

# 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



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# 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



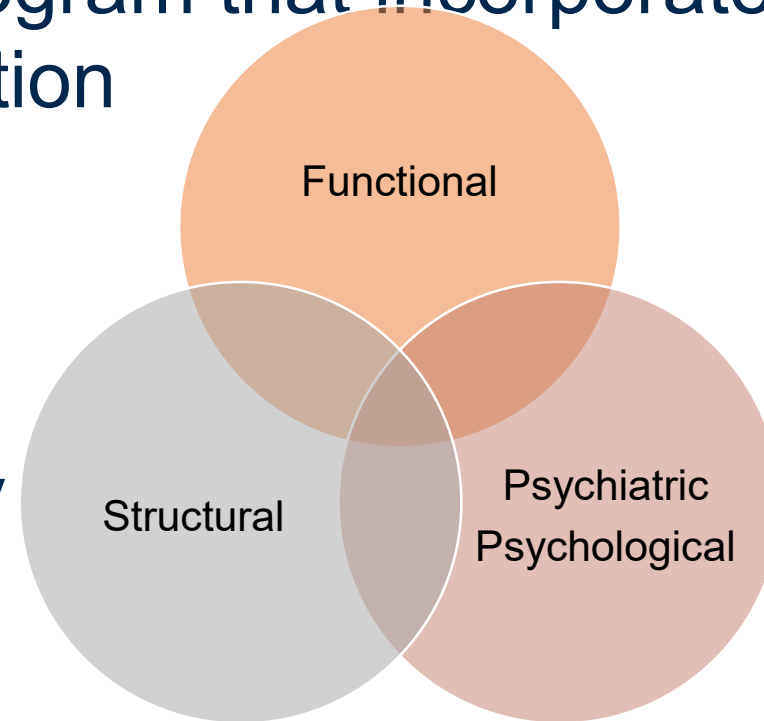
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# Concept

- 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

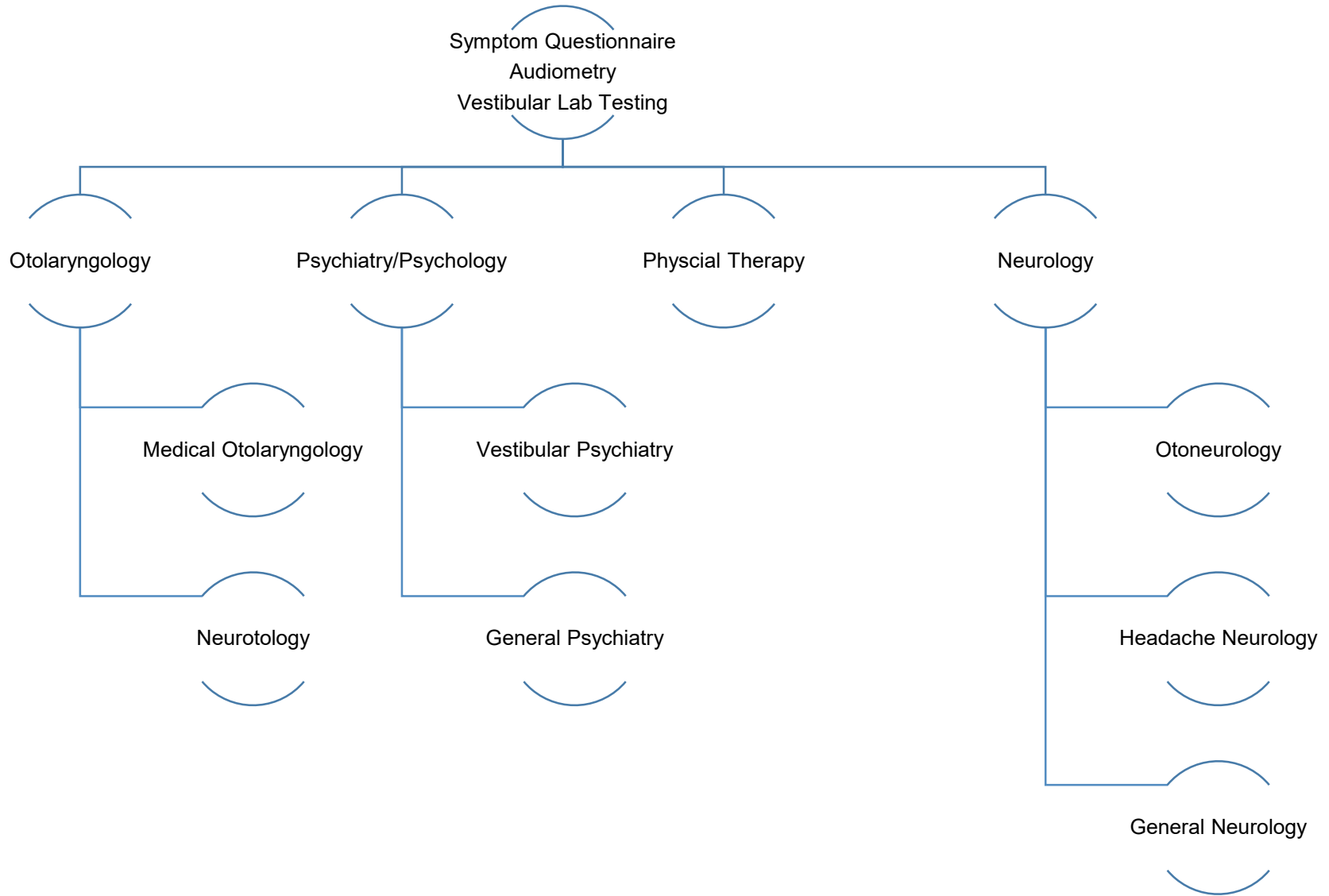
- Jeff Staab, MD
- Neil Shepard, PhD
- Scott Eggers, MD
- Devin McCaslin, PhD





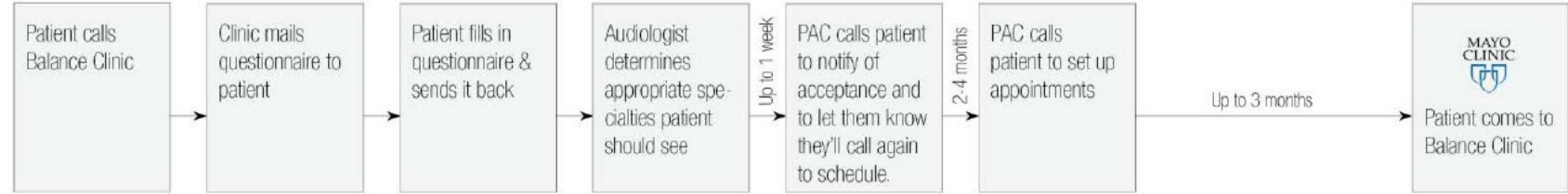
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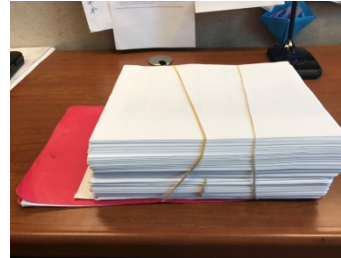


# Concept

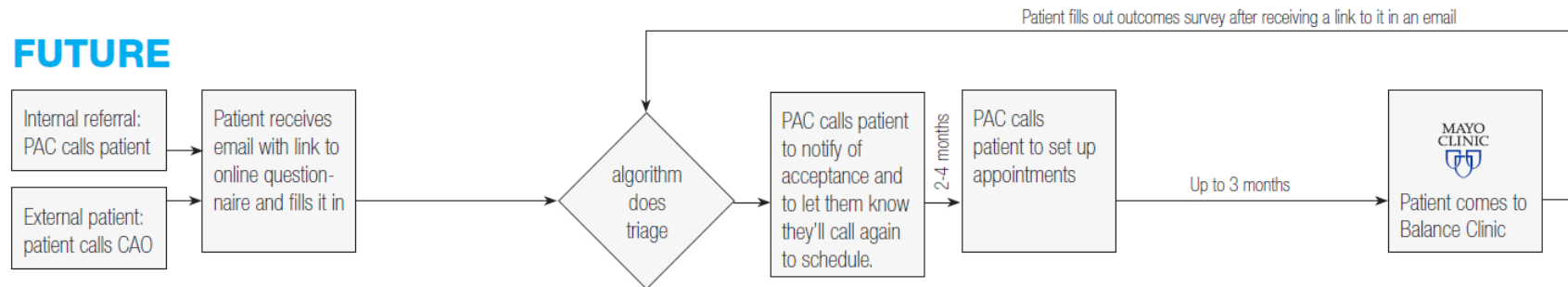
## PAST



## CURRENT



## FUTURE



# 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



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20Q: Using Artificial Intelligence to Triage and Manage Patients with Dizziness - The Mayo Clinic Experience

Course: #34637 Level: Introductory 1 Hour ★★★★★ 408 Reviews

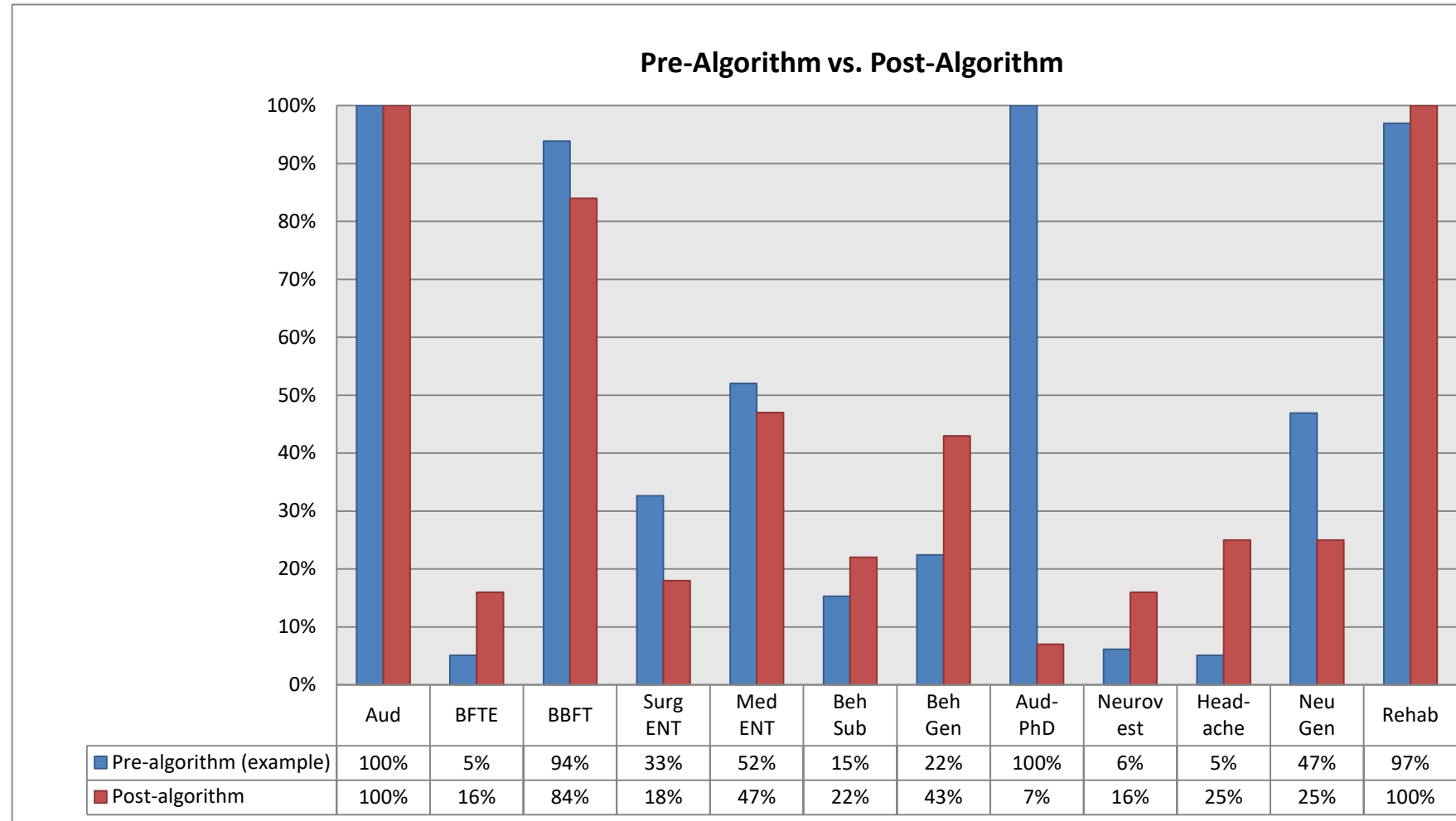


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# Pre-algorithm vs post-algorithm referrals

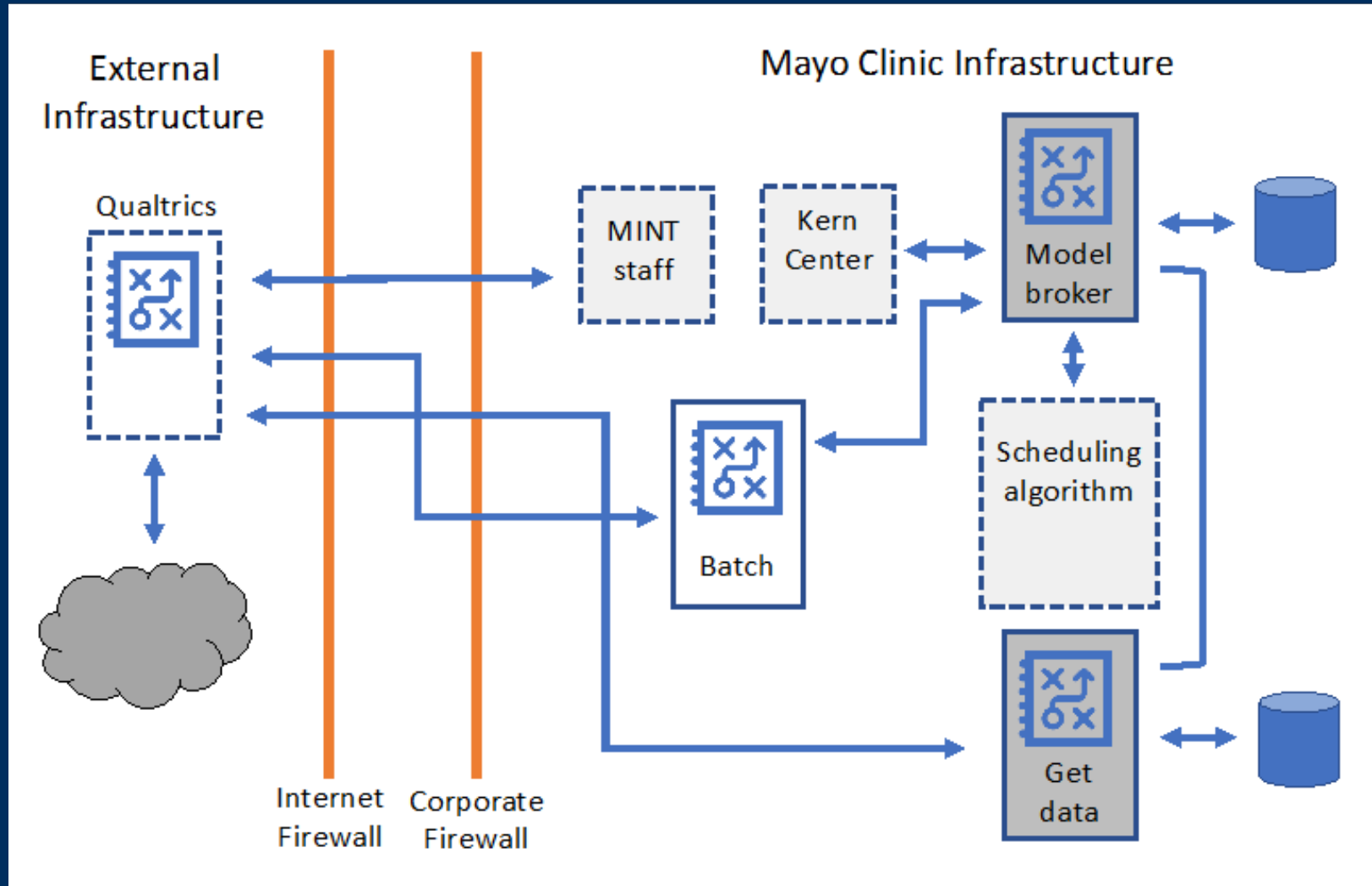




# Implementation



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# Questionnaire - electronic



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[Past related medical, surgical information](#)

[Your Problem](#)

[Associated Symptoms and Problems](#)

[Headache](#)

[Headache](#)

[Hearing](#)

[Other Medical, Surgical and Social History](#)

[Social and Family History](#)

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[Final Section](#)

[MAYO STAFF: summary](#)

[MAYO STAFF: triage](#)

[MAYO STAFF: scheduling](#)



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[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**



# Relevant features for algorithm

## Symptoms

<input checked="" type="checkbox"/> U	<input checked="" type="checkbox"/> D	<input checked="" type="checkbox"/> V	<input type="checkbox"/> 24/7	<input checked="" type="checkbox"/> spells	<input checked="" type="checkbox"/> spontaneous	<input checked="" type="checkbox"/> Hdm	<input checked="" type="checkbox"/> vm	<input checked="" type="checkbox"/> vc	<input type="checkbox"/> reading	<input type="checkbox"/> loud sounds	<input type="checkbox"/> cough, sneeze, blow nose	<input checked="" type="checkbox"/> car rides
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## Other symptoms

<input type="checkbox"/> Falls	<input type="checkbox"/> injury Y	<input type="checkbox"/> injury N	<input type="checkbox"/> Diplopia	<input type="checkbox"/> Oscil	<input type="checkbox"/> panic	<input type="checkbox"/> palp	<input checked="" type="checkbox"/> migraine
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## Hearing loss

<input type="checkbox"/> Right	<input checked="" type="checkbox"/> Left	<input type="checkbox"/> AU	<input type="checkbox"/> R>L	<input type="checkbox"/> L>R	<input type="checkbox"/> =
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## Tinnitus

<input type="checkbox"/> Right	<input checked="" type="checkbox"/> Left	<input type="checkbox"/> AU	<input type="checkbox"/> R>L	<input type="checkbox"/> L>R	<input type="checkbox"/> =
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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



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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

## Model recommendation

### Flagged symptom clusters:

- Positional vertigo symptoms
- Recent vestibular migraine symptom

## Recommended examinations:

### 1st priority

- Dix Hallpike
- Supine Roll
- vHIT Lateral canals
- vHIT RALP
- vHIT LARP
- Tone audiometry (AC & BC)

### 2nd priority

- Calorics: Monothermal warm calorics

**Dizziness/instability symptoms**

Onset of symptoms  
Sudden 03/04/2012

Description of symptoms  
Dizzy and headaches, mostly when I lie on my right side

About changing symptoms  
It became worse

Symptoms in spells

- Off balance when sitting or lying down
- Light-headed or fainting sensation
- Tumbling or spinning sensation

Length of Spell: Measured in minutes to hours, but less than 24 hours

Spell frequency: Multiple times per week

Symptoms that occur spontaneously

- Off balance
- Light-headed or fainting sensation
- Tumbling or spinning sensation

Symptoms provoked by movement

- Off balance
- Tumbling or spinning sensation

Dizzy when lying down or turning over in bed  
It lasts minutes

Symptoms made worse by

- Reaching or bending

Degenerative dizziness symptoms

**Associated Symptoms**

Current associated symptoms

- Sensation of being pulled or pushed down
- Sensation of rocking or swaying
- Panic feeling - a sudden need to leave a place
- Developing significant memory problems
- Sudden loss of bladder control

Past associated symptoms

- Double vision (side by side or up down)

**Hearing**

Documented hearing loss  
In both ears, same in both ears  
Hearing loss is constant

No tinnitus

No feeling of fullness or pressure

No ear pain

No frequent ear infections/drainage

**Headache**

First memory of headache: Age 50 to 59

Headaches have been significant in the past 6 months

Seen neurologist for headaches. Headache treatments tried: None

Experienced change in vision such as jagged lines, color spots or lightning bolts

Headaches severe enough to stop activity and stifle down

**Headache experience**

- Headaches where the discomfort localized to a region(s) of the head
- Headaches associated with your problems of dizziness or imbalance
- Headaches where the pain throbs or pulses

**Medical conditions**

- High blood pressure

**Social history**

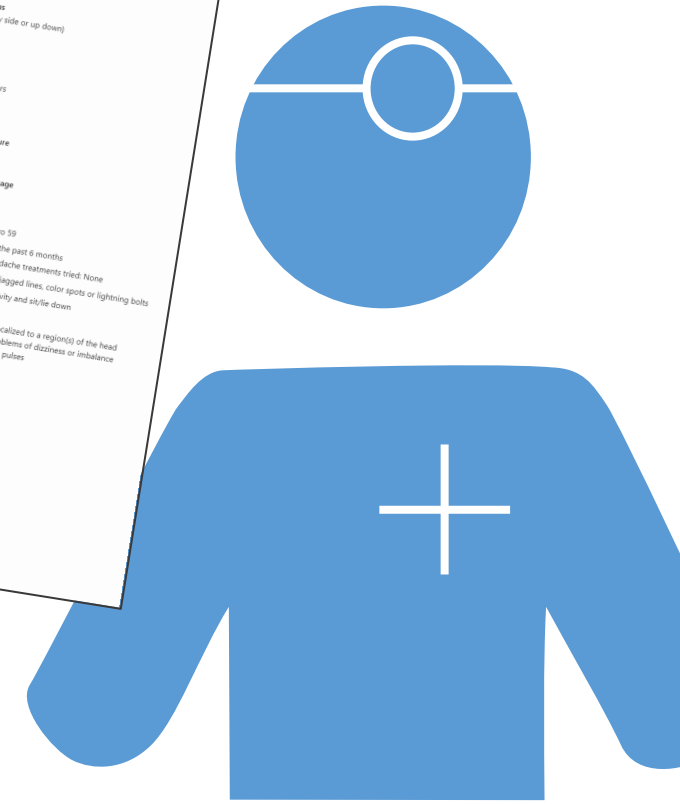
None of Social history

**Family history**

- Hearing loss
- High blood pressure

**Tests done**

- Audiogram: Result unknown
- Brain MRI without injection: Result unknown





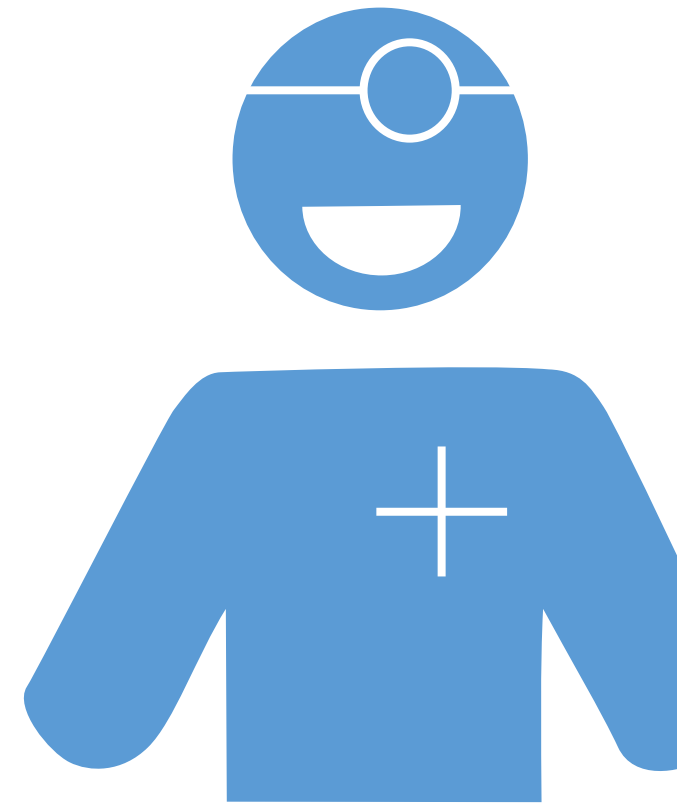
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# Advantages of Intelligent Triage

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





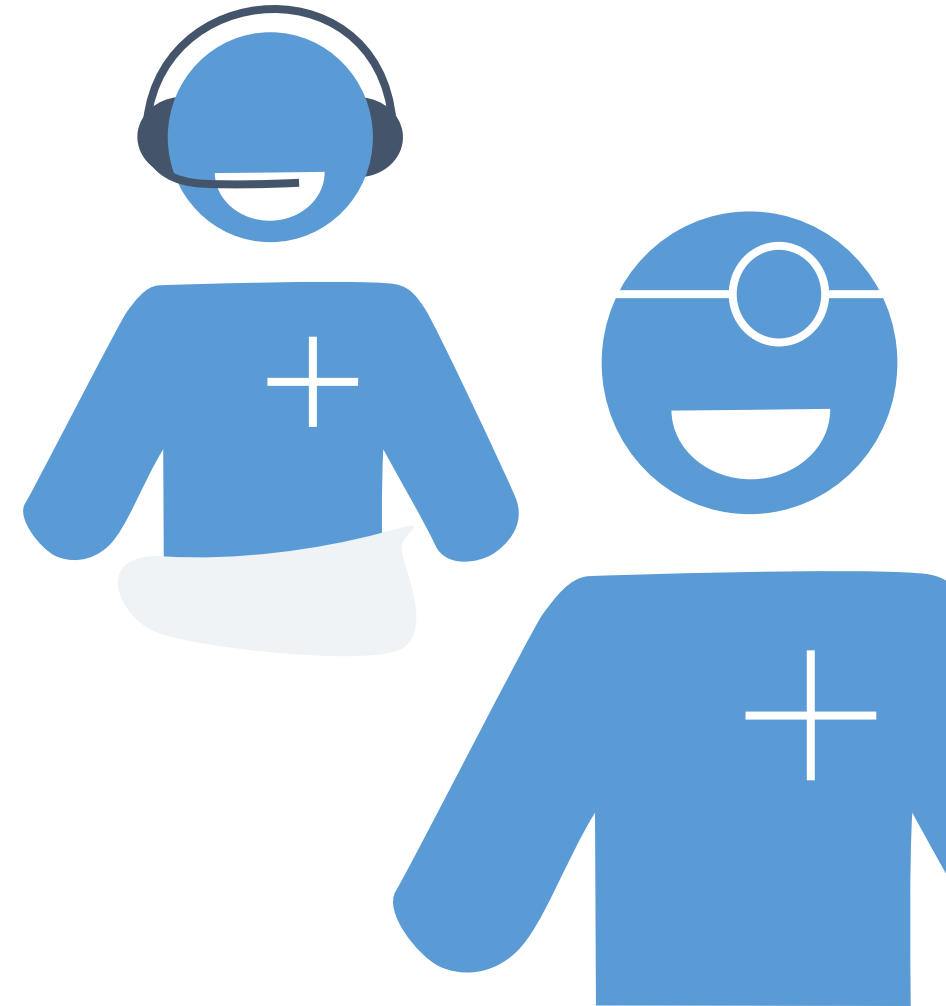
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# Symptom Clusters

- 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



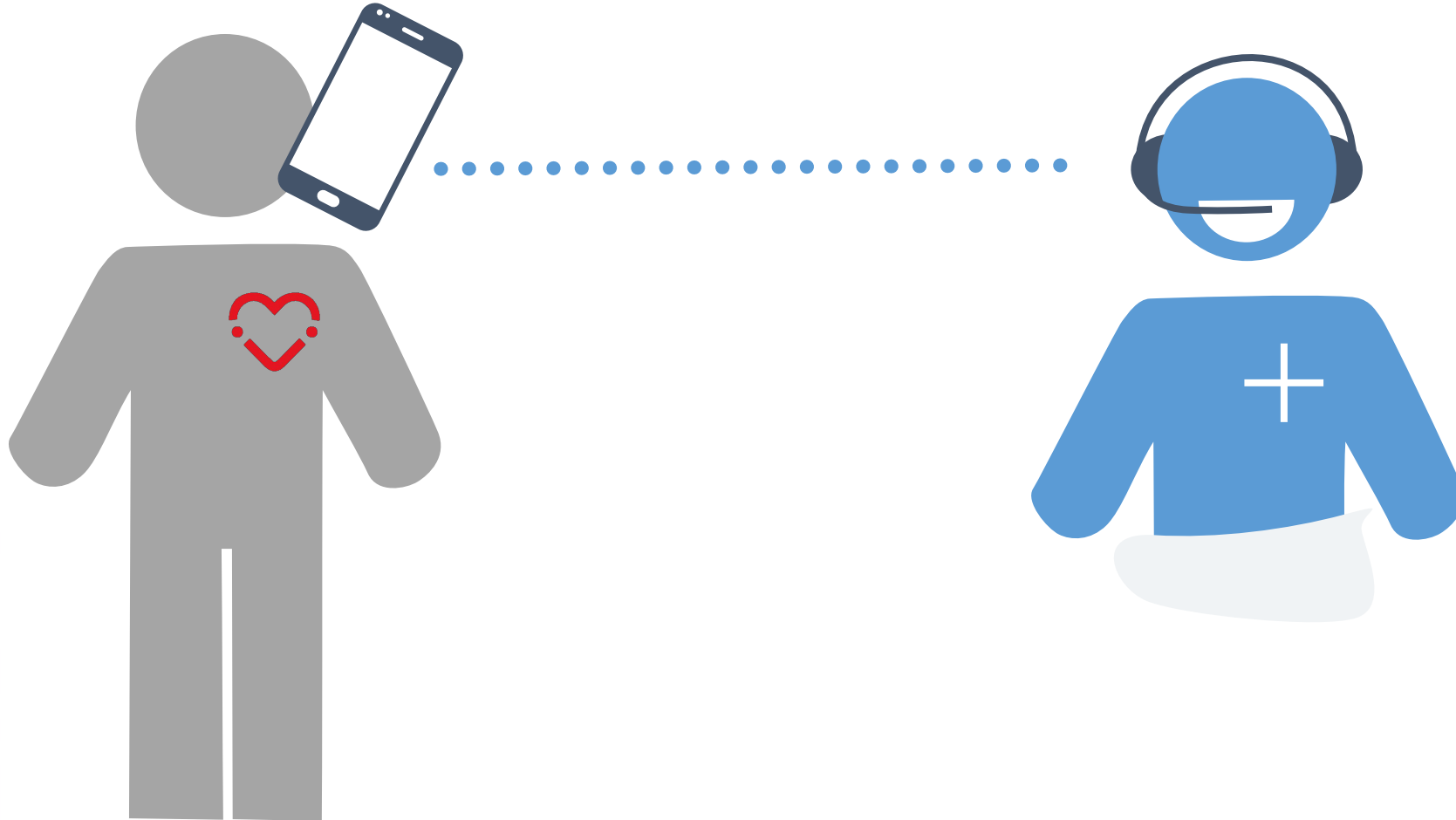


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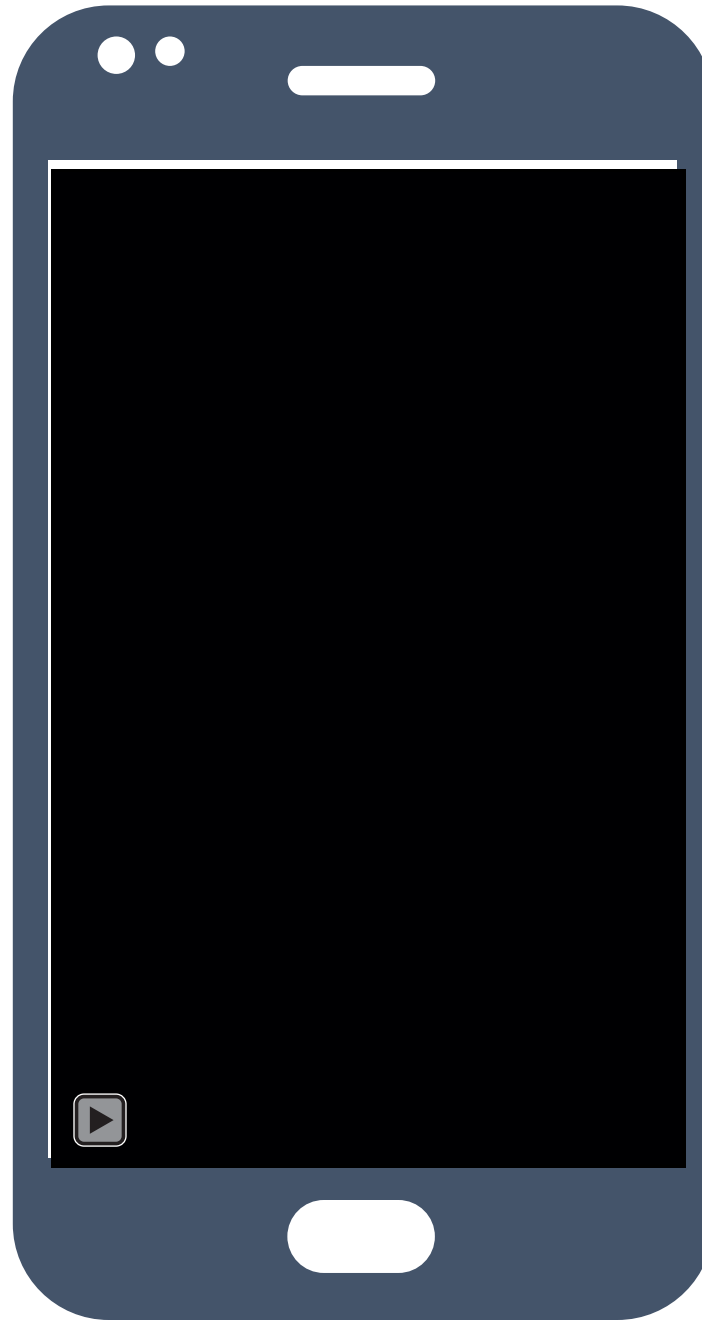
# Workflow





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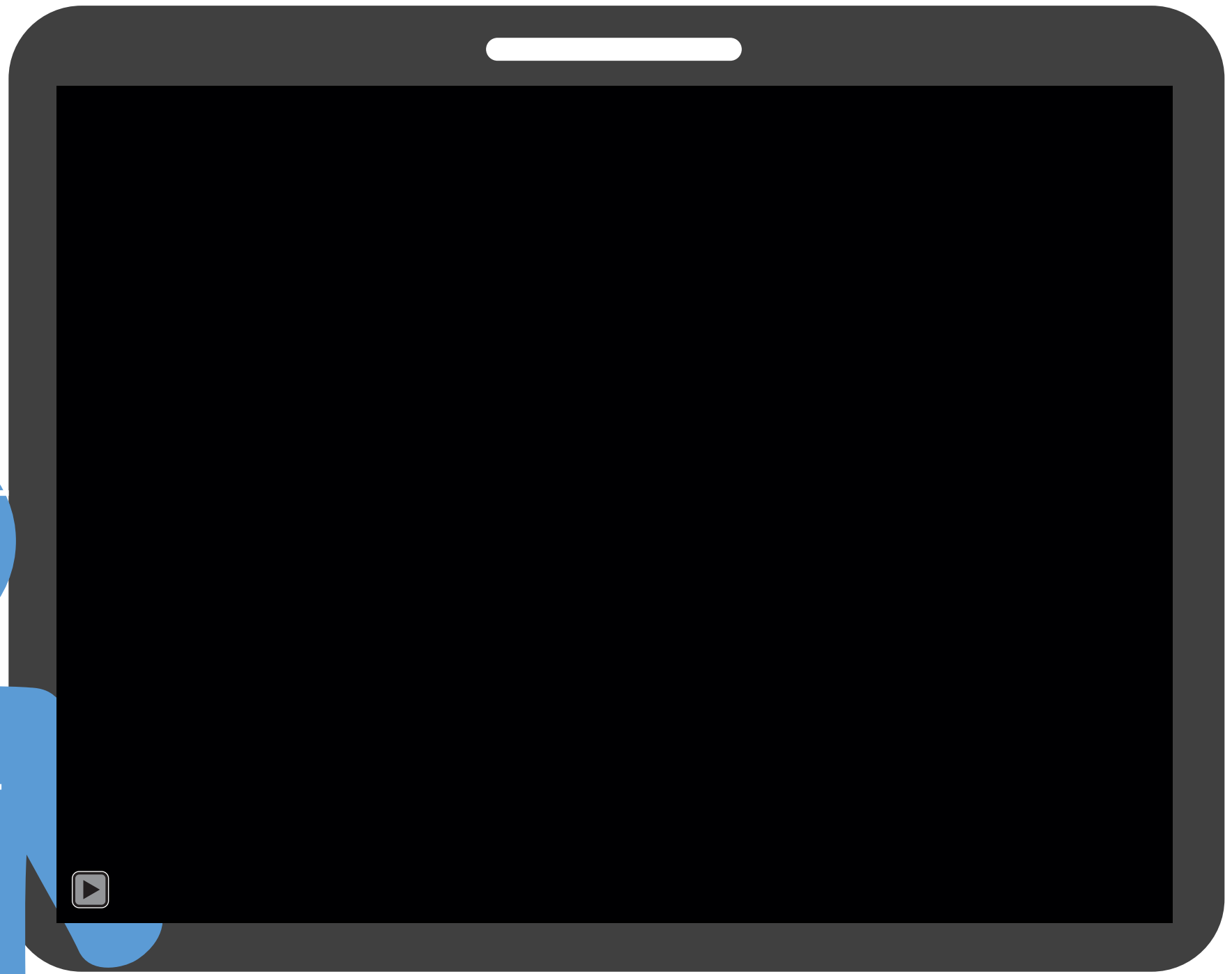
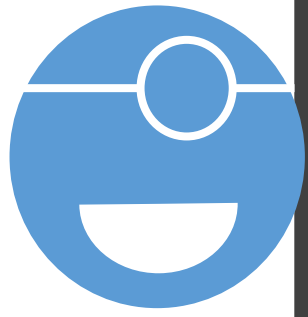
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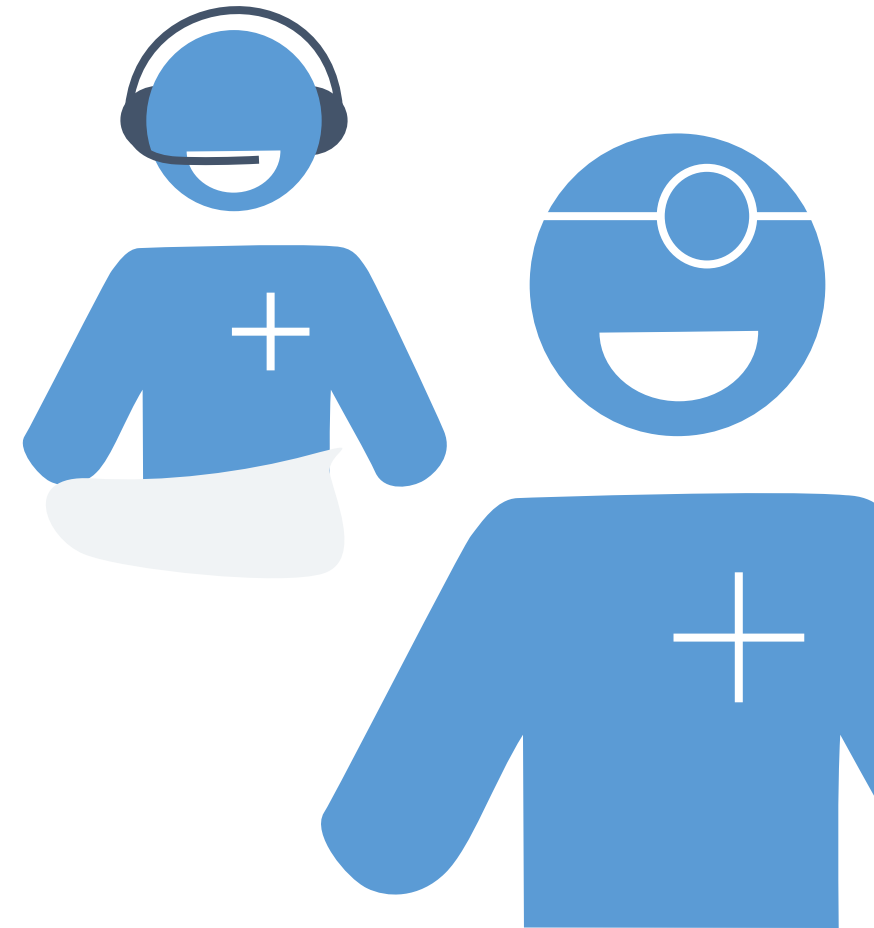
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# Multiple Algorithms

Configuration dependent on availability of

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



# Output for Clinician

The screenshot displays a clinical interface with a search bar at the top containing the text 'br'. A 'Log out' button is located in the top right corner. On the left, a 'Search result' sidebar lists two patients: 'Alaya Britton 98762' and 'Brassica Cauliflower 6124987264', with the latter selected. The main content area shows the patient's name and contact information: 'Brassica Cauliflower, 5/5/1955, 6124987264, BrassicaCauliflower@inno.health'. Below this, the interface is divided into two columns. The left column contains 'Symptom clusters' (listing 'Positional vertigo symptoms' and 'Recent vestibular migraine symptoms') and 'Recommendations' (divided into '1st priority' and '2nd priority' lists). The right column contains 'Details 8/5/2020', which includes sections for 'Dizziness/instability symptoms', 'Onset of symptoms' (Sudden 03/04/2012), 'Description of symptoms' (Dizzy and headaches, mostly when I lie on my right side.), 'About changing symptoms' (It became worse), 'Symptoms in spells' (Off balance when sitting or lying down, Light-headed or fainting sensation, Tumbling or spinning sensation), 'Length of Spells' (Measured in minutes to hours, but less than 24 hours), 'Spell frequency' (Multiple times per week), and 'Symptoms that occur spontaneously' (Off balance).



# 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.



# 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.	<i>(plan is to reduce to .2 or .1 FTE)</i>	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

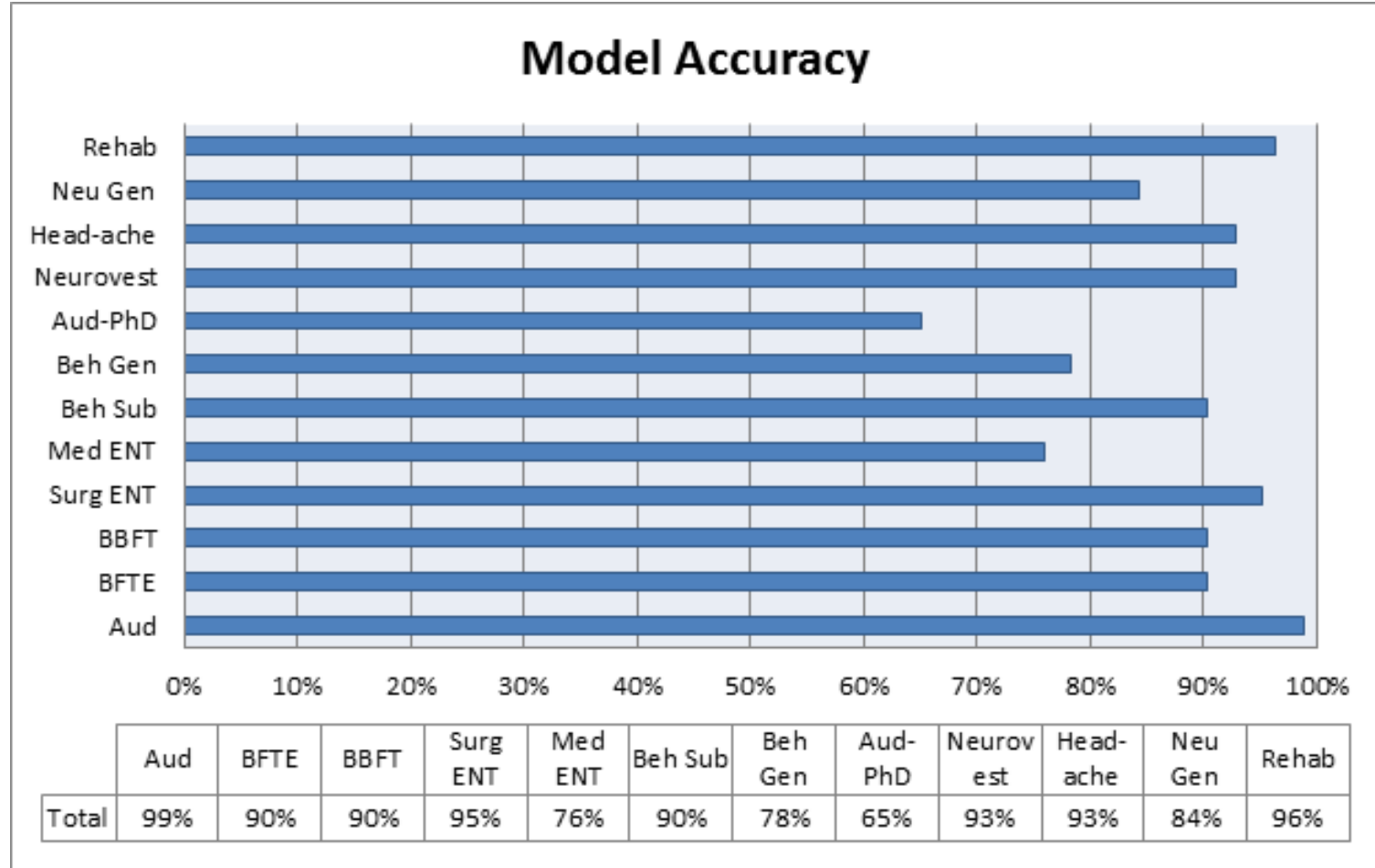


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# Validation of Model Accuracy





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# Team (no particular order)

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- Kalyan Pasupathy, PhD
- Santiago Romero-Breafo, MD, PhD
- Doug Totten, MD
- Bethany Watson AuD
- Sabrina Albertson MS
- Neil Shepard, PhD
- Jeffrey P. Staab, MD, MS
- Dawn Holmes
- Erik Sigtenbjerggaard (inno.health)
- Jos Huijnen (inno.health)



# Questions & Discussion



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