DEPARTMENT OF OTOLARYNGOLOGY - HEAD AND NECK SURGERY

Applying Machine Learning to Manage and Assess Dizzy Patients

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Disclosures

- Commercial support
  - Inno.health (licensing royalty for AI platform)
  - Starkey Technologies
- Grant support
  - U.S. National Institute of Health

Process to Development

The Problem

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The Problem

- Dizziness is the third most common complaint among primary care patients, yet its causes are notoriously difficult to diagnose accurately for many reasons.
- It is a non-specific symptom that crosses multiple medical specialties.
- Severity and handicap correlate poorly with results from laboratory tests (Hallam and Stephens, 1985; Jacobson and Newman, 1990; Yardley et al, 1992; Jacob et al, 1996).

(Kroenke & Mangelsdorff 1989)

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The Problem

- It is estimated that up to 69 million Americans have experienced symptoms of a vestibular disorder
- Approximately 10.4 million have reported chronic dizziness or imbalance.
- There is a significant shortage in the number of clinicians who can effectively manage and treat patients who present with dizziness/unsteadiness/vertigo.
- The cumulative result is poor patient outcomes and wasted healthcare resources. How do we begin to address this?

Concept Generation

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Evaluation of Existing Solutions

- Previous intelligent algorithms (never adopted)
- Paper and Pencil (ipad questionnaires)
- Electronic algorithms (not intelligent)

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Concept

- Develop and implement an interactive learning algorithm that will triage patients with different forms of dizziness to the most appropriate provider in a healthcare system
- Develop a system that track outcomes and learn
- Use data collected over time from millions of patients to inform triage and treatment recommendations
- Three driving factors to create value (cost/improvement) – how to get decision makers to adopt the new system
  - Fastest time to diagnosis
  - Least cost
  - Best outcomes

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Concept

- Three driving factors to create value (cost/improvement) – how to get decision makers to adopt the new system
  - –Fastest time to diagnosis
  - –Least cost
  - –Best outcomes

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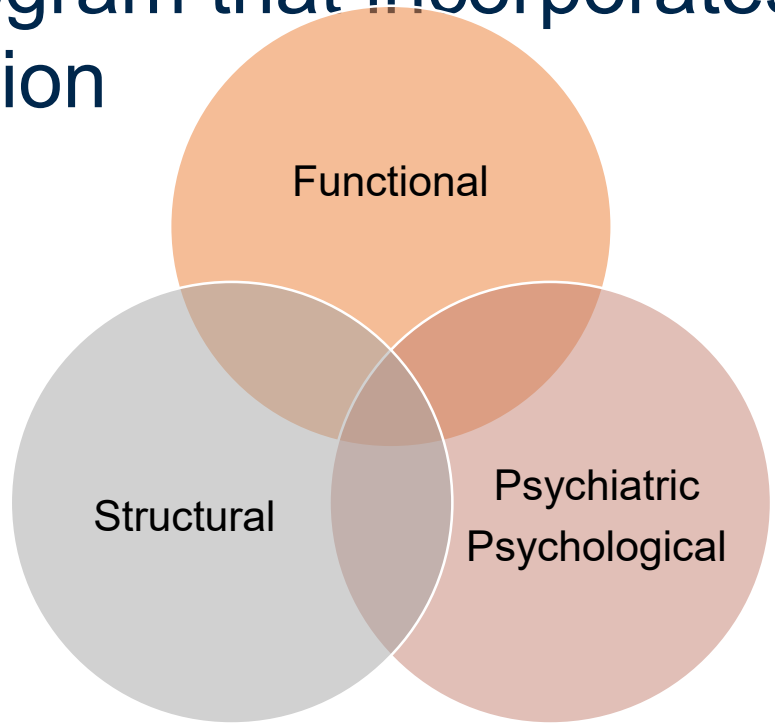
Concept

- Mayo Clinic has a fully integrated Dizziness & Balance Disorders Program that incorporates multi-specialty integration
- Core specialists
  - Otolaryngology
  - Neurology
  - Psychiatry/Psychology
  - Audiology
  - Physical Therapy



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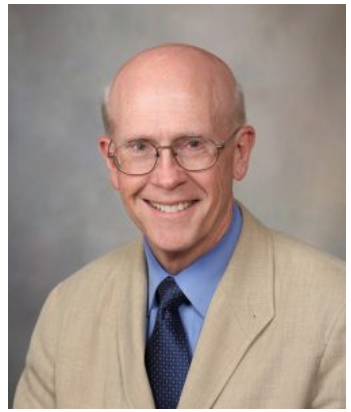
Clinical Team

- Jeff Staab, MD
- Neil Shepard, PhD
- Scott Eggers, MD
- Devin McCaslin, PhD



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Symptom Questionnaire
Audiometry
Vestibular Lab Testing

- Otolaryngology
  - Medical Otolaryngology
  - Neurotology
- Psychiatry/Psychology
  - Vestibular Psychiatry
  - General Psychiatry
- Physcial Therapy
- Neurology
  - Otoneurology
  - Headache Neurology
  - General Neurology

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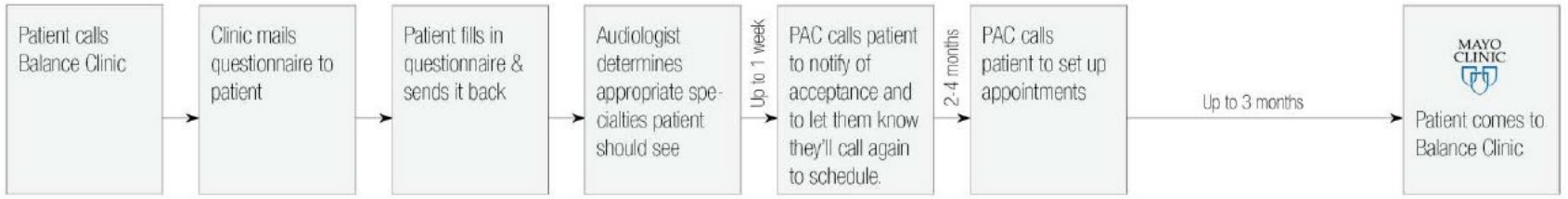
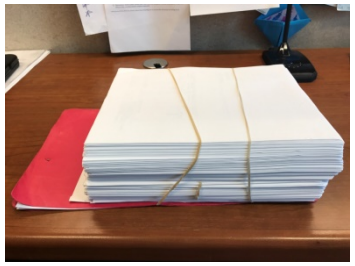
Concept

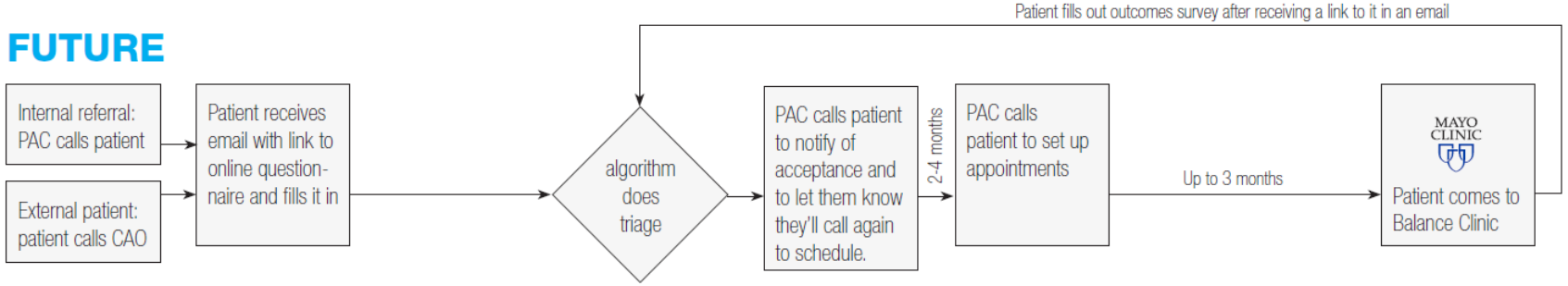
PAST



CURRENT



FUTURE



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Concept Generation

- Development of the Model
  - Getting the team together
    - Model creators and data scientists
    - Schedulers
    - Clinicians
    - Patients
- Modules
  - Prediction of itineraries (schedules)
  - Prediction of most appropriate diagnostic tests
  - Prediction of most likely source of the patient's complaints
  - Generate standardized reports
  - Be able to conform to different clini

MAYO CLINIC ROBERT D. AND PATRICIA E. KERN
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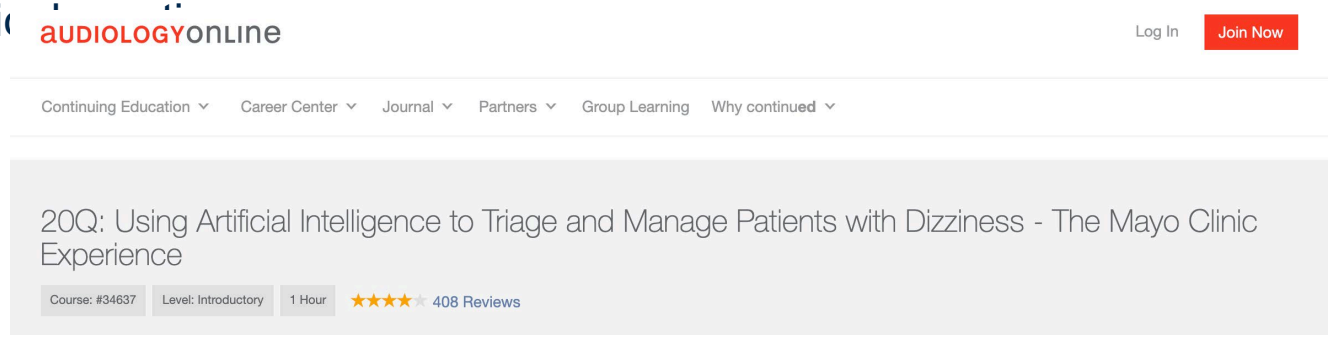

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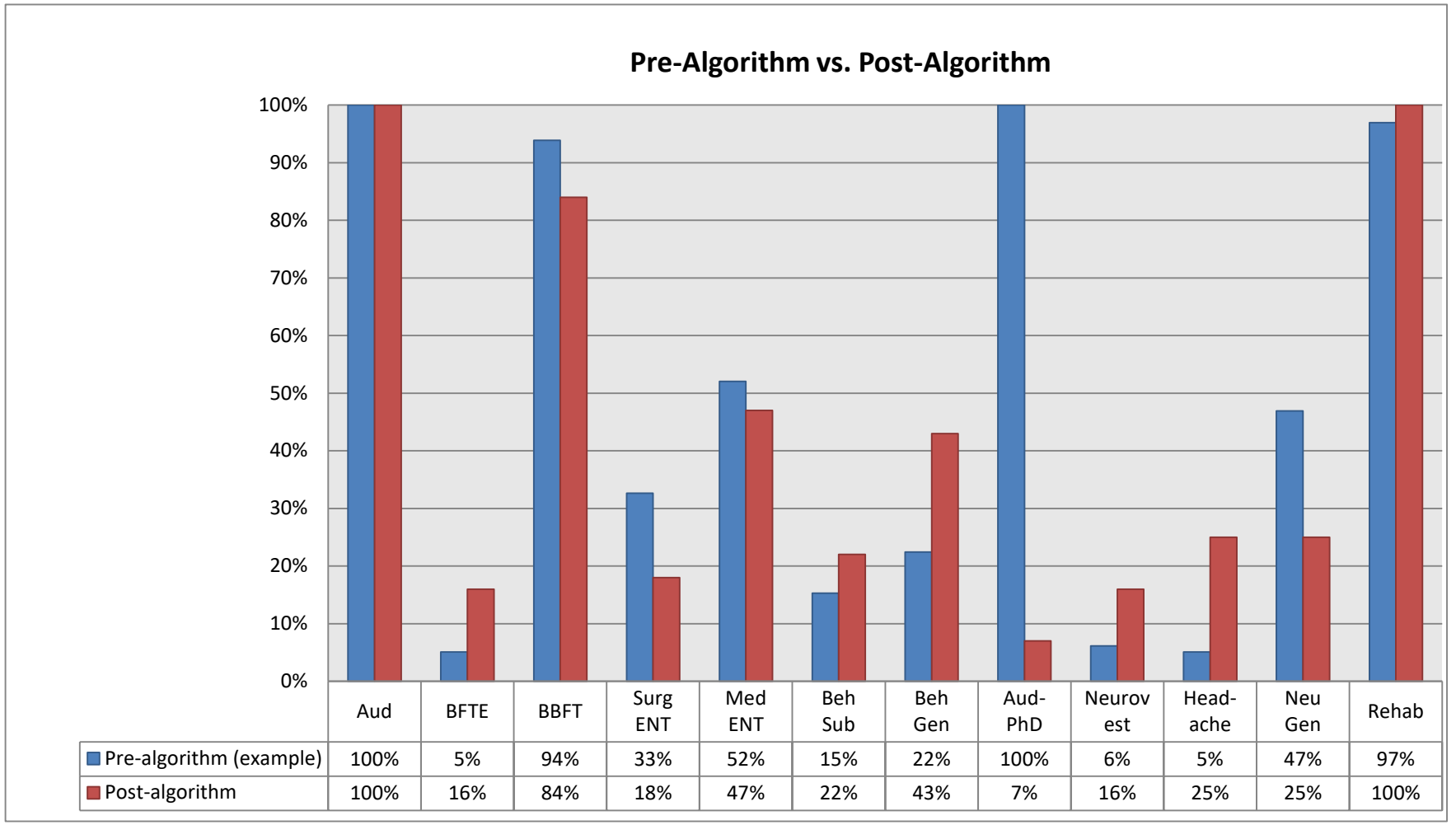
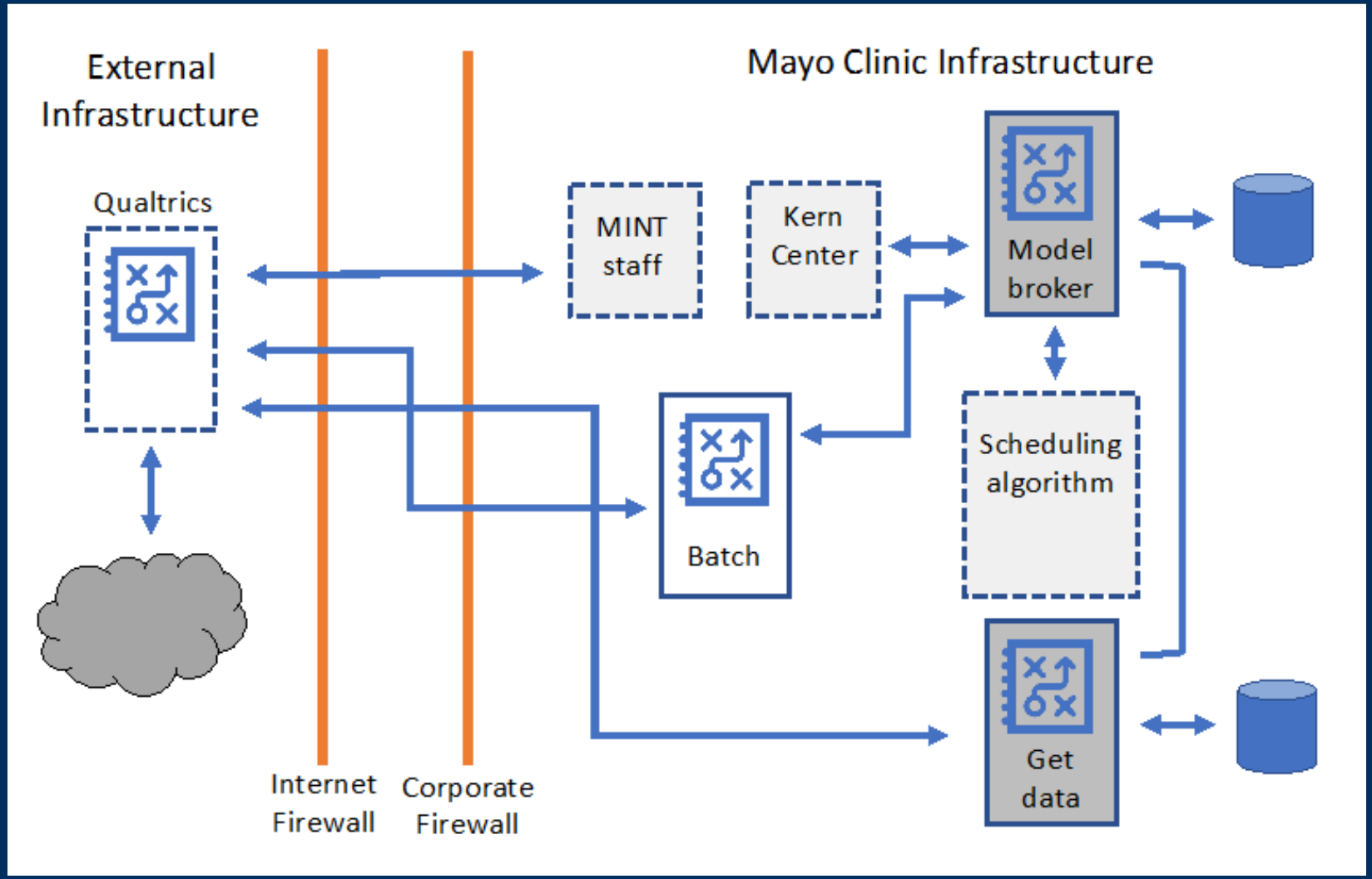
Pre-algorithm vs post-algorithm referrals



	Aud	BFTE	BBFT	Surg ENT	Med ENT	Beh Sub	Beh Gen	Aud-PhD	Neurovest	Head-ache	Neu Gen	Rehab
Pre-algorithm (example)	100%	5%	94%	33%	52%	15%	22%	100%	6%	5%	47%	97%
Post-algorithm	100%	16%	84%	18%	47%	22%	43%	7%	16%	25%	25%	100%

Implementation


External Infrastructure
Mayo Clinic Infrastructure
Qualtrics
MINT staff
Kern Center
Model broker
Batch
Scheduling algorithm
Get data
Internet Firewall
Corporate Firewall

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Questionnaire - electronic

MAYO CLINIC

Mayo staff page

- Past related medical, surgical information
- Your Problem
- Associated Symptoms and Problems
- Headache
- Headache
- Hearing
- Other Medical, Surgical and Social History
- Social and Family History
- Anxiety and depression symptoms
- Final Section
- MAYO STAFF: summary
- MAYO STAFF: triage
- MAYO STAFF: scheduling

Mayo staff page

- Past related medical, surgical information
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- MAYO STAFF: triage
- MAYO STAFF: scheduling

Headache

Have you had a total of 5 or more headaches (does not matter how severe) in your lifetime?

- Yes
- No

Have you ever had a headache that was severe enough to make you stop your activity and sit or lie down?

- Yes
- No

Have you ever experienced a temporary change in your vision, such as jagged lines, color spots or lightning bolts in your vision?

- Yes
- No

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Implementation

- Timing
  - Episodic, constant, fluctuating, progressive
  - Episode duration: seconds, minutes, hours, days
- Triggers
  - Movements, environments, foods
- Accompanying symptoms
  - Hearing loss, pressure headache,
- Symptom quality
  - May be unclear, unreliable & inconsistent
  - **Spinning vertigo ≠ vestibular disorder**

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Relevant features for algorithm

Symptoms

U	D	V	24/7	spells	spontaneous	Hdm	vm	vc	reading	loud sounds	cough, sneeze, blow nose	car rides

Other symptoms

Falls	injury Y	injury N	Diplopia	Oscil	panic	palp	migraine

Hearing loss

Right	Left	AU	R>L	L>R	=

Tinnitus

Right	Left	AU	R>L	L>R	=

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Model's Recommendation/Prediction

The model has processed the patient responses: 1 (1=yes)

The model's recommendation for audiology: **yes**

Audiology

Yes	No

The model's recommendation for vestibular testing: **BBFT**

Vestibular testing

BFTL	BBFT	BFTE	BFTF

The model's recommendation for NDC/McCaslin: **yes**

NDC

Yes	No

Med ENT

face-to-face consult

Otology

1st available

The model's recommendation for neurology: **no**

Neurology

General adult	Headache	pediatric	Eggers

The model's recommendation for behavioral medicine program: **no**

Behavioral medicine program for dizziness

adult	pediatric	Staab

The model's recommendation for vestibular and balance therapy: **yes**

Strategy and Business Plan

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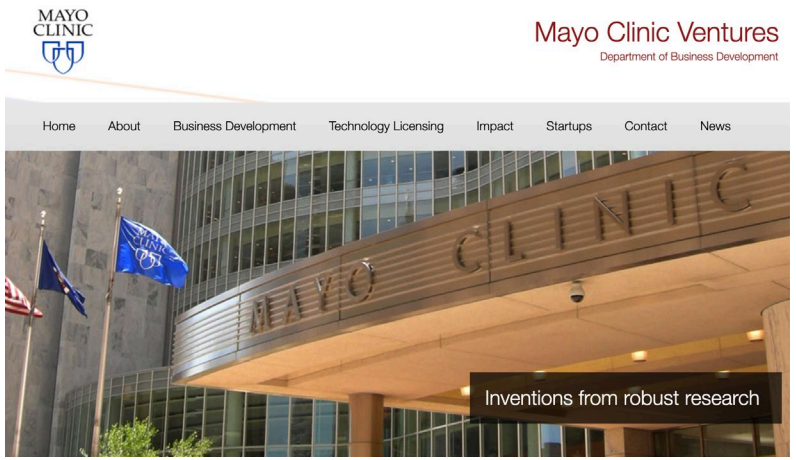
Strategy and Business Plan

- Intellectual property strategy (Mayo Ventures)
- Identify a strategic partner to scale the project – inno.health
- Clinical and regulatory strategy

inno.health



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Advisory Board

- Jeff Staab, MD
- Mans Magnusson, MD
- Mikael Karlberg, MD
- Neil Shepard, PhD
- Scott Eggers, MD
- Devin McCaslin, PhD

DizzyGuide Patient Interface

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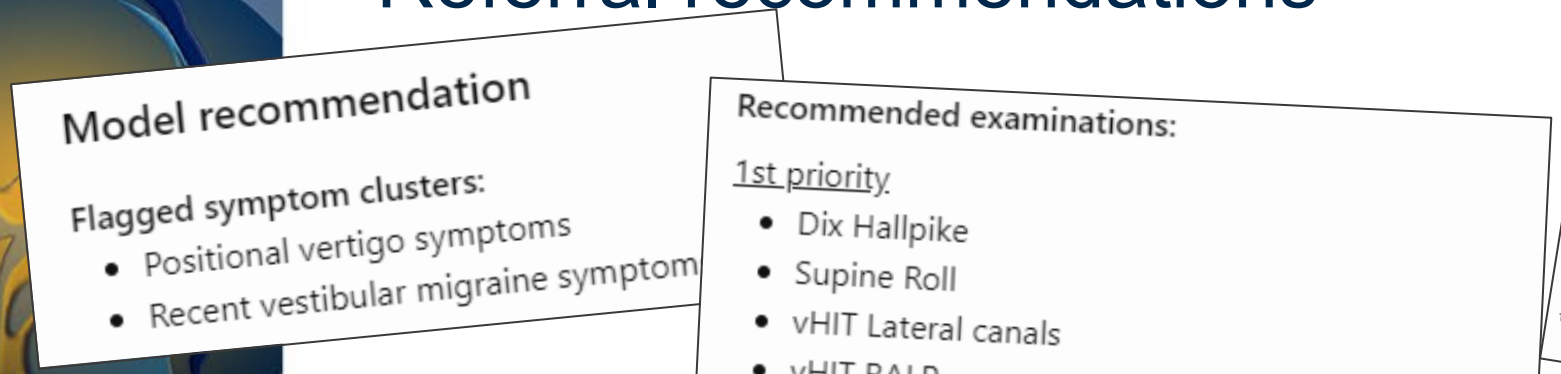
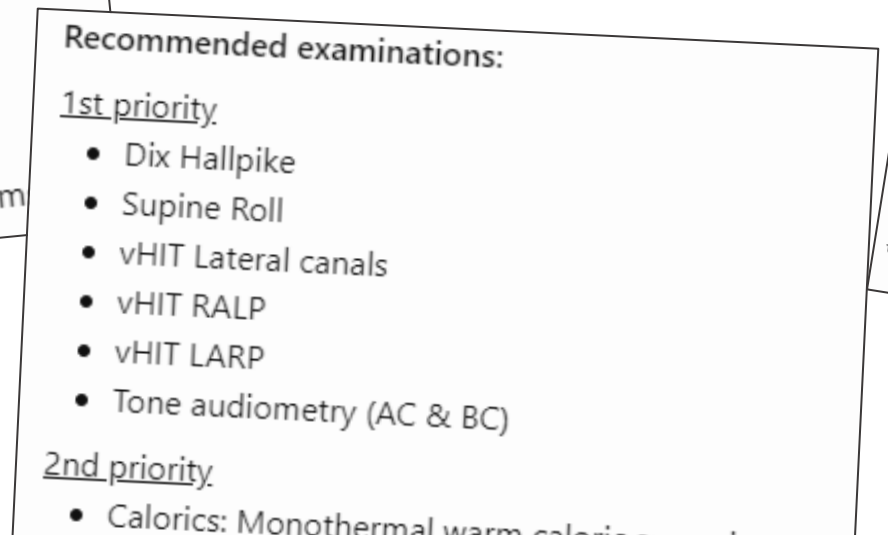
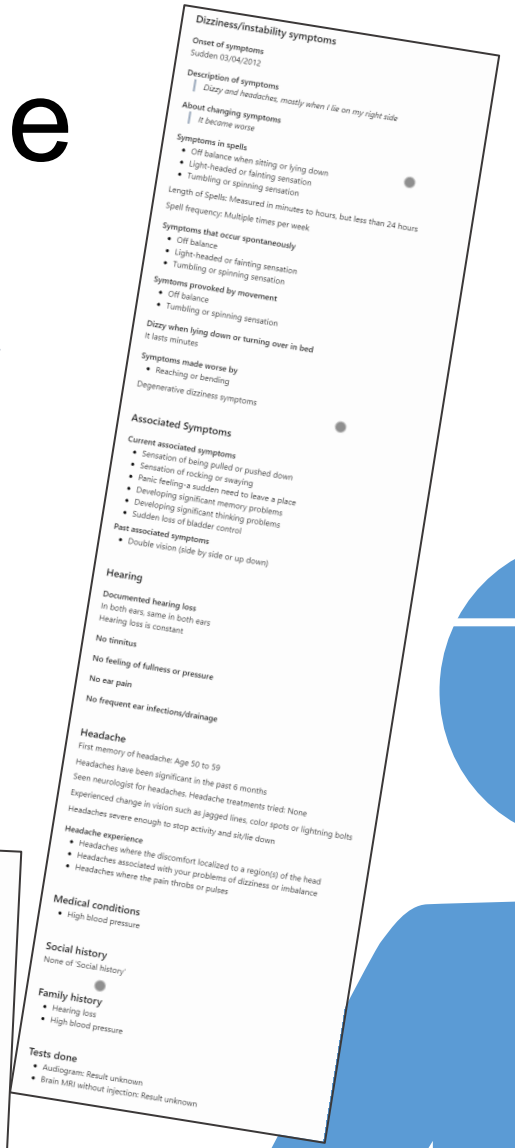
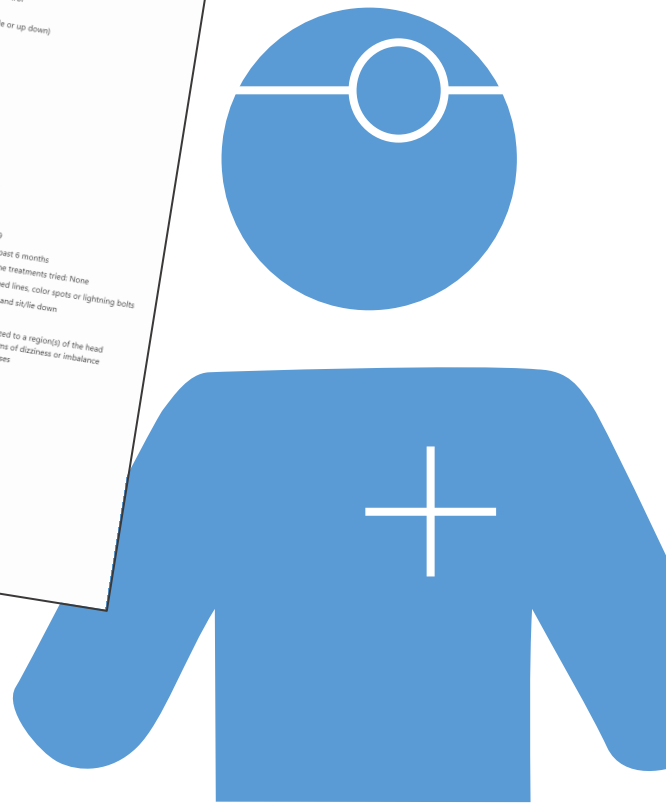
DizzyGuide

- Full vestibular anamnestic report
- Symptom clusters
- Examination recommendations
- Referral recommendations









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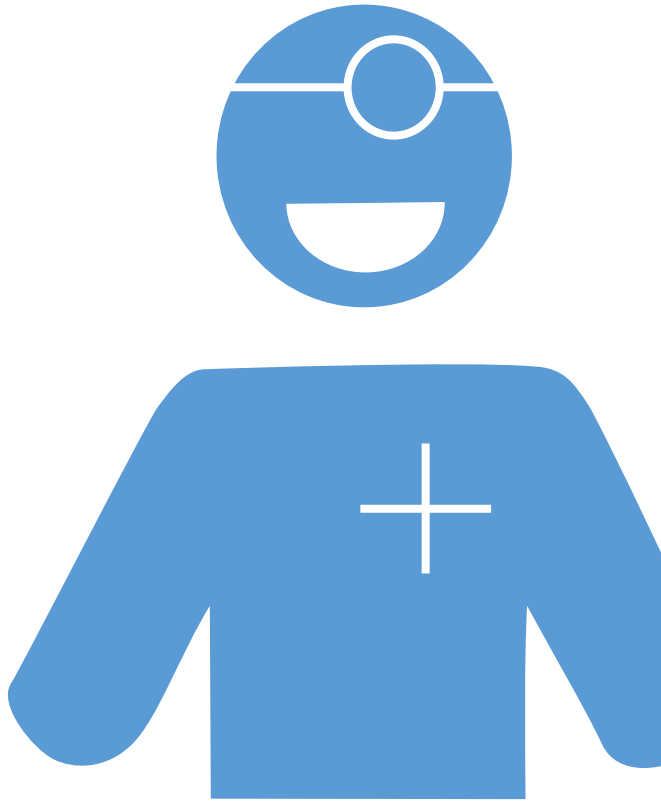
Advantages of Intelligent Triage

- Access to up to date international vestibular knowledge
- More effective use of healthcare resources
- Quicker patient care
- More time for additional patients



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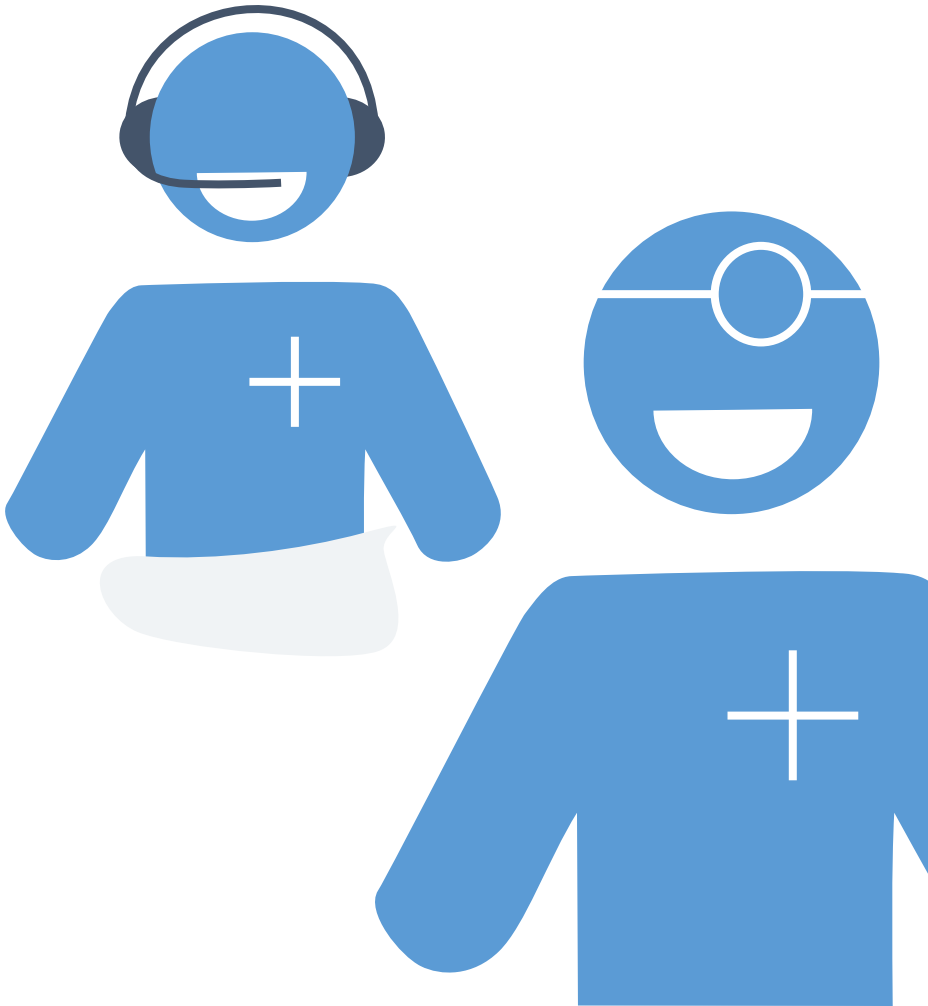
Symptom Clusters

- Semicircular Canal Dehiscence symptoms
- Menieres symptoms
- Positional vertigo symptoms
- Visual vertigo symptoms
- Vestibular migraine symptoms
- Persistent dizziness symptoms
- Degenerative dizziness symptoms
- Dizziness concussion symptoms
- Treatment resistant headache symptoms
- Unexplained falls
- Anxiety and/or depression symptoms



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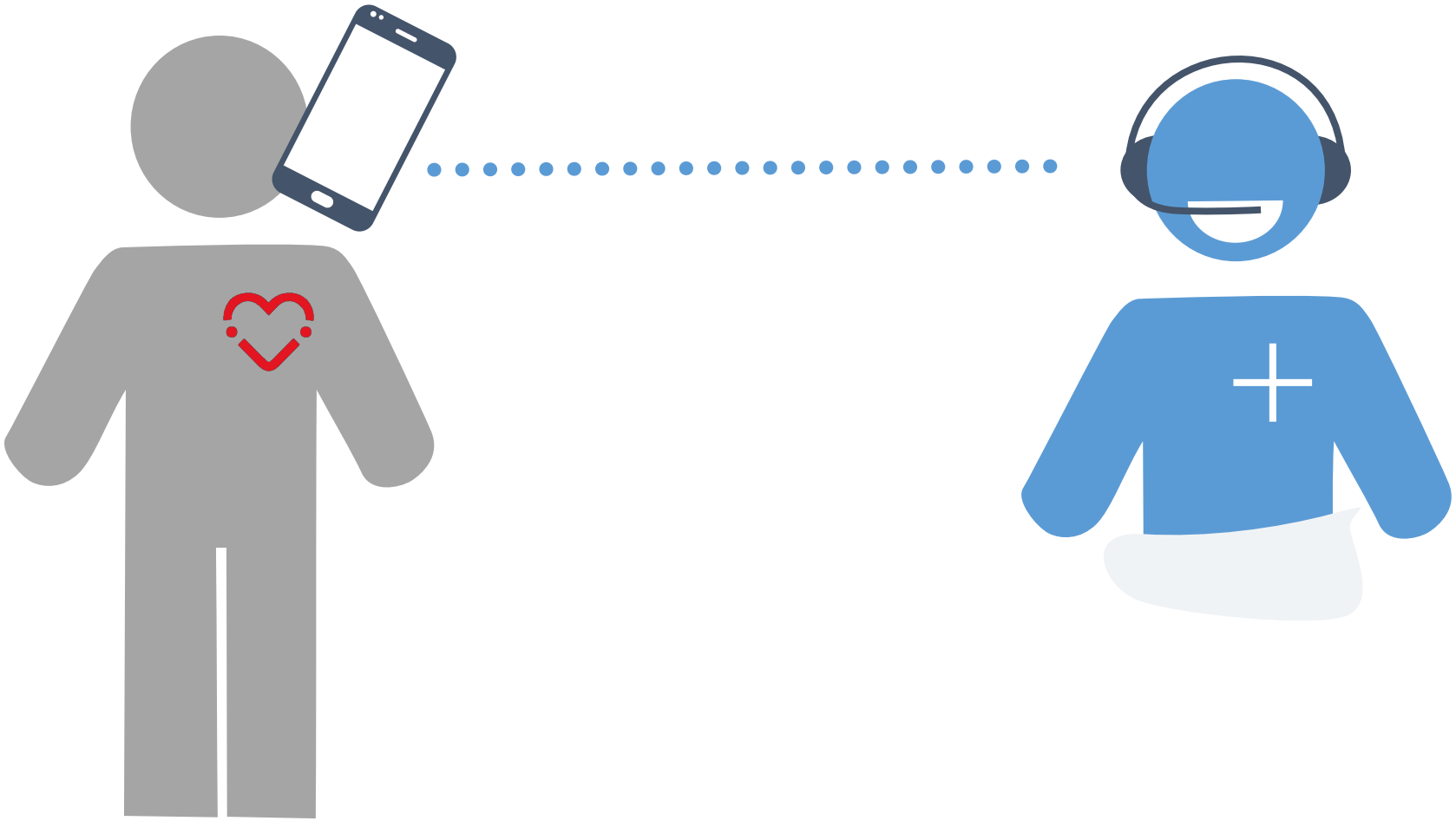
Workflow



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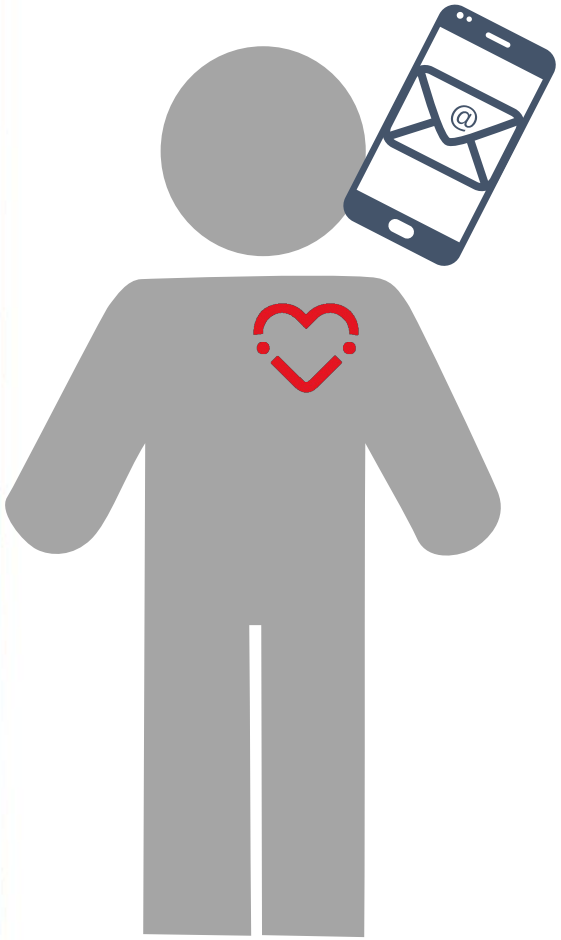

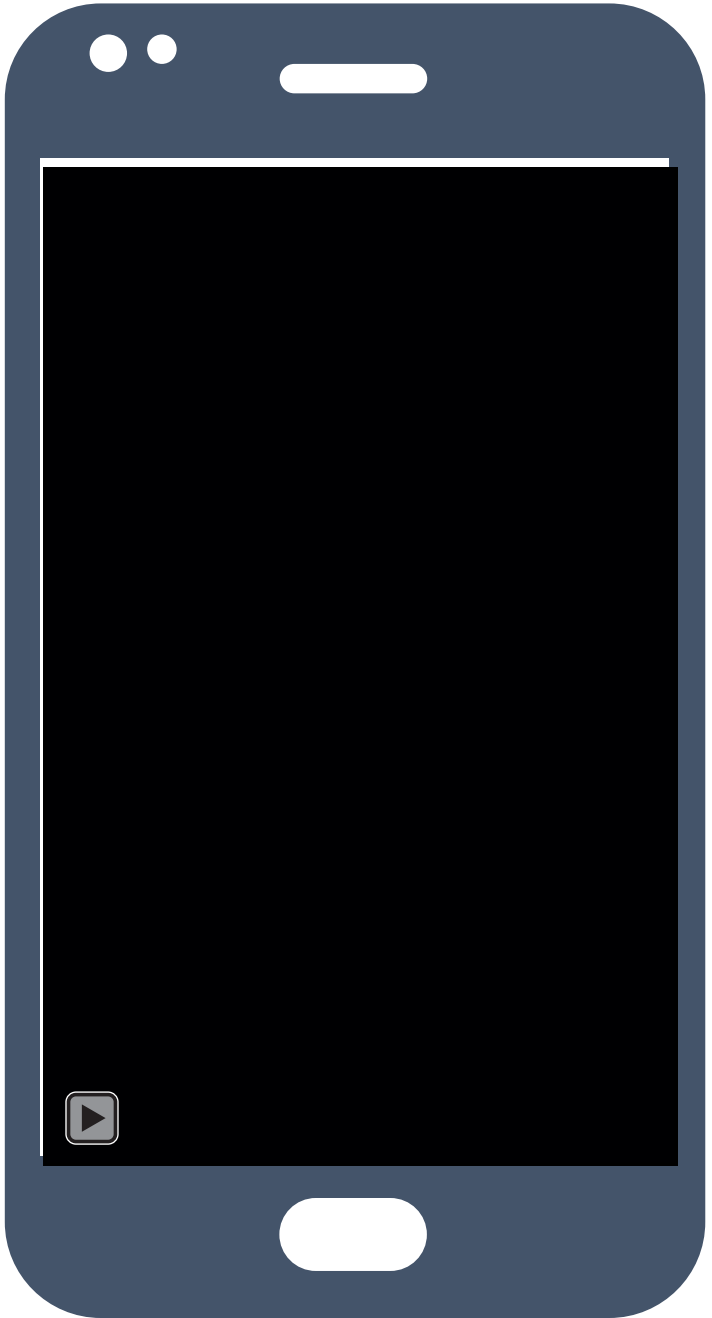

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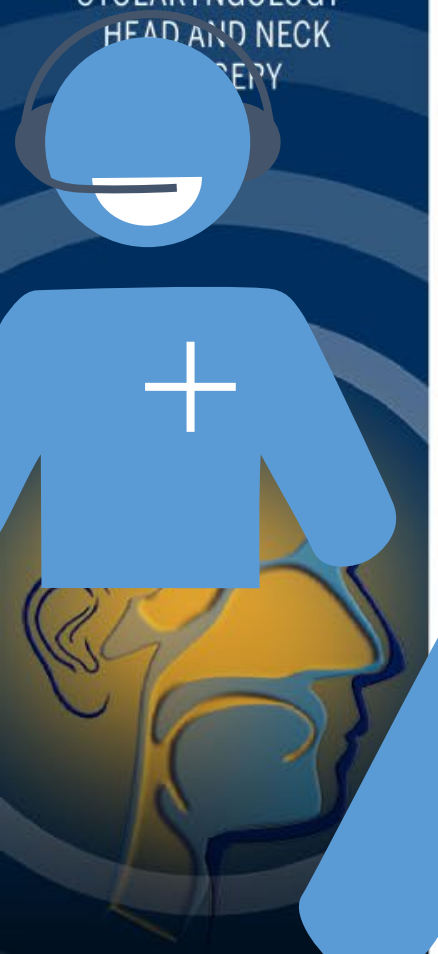

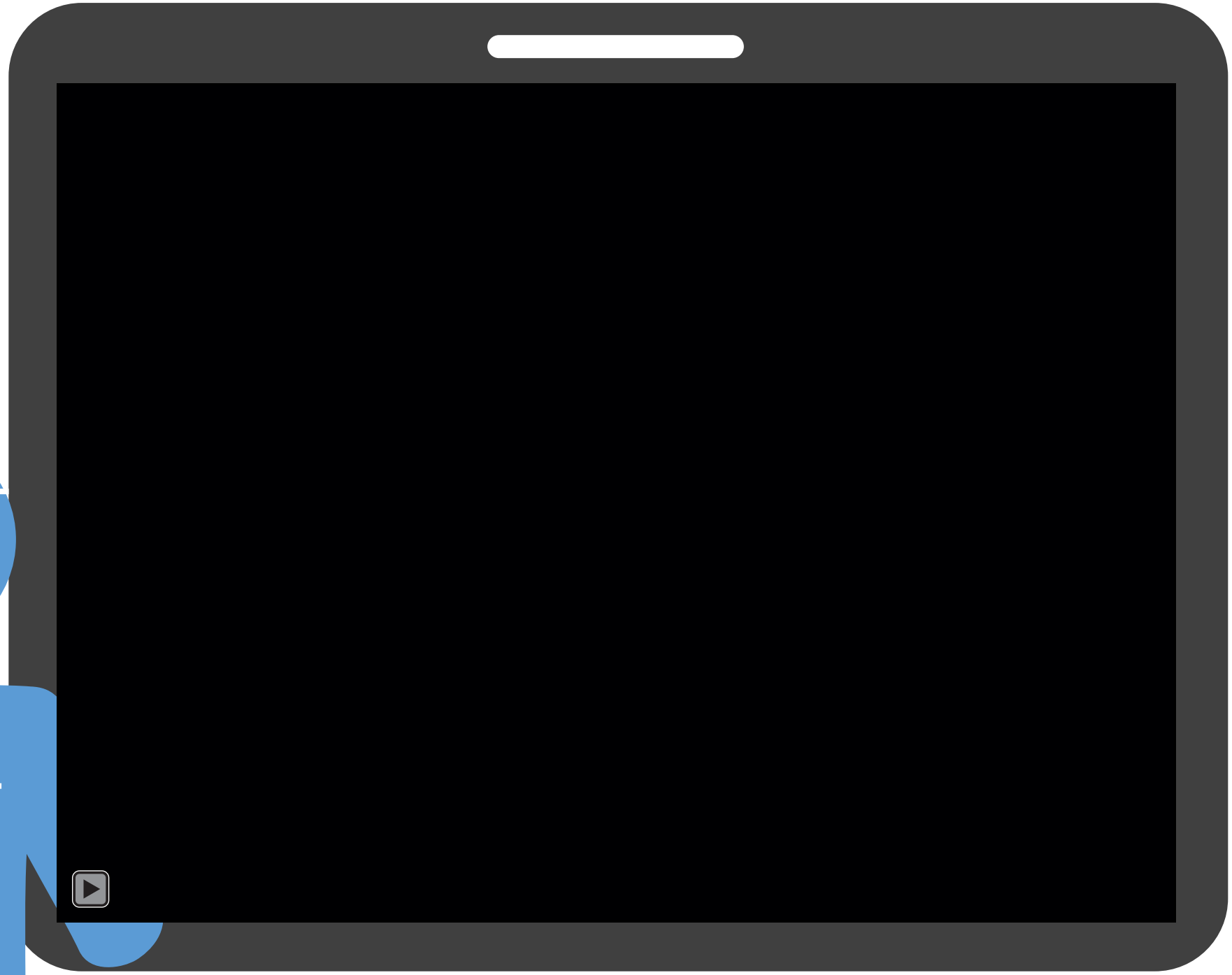

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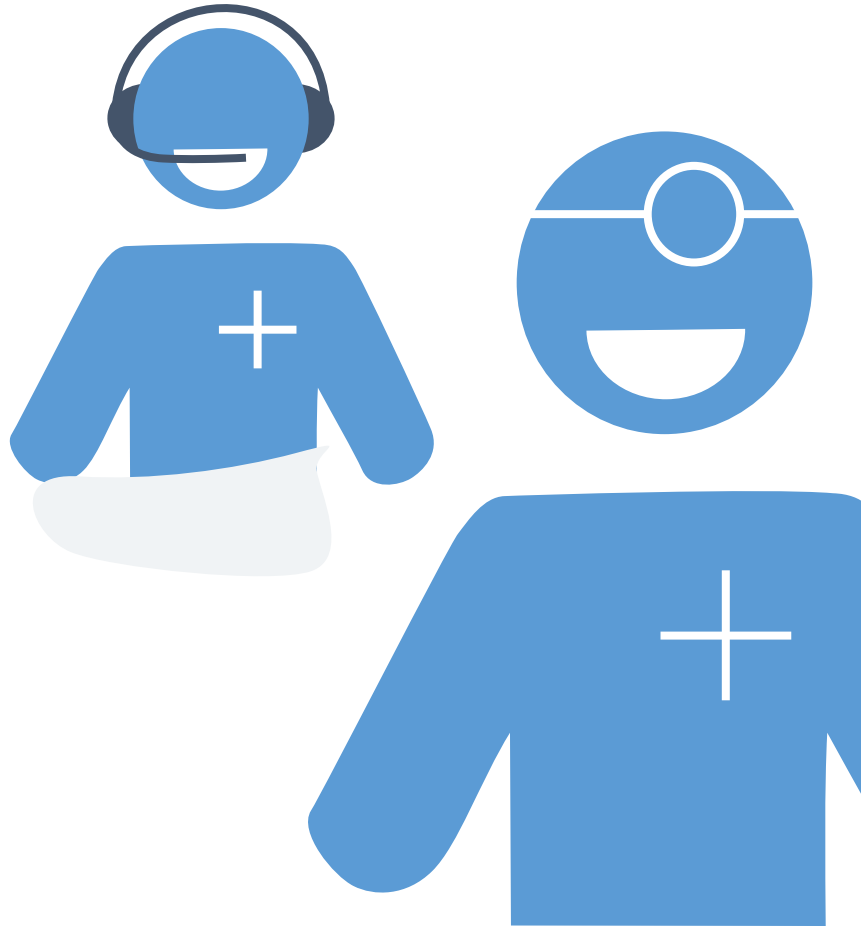
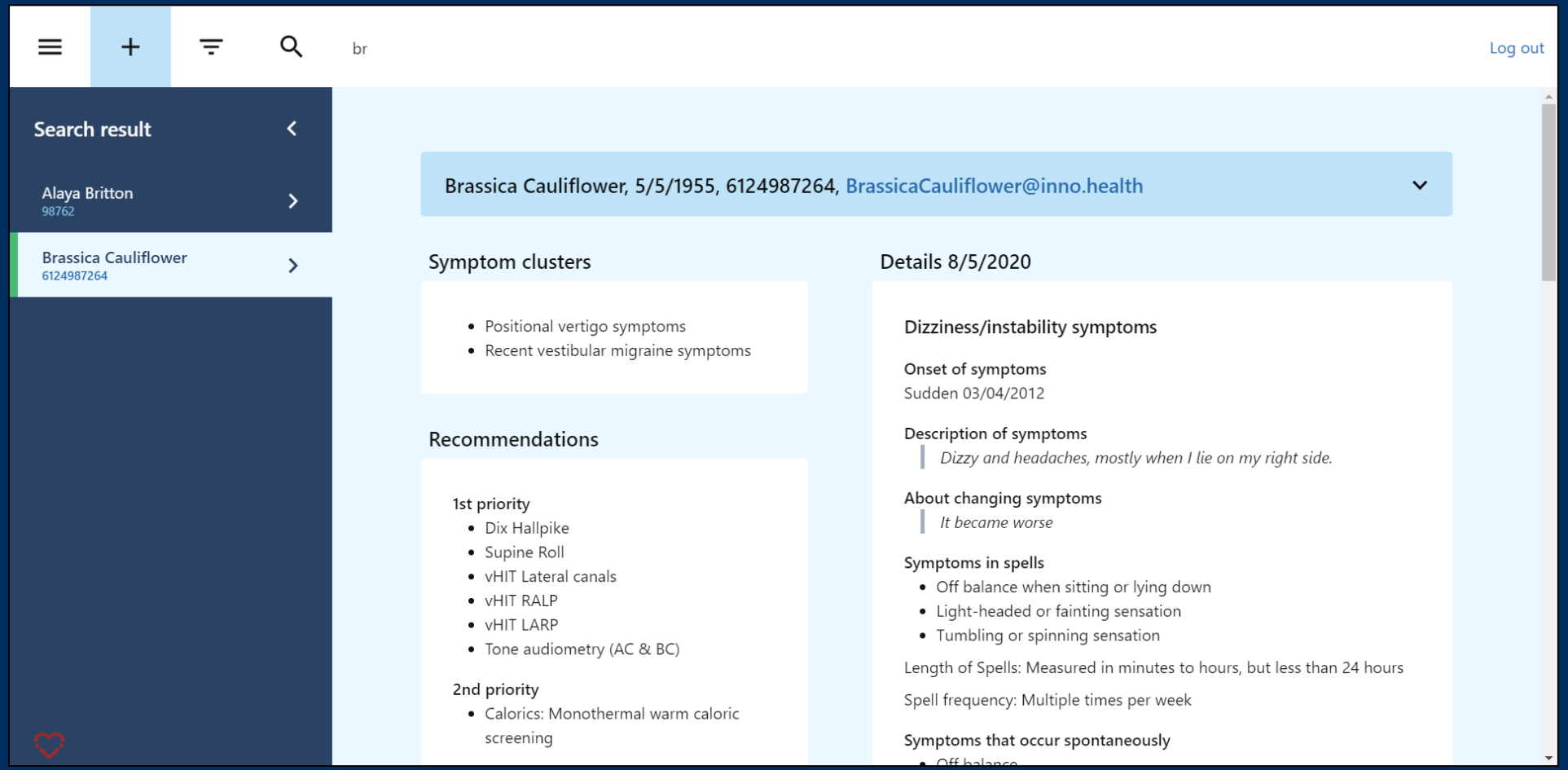
Multiple Algorithms

Configuration dependent on availability of

- Test equipment
- In house specialization
- Specialists in the area
- Local preferences



Output for Clinician



Clinic Optimization

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Estimate of appointments saved

- Total number of surgical appointments
  - Pre-algorithm: 33% of patients
  - Post algorithm: 18% of patients
  - At around 600 patients/year, this is a saving of 90 appointments per year

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Estimate of appointments saved (con't)

- Total number of appointments per patient
  - Pre algorithm: 5.17 appointments per patient
  - Post-algorithm: 4.89 appointments per patient
  - $P<0.05$
  - At around 600 patients/year, this is a saving of ~140 appointments per year.

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Independent Mayo Review - Metrics

Project Metric Description	Baseline Measurement	Target Measurement	Current Measurement	Met Requirement
Algorithm accuracy	N/A	Initial accuracy of 60% compared to pre-project.	87%	Yes
Clinician time used to review charts and triage patients.	.4FTE annually, estimated to cost $172,000, for chart review.	50% reduction to clinician time.	*(plan is to reduce to .2 or .1 FTE)*	Continuously improving
Patient outcomes. Counterbalance Measure	Measured by DHI score.	No reduction to baseline. This will be measured six months post-triage.		Continuously improving
Average number of appointments scheduled per patient measured as a whole and per specialty.	Number of appointments per patient. A detailed breakdown by specialty is available for review.	The project will track the number of appointments as a whole as well in specialty areas.	-5% appointments per patient ($p<0.05$)	Yes
Clinician assessment of value of the appointment.	N/A	A separate pilot to support improving the algorithm accuracy.		Continuously improving
Consultant cost assessment calculated based on the change in the number of patient appointments recommended per specialty.	Calculated change in cost from current process versus algorithm.	The project aims to reduce appointments; however, in some specialties appointments may increase.	Estimated $120,000 savings per year ($42,000 in appointments + $86,000 in triage time)	Yes
Sub metric of accuracy: Number of appointments made with the surgical practices.	Number of appointments per patient in surgical areas.	The project will track the number of appointments in surgical areas such as ENT.	-45% ($p<0.05$)	Yes

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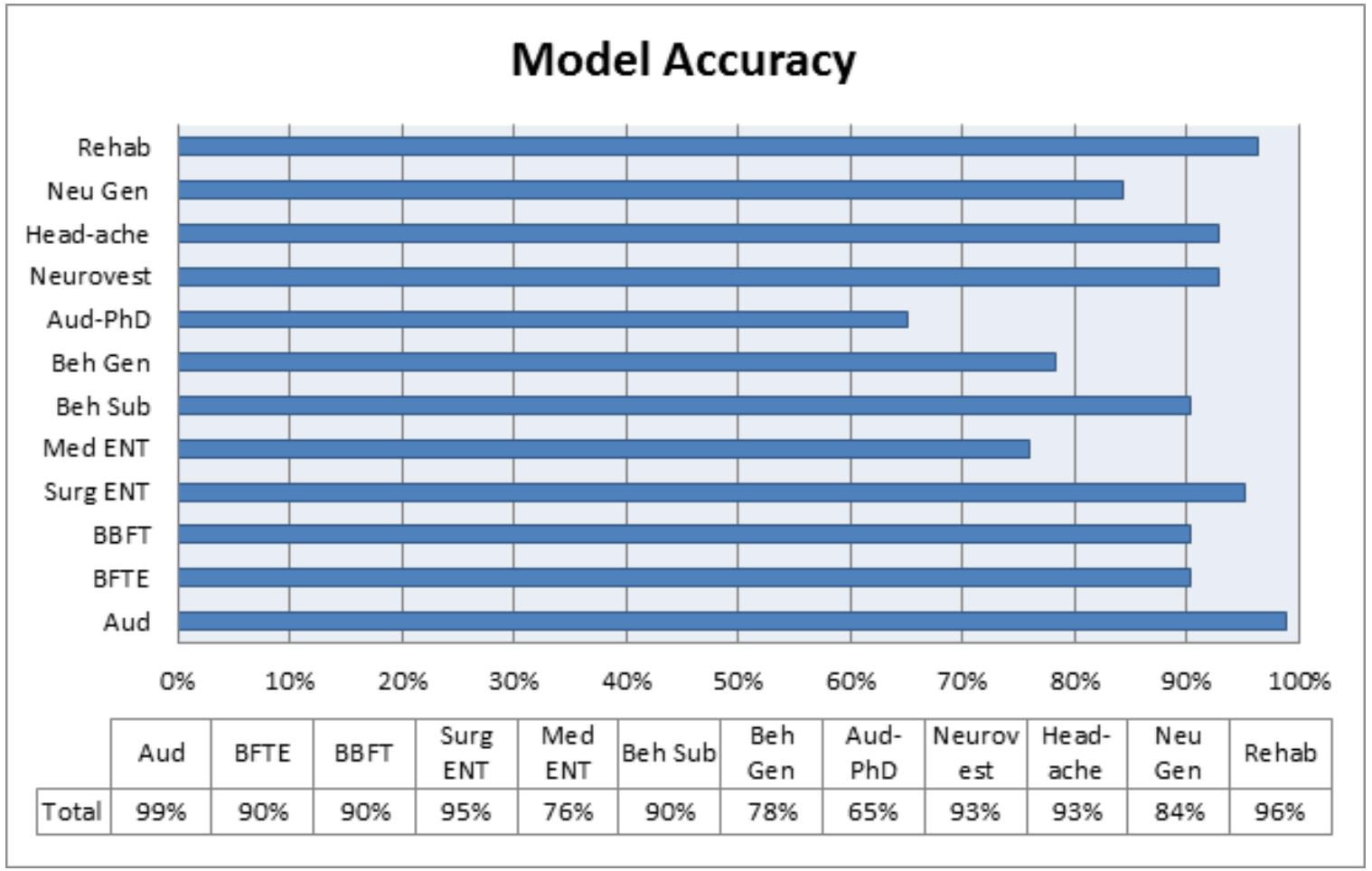
Validation of Model Accuracy



	Aud	BFTE	BBFT	Surg ENT	Med ENT	Beh Sub	Beh Gen	Aud-PhD	Neurovest	Head-ache	Neu Gen	Rehab
Total	99%	90%	90%	95%	76%	90%	78%	65%	93%	93%	84%	96%

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Team (no particular order)

- Scott D.Z. Eggers, MD
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- Santiago Romero-Breafu, MD, PhD
- Doug Totten, MD
- Bethany Watson AuD
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- Jeffrey P. Staab, MD, MS
- Dawn Holmes
- Erik Sigtenbjerggaard (inno.health)
- Jos Huijnen (inno.health)

Questions & Discussion