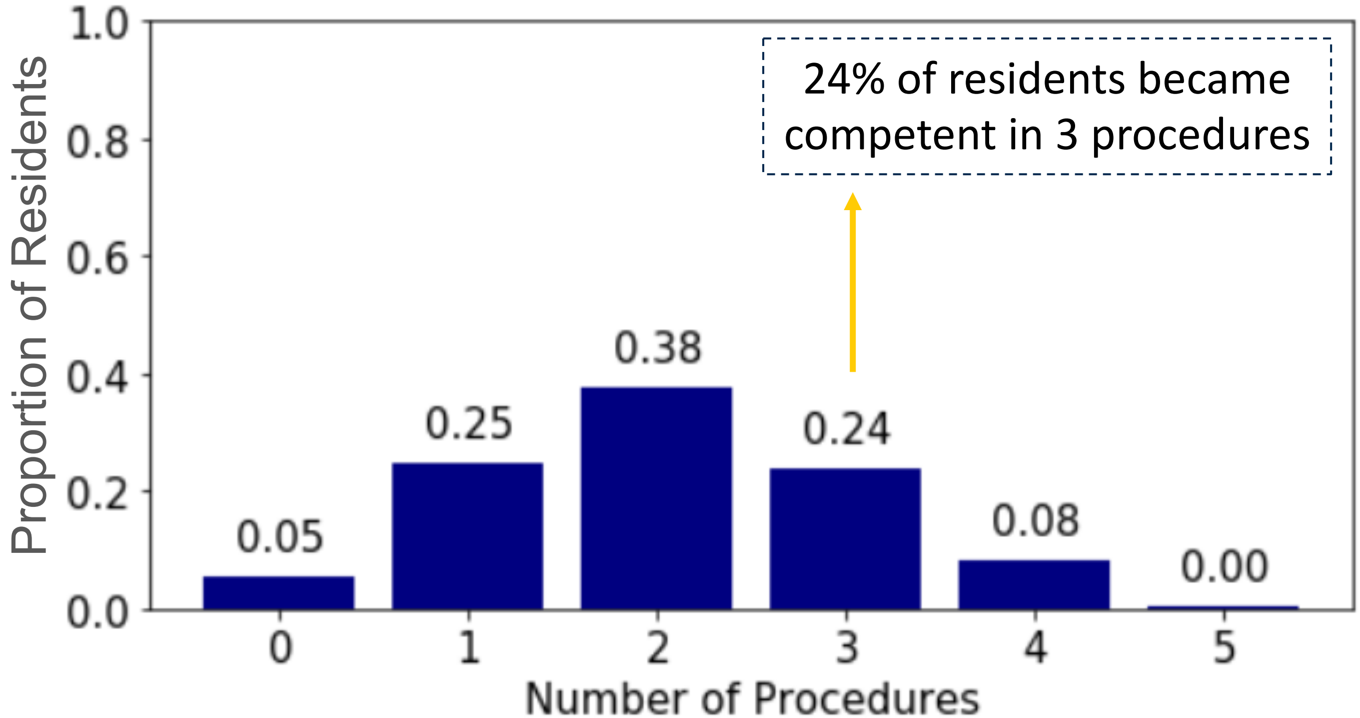
Percent of Residents that Achieve at least 90% Competency in Multiple Procedures



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VERSION V: Transfer of Learning between Procedures

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Transfer of Learning Between Procedures

- Residents gain **transferable skills** when working on procedures
- Skills learned through Procedure A may assist residents in performing Procedure B
- Transfer of skills occurs with **diminishing returns**

Performing Procedure A provides transferrable skills to Procedure B → Decreases number of cases *needed* to achieve competency in Procedure B → Increases likelihood that resident achieves competency in Procedure B

Version V

Representation in our model

- Logistic curve represents transfer of learning between two procedures
- Case completions of Procedure A transfer to case completions of Procedure B
- Generated for each resident and each directional pair of procedures

Transfer from A → B may be different from B → A

Version V

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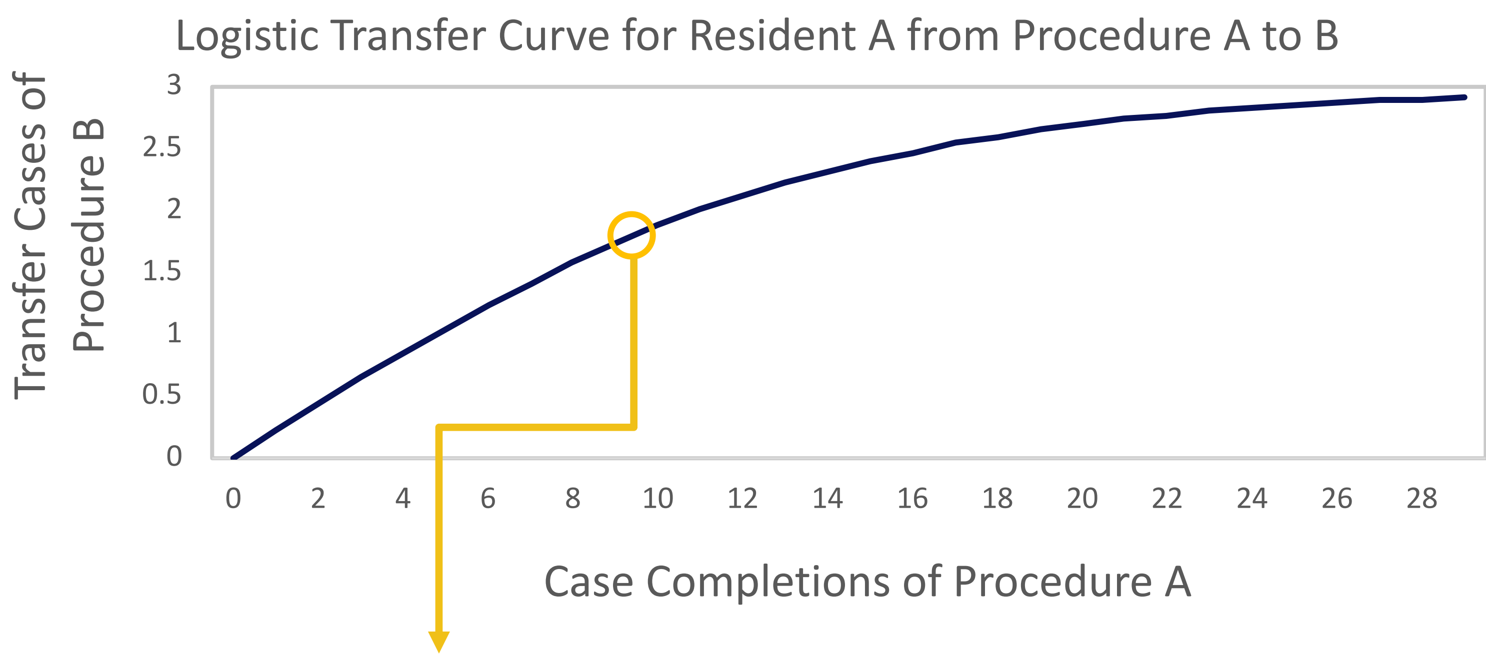
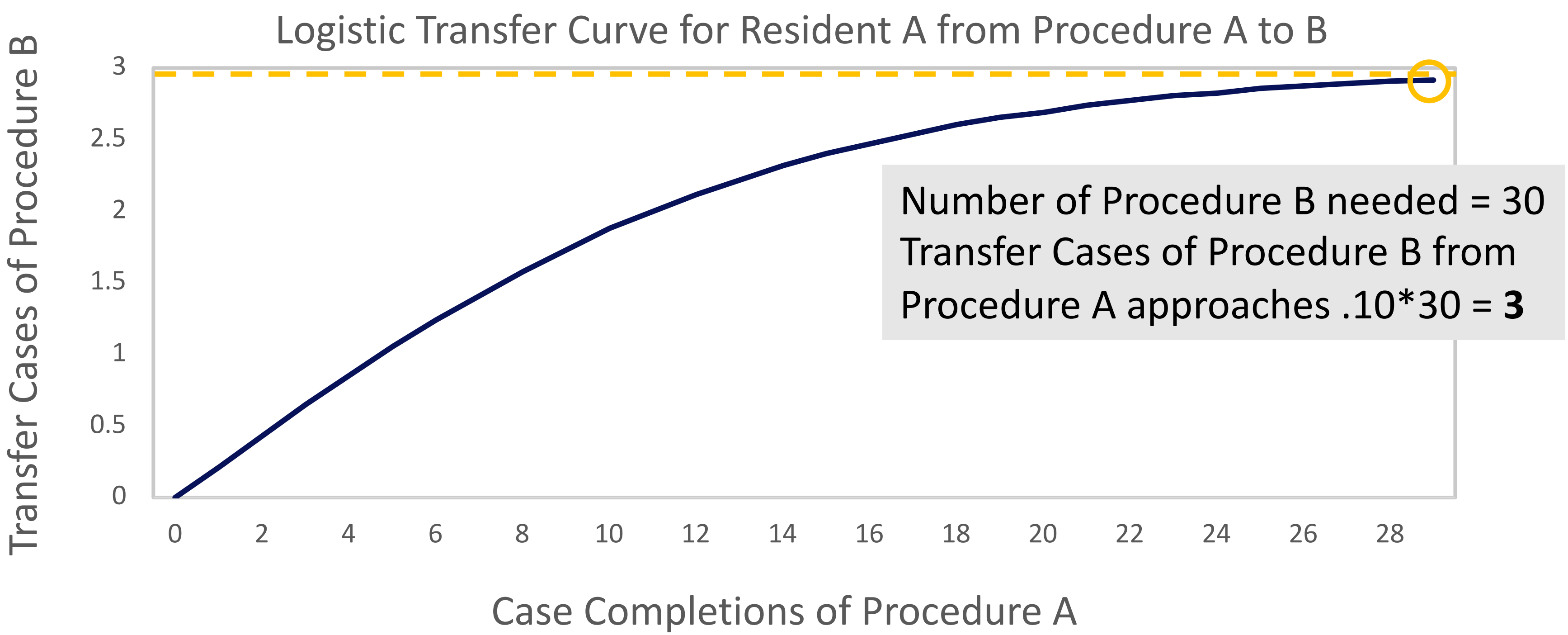
Generation of Logistic Learning Transfer Curve



10 case completions of Procedure A → 2 transfer cases to Procedure B

Version V

As case completions of Procedure A approach infinity, transfer cases to Procedure B approach x% (10% in this case) of the number of Procedure B needed for each resident to achieve competency



Version V

Logistic Learning Transfer Curve is generated for each resident and each directional pair of procedures using:

- The maximum percent of transfer for each directional pair of procedures
- The number of cases each resident needs to achieve competency in each procedure

Version V

Version V Model Structure

- Simulation with 1000 residents, 5 procedures
- Each resident receives random number of cases for each procedure (Poisson Distribution)
- Each resident requires random number of cases to achieve 90% competency for each procedure (Normal Distribution)
- Logistic learning curve for each resident and each procedure
- Logistic learning transfer curve for each resident and each directional pair of procedures
- Residents' competency assessed on case arrivals + transfer arrivals

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Example 6

- Mean number of case arrivals ~ Poisson(mean)

Proc A	Proc B	Proc C	Proc D	Proc E
15	30	40	25	20

- Mean number of cases to become 90% competent ~ Normal (mean, std = 3)

Proc A	Proc B	Proc C	Proc D	Proc E
18	32	40	30	18

Version V

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Example 6 continued

- Maximum percent of transfer for each directional pair of procedures

x%	Proc A	Proc B	Proc C	Proc D	Proc E
Proc A	0	.12	.08	.08	.08
Proc B	.04	0	.04	.04	.04
Proc C	.05	.08	0	.07	.07
Proc D	.05	.08	.07	0	.07
Proc E	.05	.08	.07	.07	0

Maximum percent of transfer from Procedure E to Procedure B = 8%

a.k.a.

Up to 8% of the number of Procedure B that a resident needs to achieve competency can arrive via transfer from Procedure E

Version V

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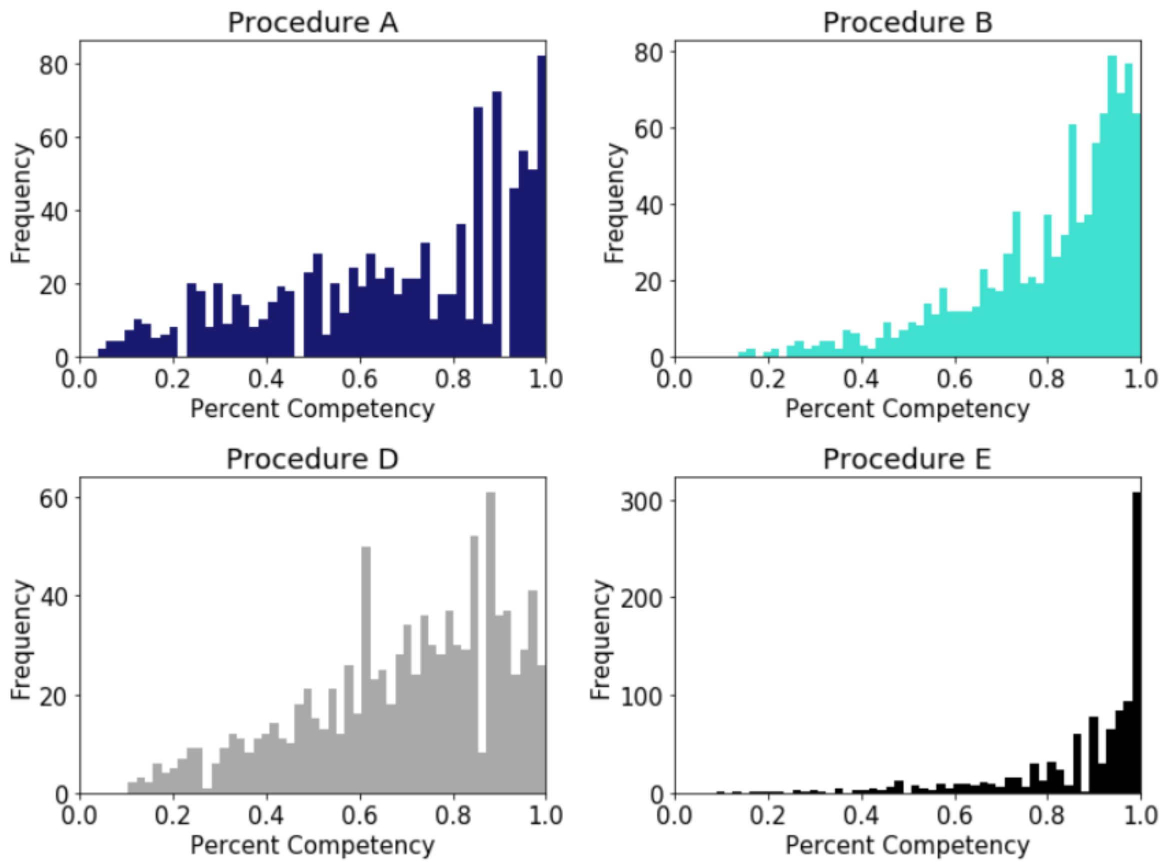
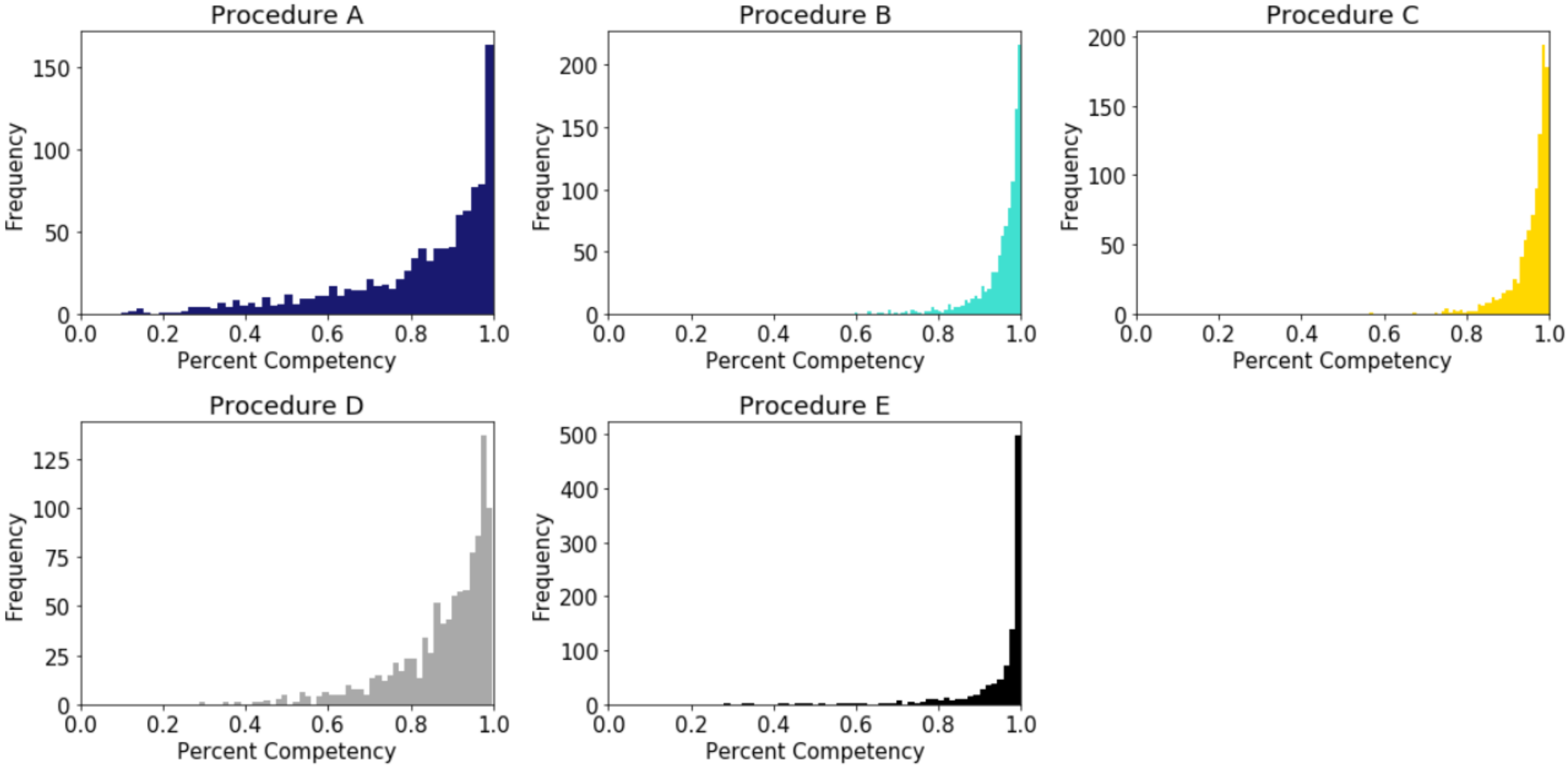
Histograms of Simulated Resident Competency Results for Each Procedure – **Without Transfer**



Version V

Histograms of Simulated Resident Competency Results for Each Procedure – **With Transfer**



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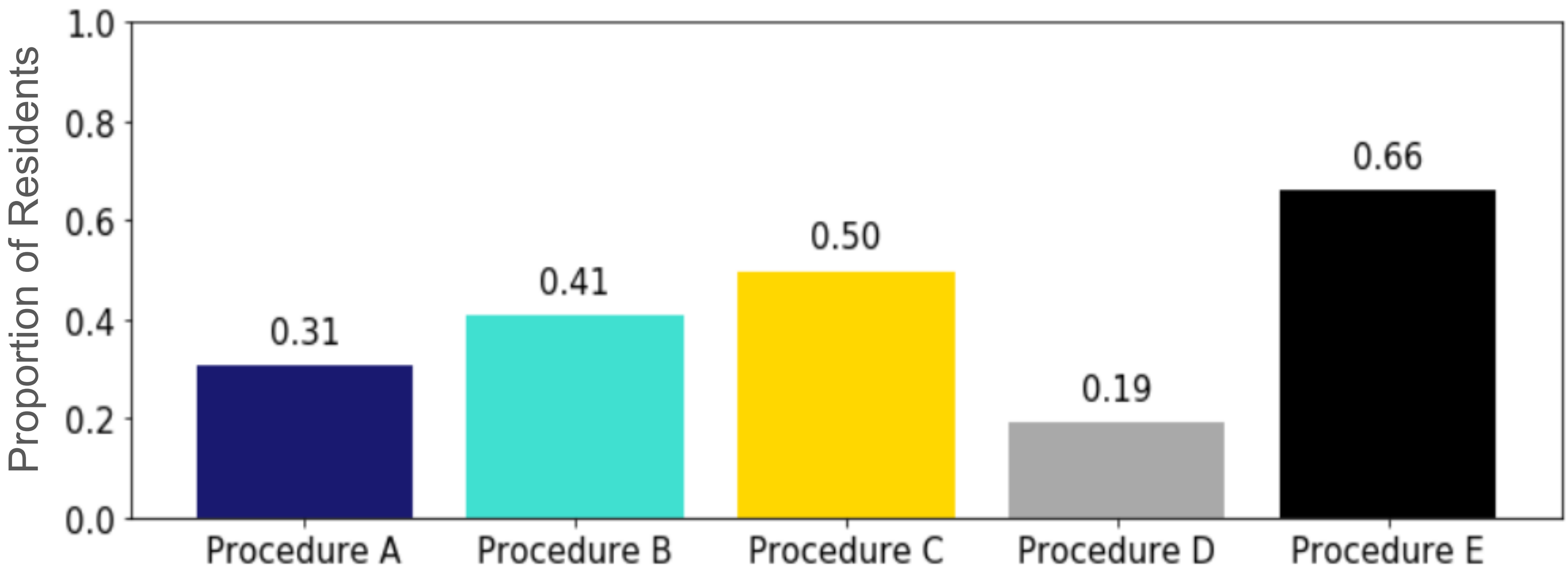
Percent of Residents that Achieve Competency for Each Procedure – **Without Transfer**



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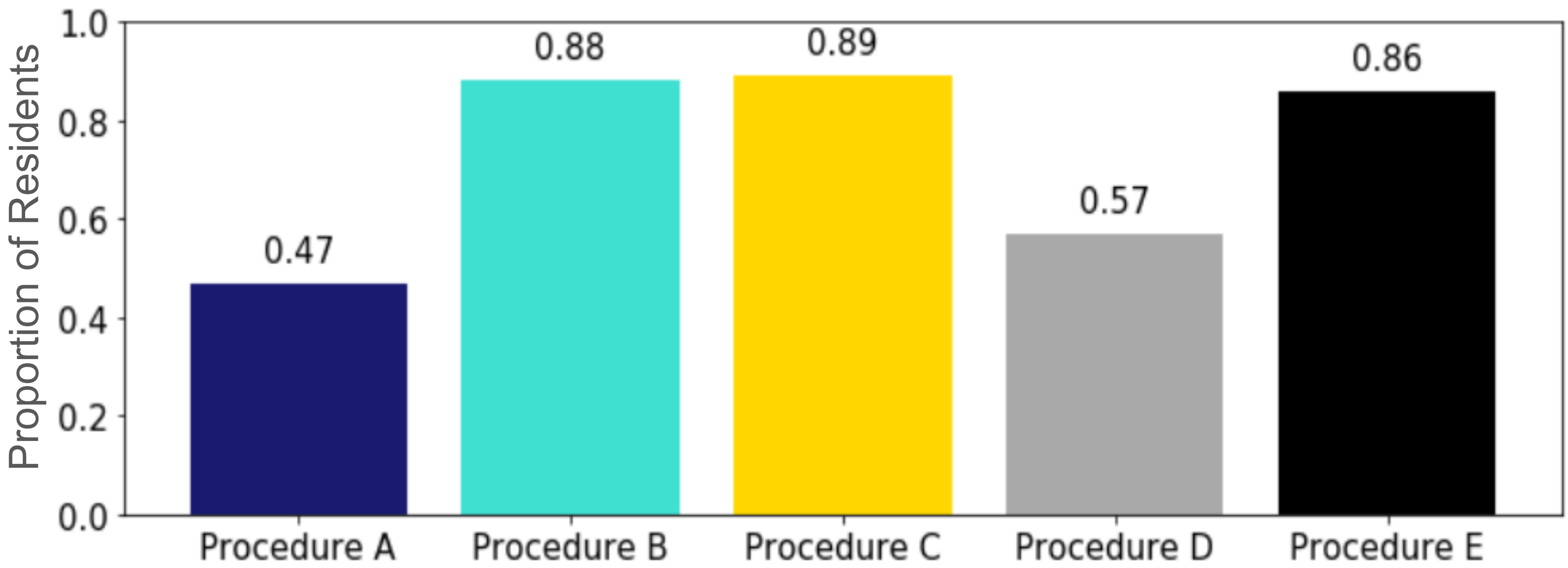
Percent of Residents that Achieve Competency for Each Procedure – **With Transfer**



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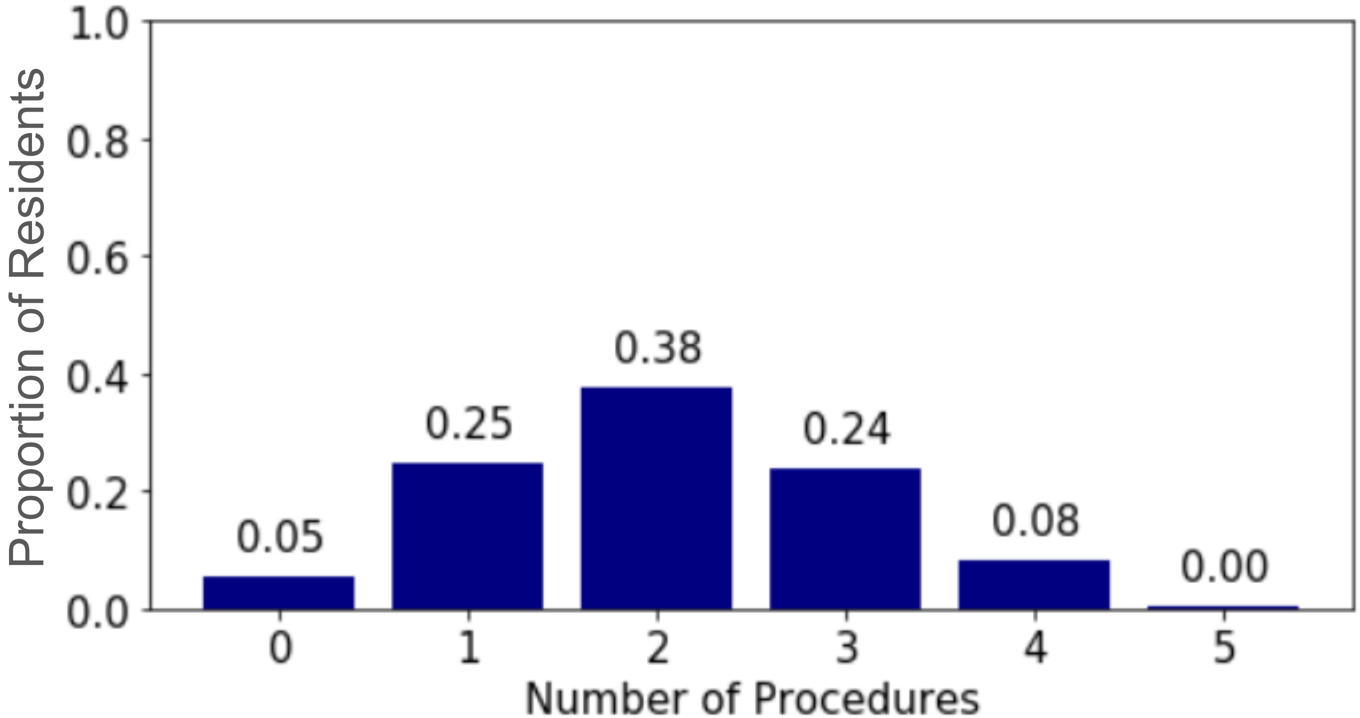
Percent of Residents that Achieve Competency in Multiple Procedures – **Without Transfer**



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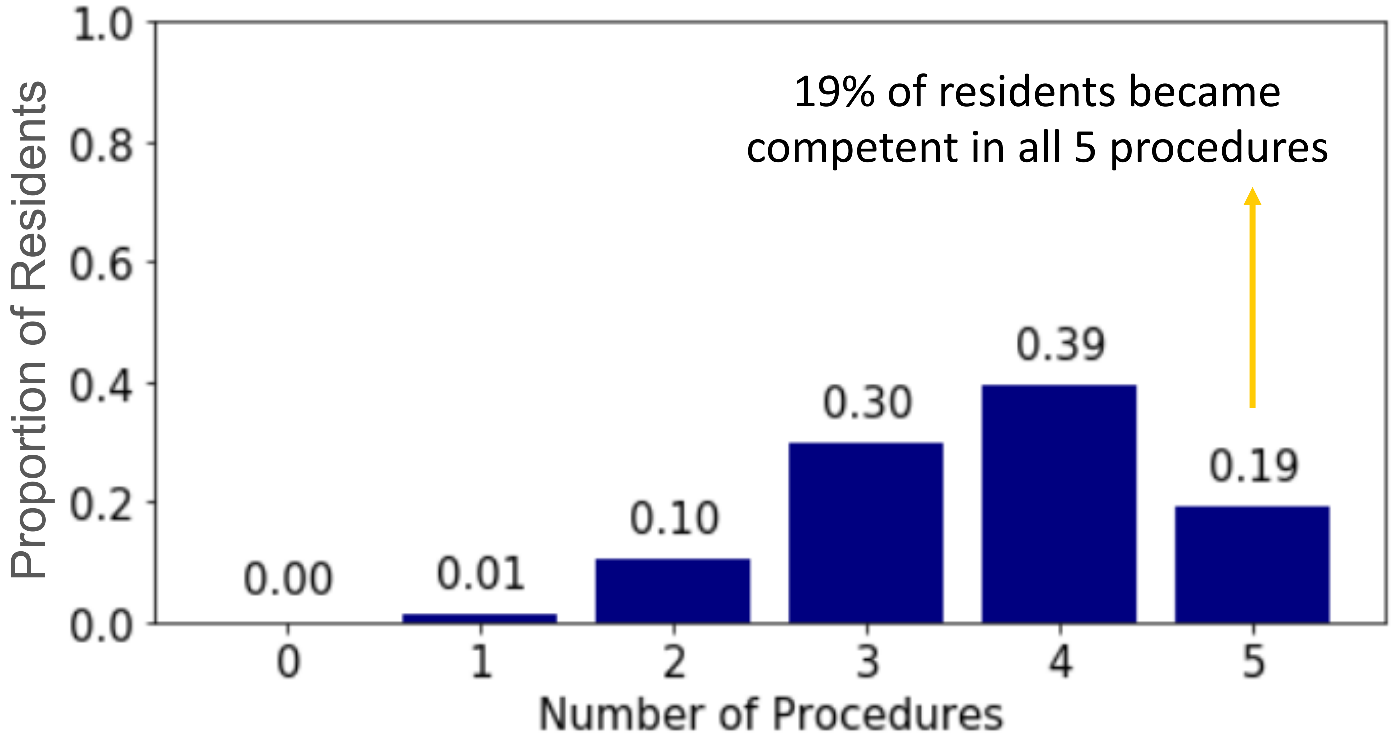
Percent of Residents that Achieve Competency in Multiple Procedures – **With Transfer**



What's Next?

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Short term

- Our model currently estimates the answer to the question:
  – What percent of residents will achieve competency in a given procedure, when provided a set time frame?
- We next want to answer the question:
  – How much time will it take for a certain percent of residents to achieve competency in all of their required procedures?

What's Next?

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Long term

- Work closely with clinical collaborators and their research to develop a time-based surgical residency program
  - Need to further refine transfer parameters among procedures
- Utilize optimization techniques to distribute cases among residents in a way that achieves a desired distribution of competencies across residents