



# Application of AI in Chronic Disease Management

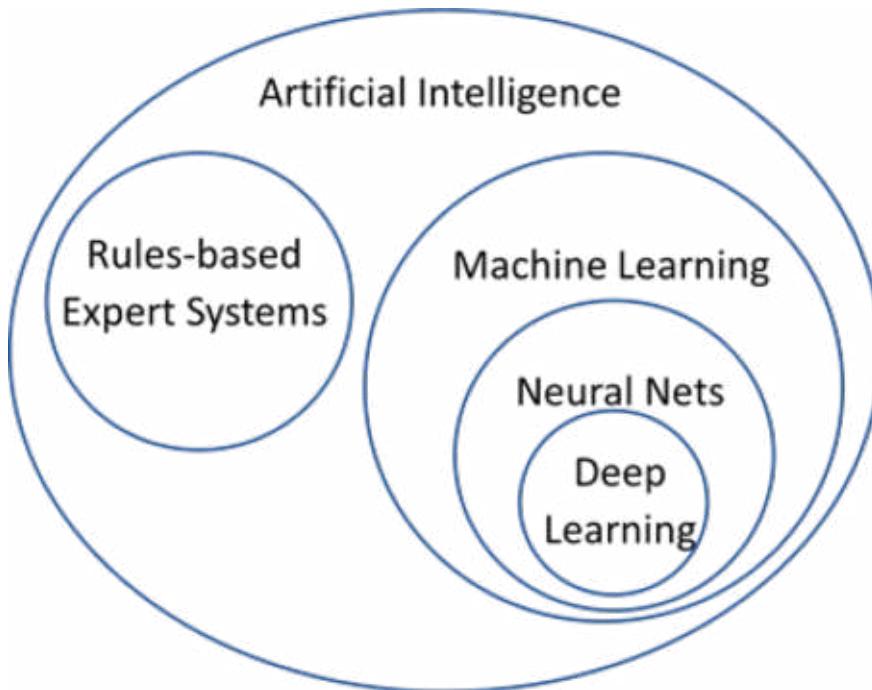
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Assistant Professor, Department of Biomedical Data Science, School of Applied Computational Sciences,  
Meharry Medical College

AMS Fellow in Compassion and Artificial Intelligence, 2022

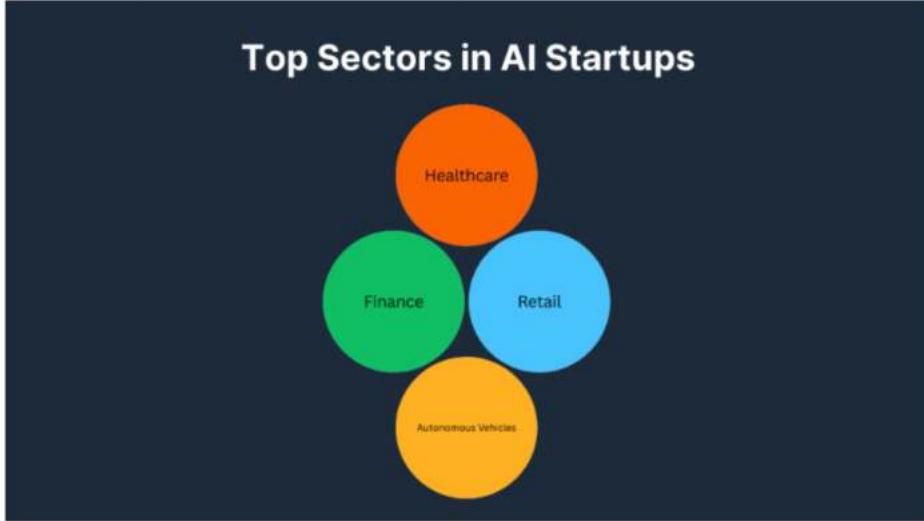


# AI vs ML vs DL



- In its simplest definition AI is the computerized ability to perform tasks commonly associated with human intelligence for example reasoning, discovering patterns, generalizing knowledge and learning from experience.
- AI can be a misleading phrase though and maybe **simulated intelligence or even simulated decisions** might be a better description.

# AI in Healthcare



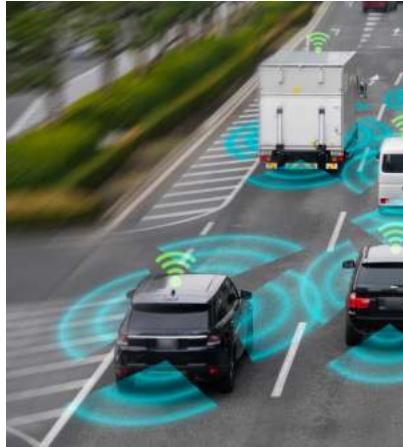
Top Sectors	Examples
Healthcare	Precision medicine, medical imaging
Finance	Fraud detection, risk modeling
Retail	Recommendation systems, inventory management
Autonomous Vehicles	Computer vision, predictive modeling

- **80% start-up fails.**

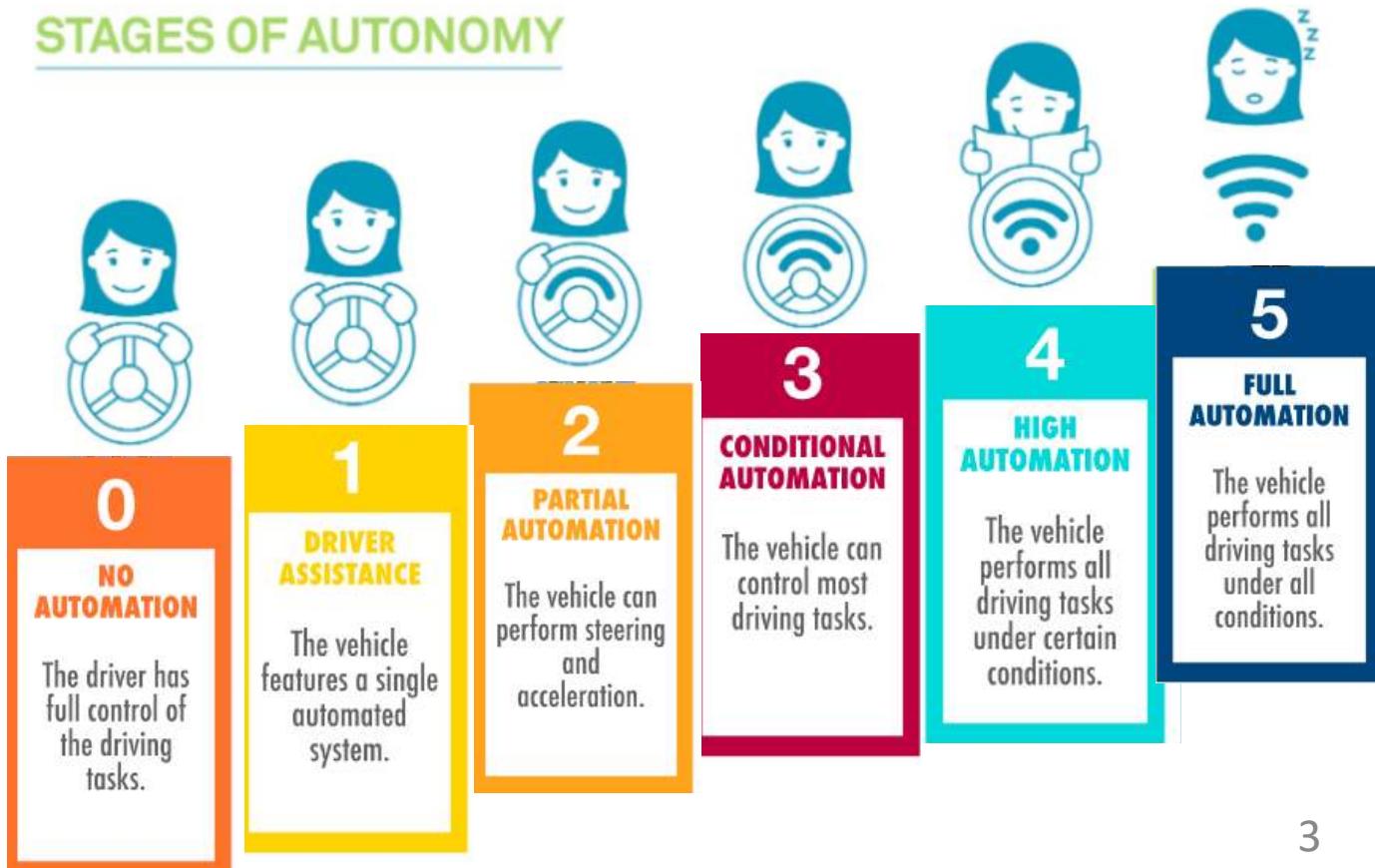
**WHY??**

- **When AI startups rush for quick profits, they may overlook crucial development stages.**
- **Many AI startups feel pressured to succeed quickly.**
- **Sustainable AI Technology.**

# AI in Healthcare – Analogy

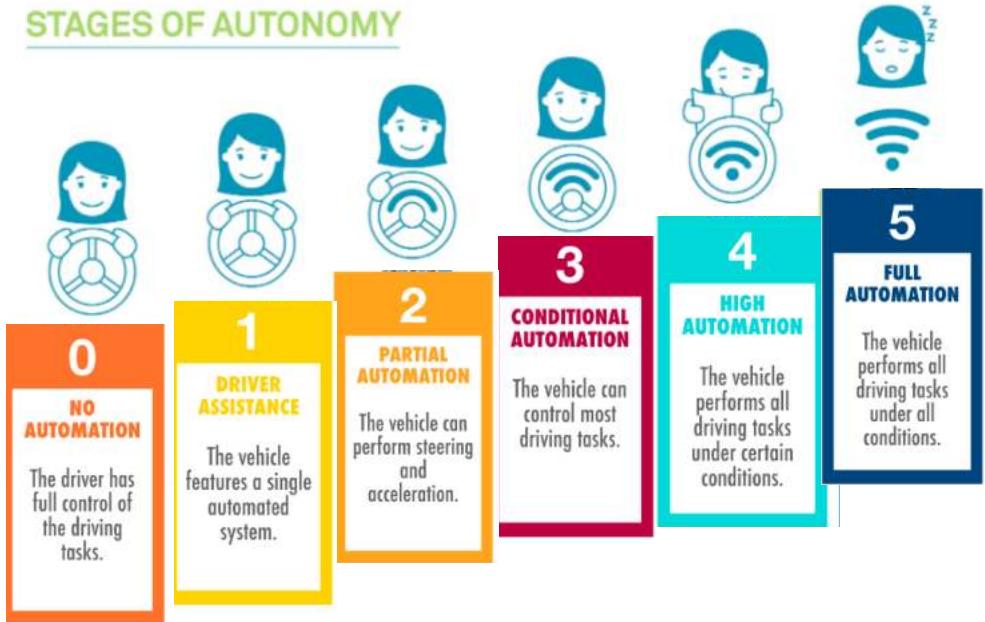


## STAGES OF AUTONOMY

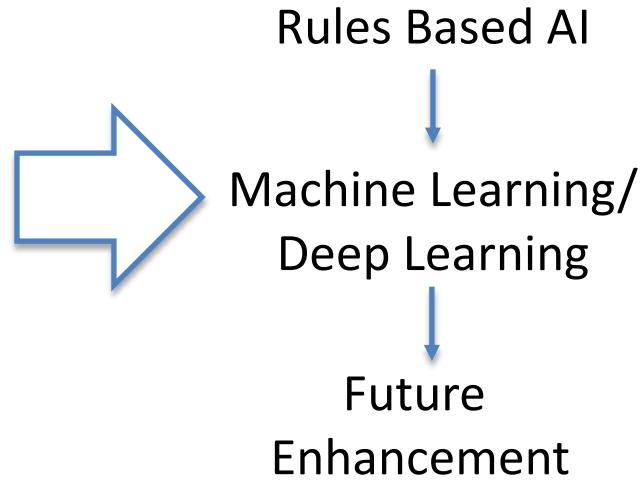


# AI in Healthcare – Analogy

## STAGES OF AUTONOMY



## AI in Health-Tech



# Chronic Diseases

Chronic diseases are defined broadly as conditions that last 1 year or more and require ongoing medical attention.

Six in ten adults in the US have a chronic disease and four in ten adults have two or more.



HEART  
DISEASE



CANCER



CHRONIC LUNG  
DISEASE



STROKE



ALZHEIMER'S  
DISEASE



DIABETES

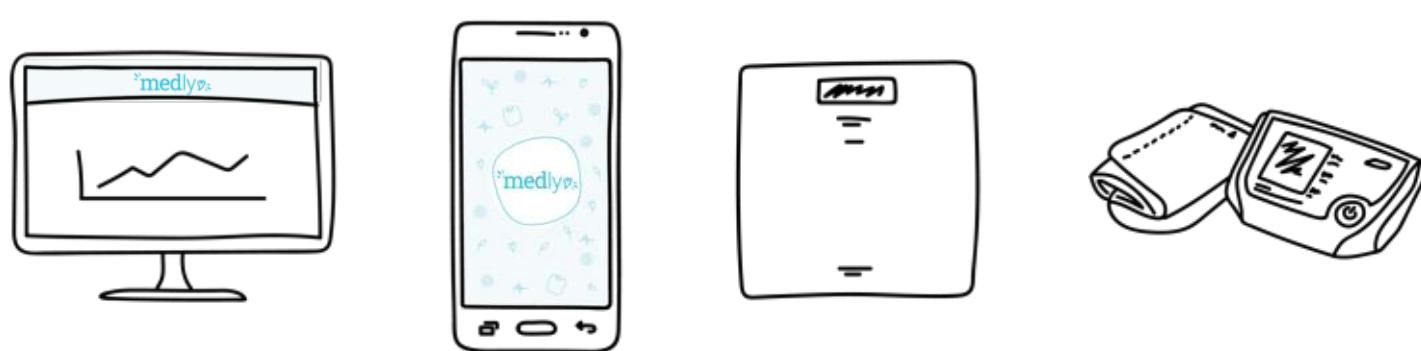


CHRONIC  
KIDNEY DISEASE

- Leading causes of death and disability in the United States.
- Annual health care costs: **\$4.1 trillion**



for  
**Heart Failure Management**

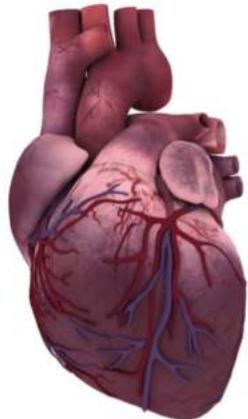


# Heart Failure Management

## ***Heart Failure***

1 the inability of the heart to pump adequately to meet the needs of the body

- 1 in 5 people over 40 will develop HF
- 1 in 2 people have been touched by HF
- Average life expectancy 2.1 years
- 40-50% will die within 5 years of diagnosis
- 80% will die within 10 years of diagnosis
- Heart failure was a contributing cause of 1 in 8 deaths in 2017



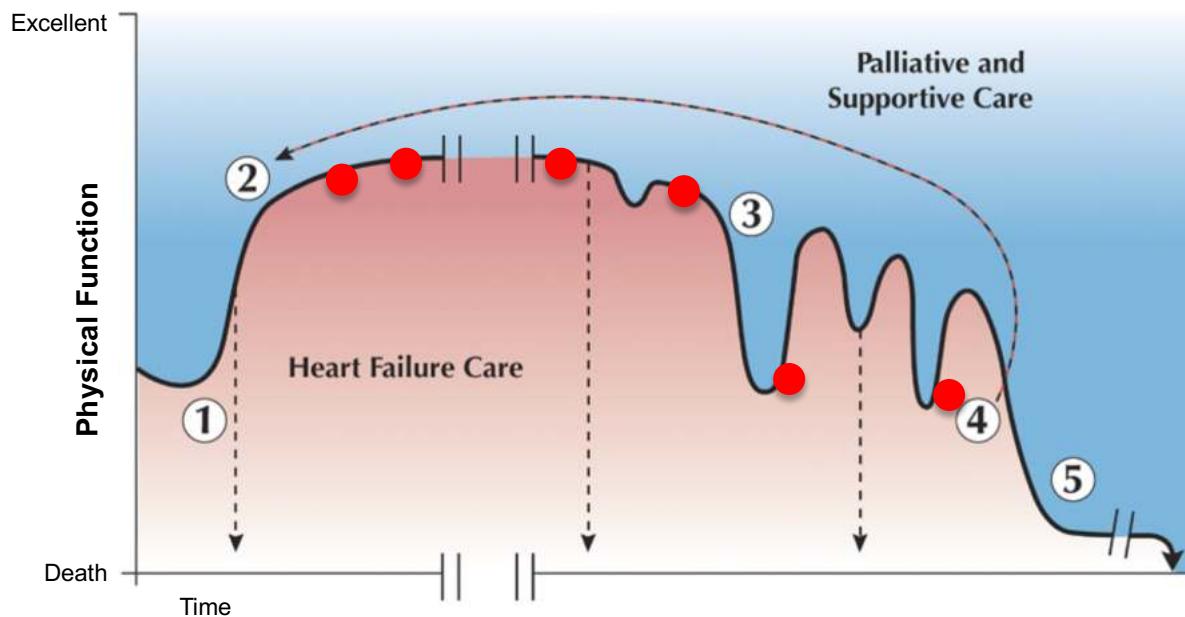
Benjamin EJ, et al. Heart disease and stroke statistics—2019 update: a report from the American Heart Association. *Circulation*. 2019;139(10):e56–528. 2)Centers for Disease Control and Prevention, National Center for Health Statistics. [Underlying Cause of Death, 1999–2017](#).

# Heart Failure Management

## Problem Statement:

Physicians provide care in episodes, at scheduled visits at distinct points in time.

It would be blind luck for physician if a patient would actually have an worsening of Heart Failure ( Decompensated HF) at their routine visit.



# Solution: MEDLY

The evidence-based Medly Program, developed at the University Health Network (UHN), goes beyond traditional remote patient monitoring by merging an advanced and low-cost digital tool with clinical best practices to deliver a **comprehensive model of heart failure care**.

The Medly software was developed using an Agile development process and meets **ISO 13485 quality management standards**.

Medly is **licensed by Health Canada as a Class II Medical Device**.



Health  
Canada

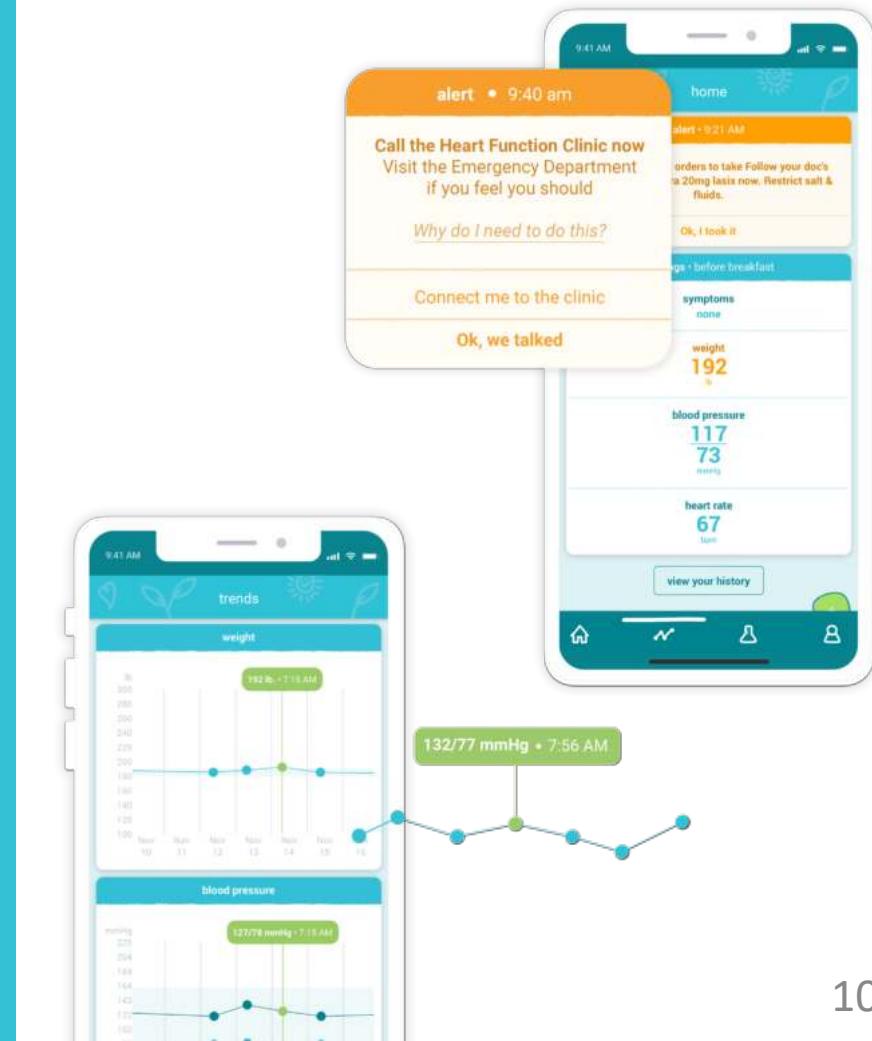
LN/NH: 104447

Santé  
Canada



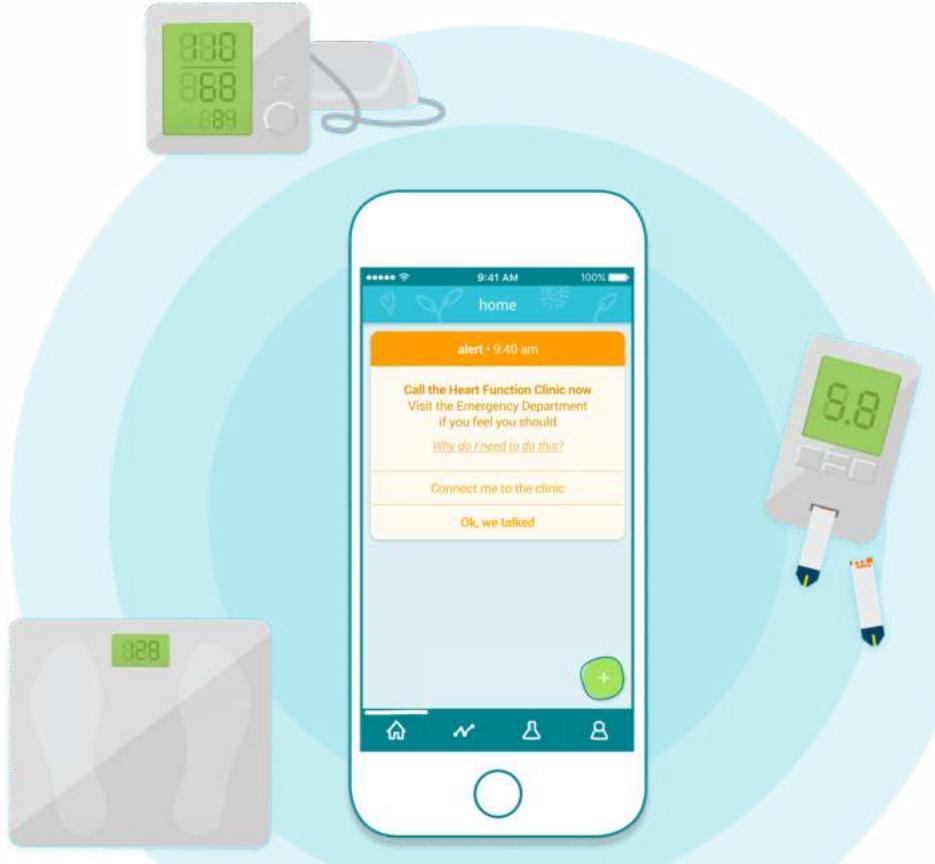
# Patient Application

- Enter daily measurements of weight, blood pressure, heart rate, and symptoms
- Receive instant feedback through the in-app Medly algorithm, which compares readings against personalized thresholds
- Monitor your health status through reviewing trends, laboratory data, and alert history



**Helping patients monitor their symptoms and measurements, and provide self-care guidance, all at home.**

- Chronic heart failure
- Receive feedback and instructions from their healthcare team
- Bluetooth enabled peripheral devices
- Integrates seamlessly with Apple Health



# Daily Measurements

## Take daily morning measurements

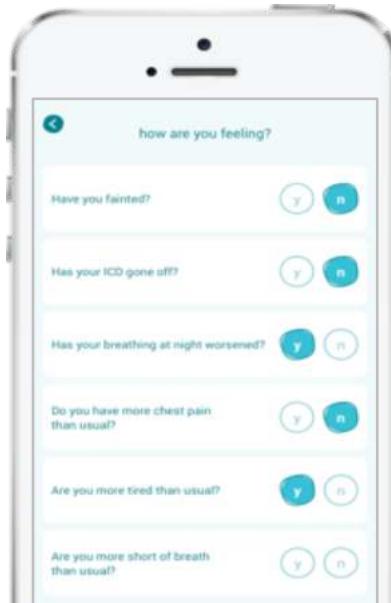
View instructions to take readings and health information at a glance.



## Answer Symptom Tracking

### Questions

Questionnaires for self-monitoring.



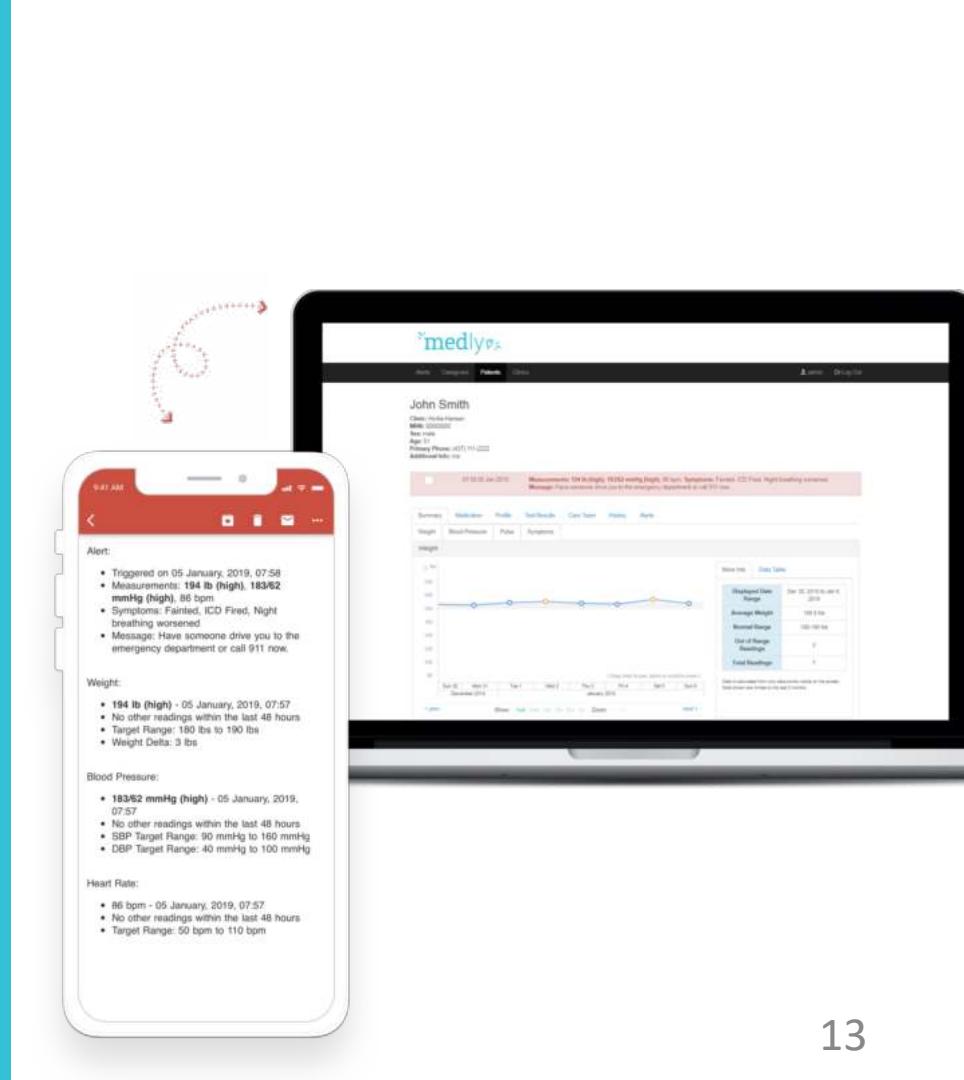
## Review trends

View trends and identify patterns.



# Clinician Dashboard

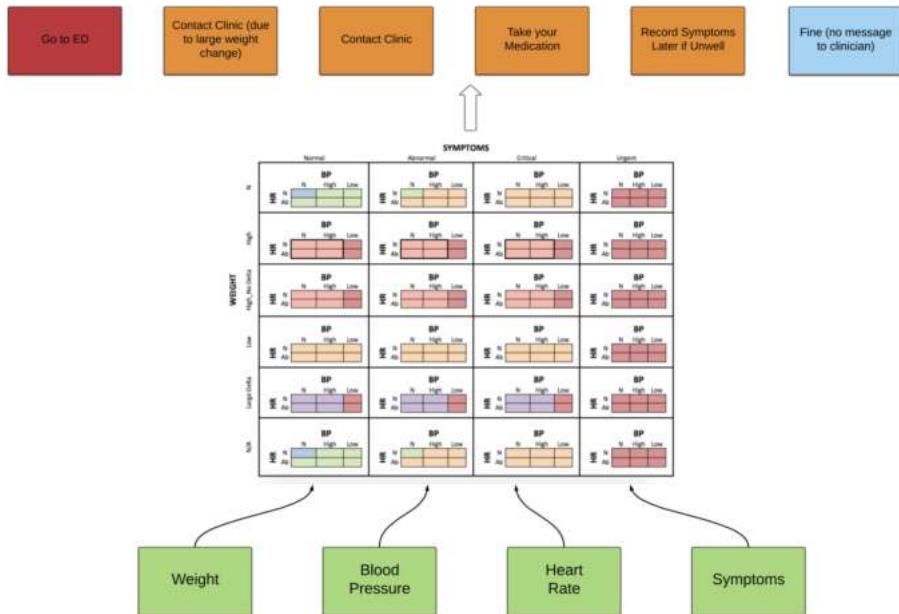
- Review the alerts centre to rapidly identify and respond to patients who have alerted through Medly
- Assess patient health status through the patient profile (e.g. thresholds, medication list, lab data and historical trends)
- Review critical alerts and communications from the patient care team through secure email



# Medly Algorithm

The Medly algorithm is a rules-based expert system that was developed and vetted by heart failure clinicians at UHN.

- Analyzes the vitals taken by the patients and generates self-care feedback messages based on individualized patient thresholds
- Parameters that fall outside the threshold alert clinicians to assess for further clinical intervention

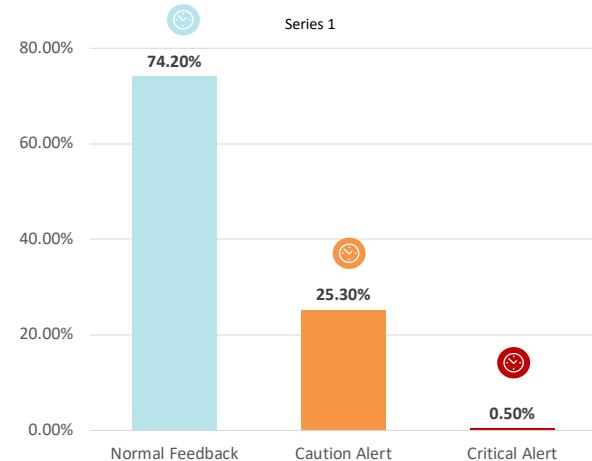


# Medly Algorithm

The Medly algorithm is a rules-based expert system that was developed and vetted by heart failure clinicians at UHN.

- Because of this advanced clinical decision support tool, our clinicians are able to prioritize or focus on the patients who either need immediate clinical care or those who may benefit from educational or clinical interventions
- The Medly software is licensed as **Health Canada Class II Medical Device**, due to its robust clinical evidence base and advanced clinical-decision support functionality.

## PATIENT ALERT STATES



Clinician review not required

Patient follows self-care instructions; clinician follow-up as needed

Triaged for immediate clinician follow-up

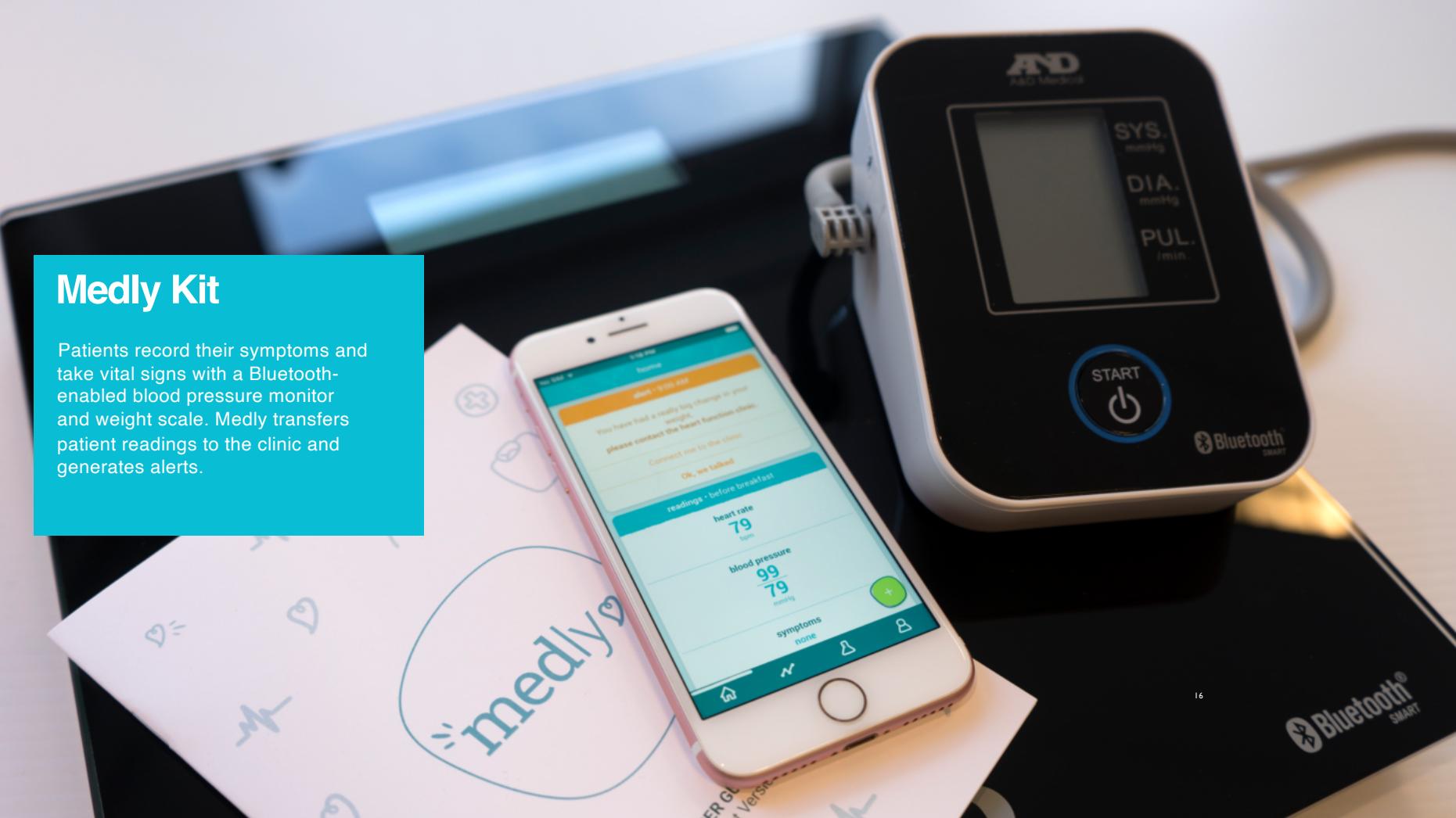


Health  
Canada  
LN/NH: 104447

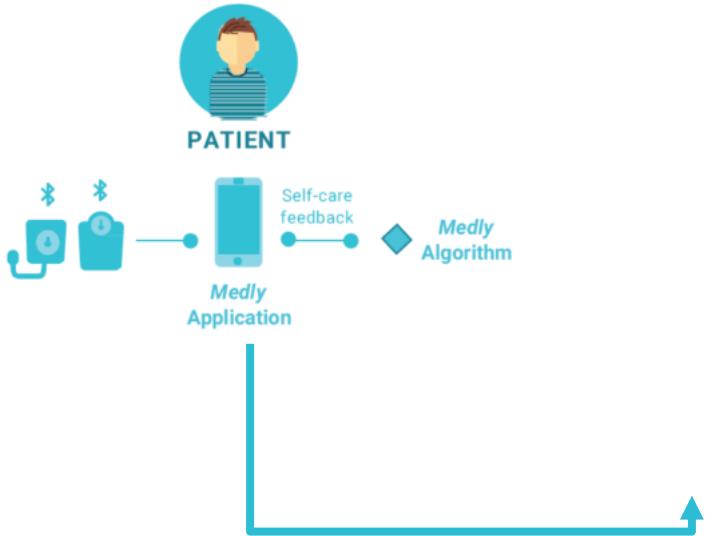
Santé  
Canada

## Medly Kit

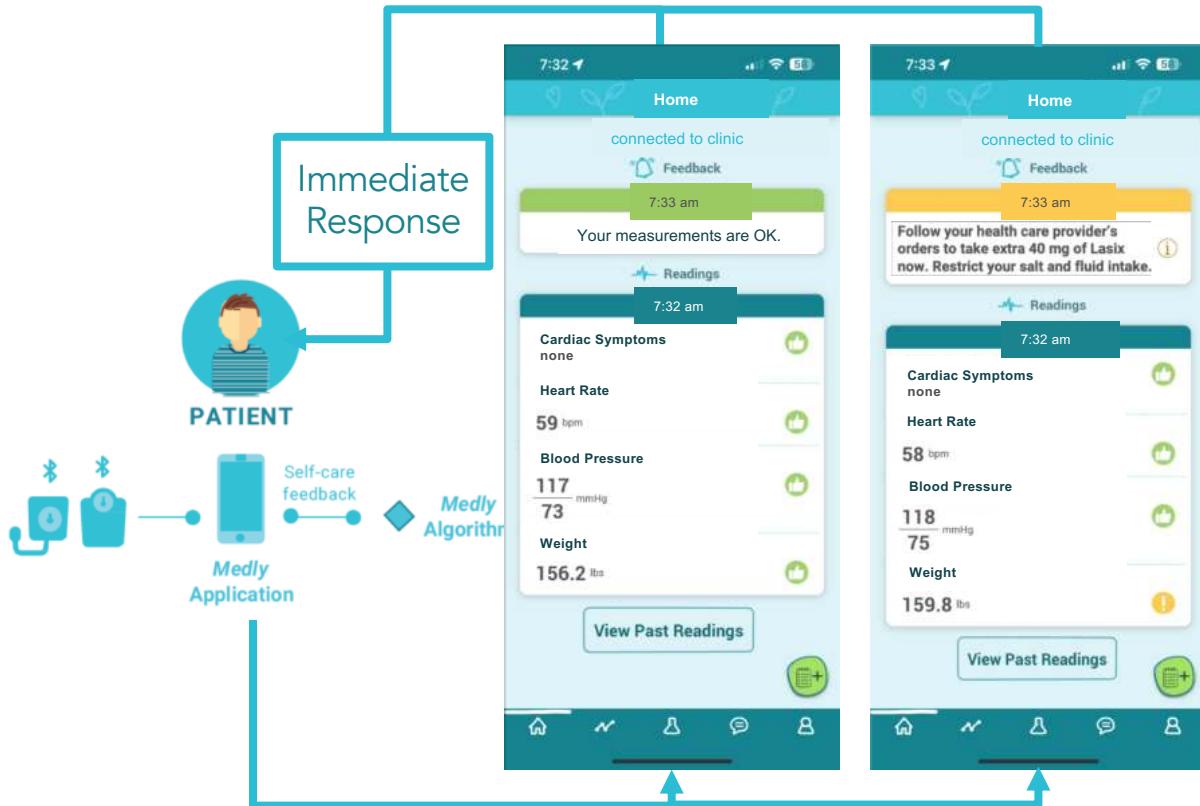
Patients record their symptoms and take vital signs with a Bluetooth-enabled blood pressure monitor and weight scale. Medly transfers patient readings to the clinic and generates alerts.



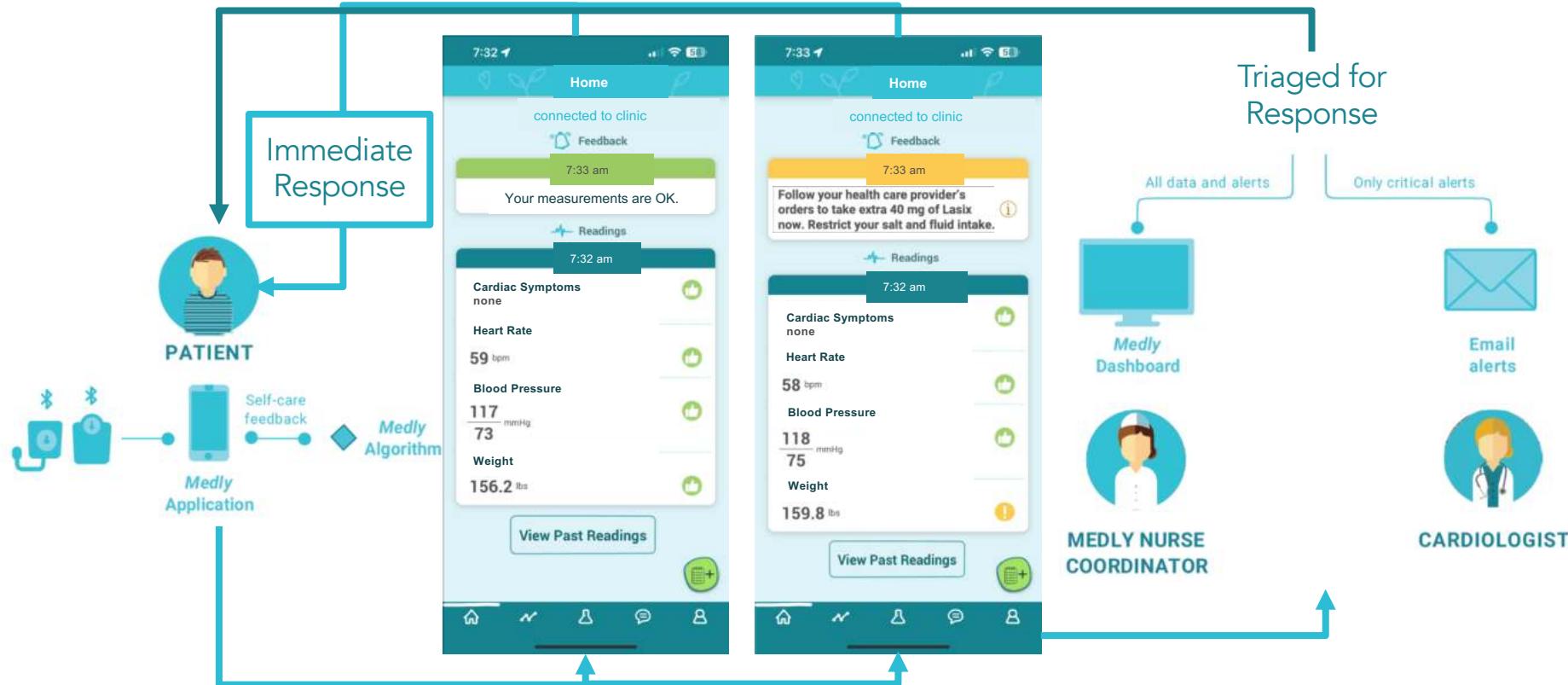
# Medly Model Overview:



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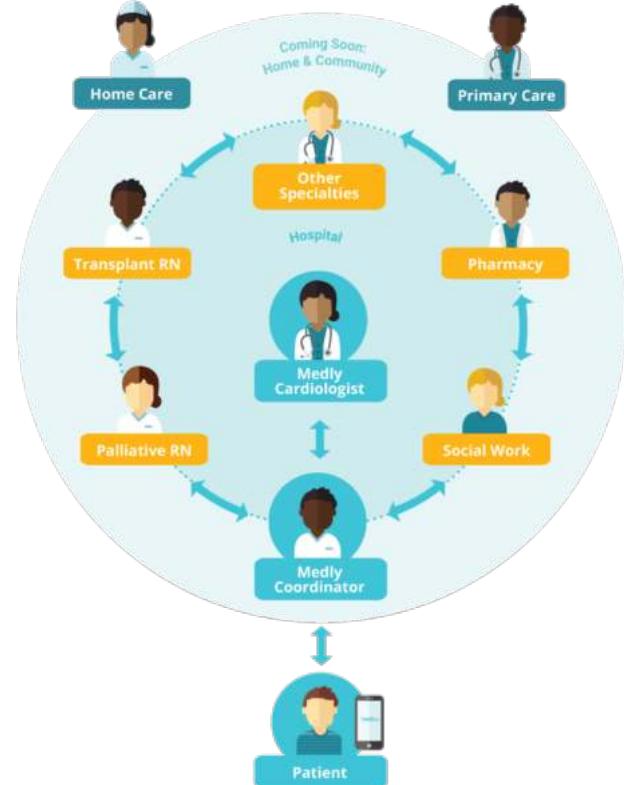
# Medly Model Overview:



# Model of Care Delivery

**1 Medly Nurse Coordinator is able to provide comprehensive care for up to 350 complex chronic patients.**

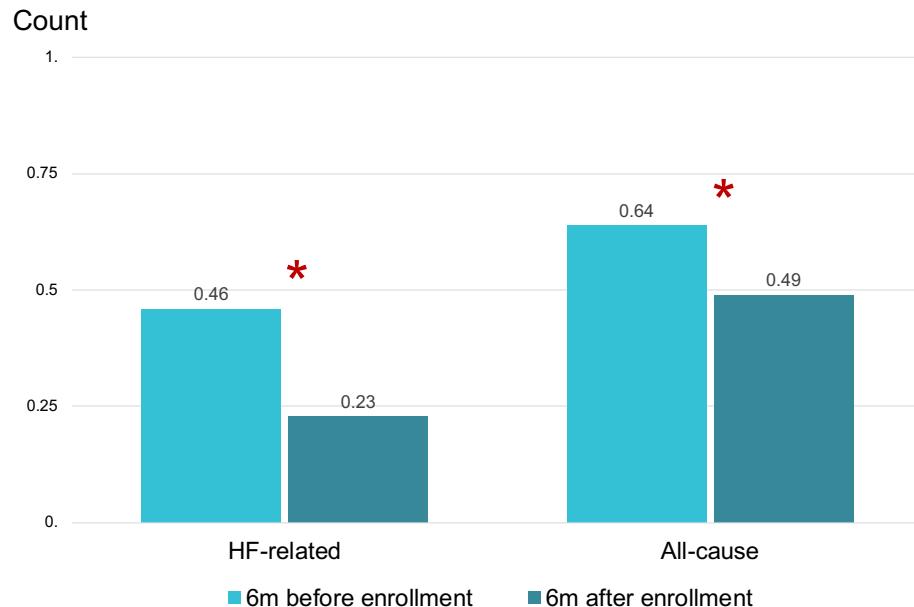
- Single point of contact for patients and caregivers
- Provides patient education and supports care navigation over the course of the Medly Program experience
- Care is coordinated amongst all hospital providers in the patient's circle of care
- The model leverages straightforward technology to improve the delivery of care



# Medly's Impact till Date

# HEALTH SERVICE UTILIZATION

## Number of Hospitalizations



\* Statistically significant change ( $P < .05$ )

## INTERPRETATION

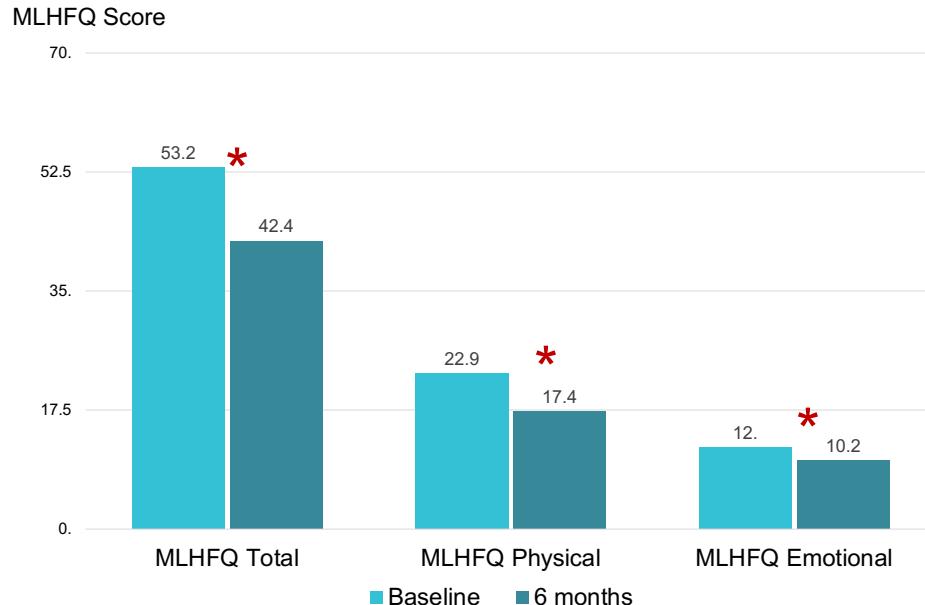
Enrollment in the Medly Program resulted in  
a:

- ✓ **50 % reduction** in heart failure-related hospitalizations
- ✓ **24% reduction** in all-cause hospitalizations

Ware P et al.. Outcomes of a Heart Failure Telemonitoring Program Implemented as the Standard of Care in an Outpatient Heart Function Clinic: Pretest-Posttest Pragmatic Study. J Med Internet Res 2020;22(2):e16538;

# QUALITY OF LIFE

## Minnesota Living with Heart Failure Questionnaire (MLHFQ)



### INTERPRETATION

Enrollment in the Medly Program resulted in an improvement in:

- ✓ **Overall** heart failure-related quality of life
- ✓ **Physical** heart failure-related quality of life
- ✓ **Emotional** heart failure-related quality of life

Ware P et al.. Outcomes of a Heart Failure Telemonitoring Program Implemented as the Standard of Care in an Outpatient Heart Function Clinic: Pretest-Posttest Pragmatic Study. J Med Internet Res 2020;22(2):e16538;

\* Statistically significant change ( $P < .05$ )

# SELF-CARE

## Self-Care of Heart Failure Index (SCHFI)



\* Statistically significant change ( $P < .05$ )

## INTERPRETATION

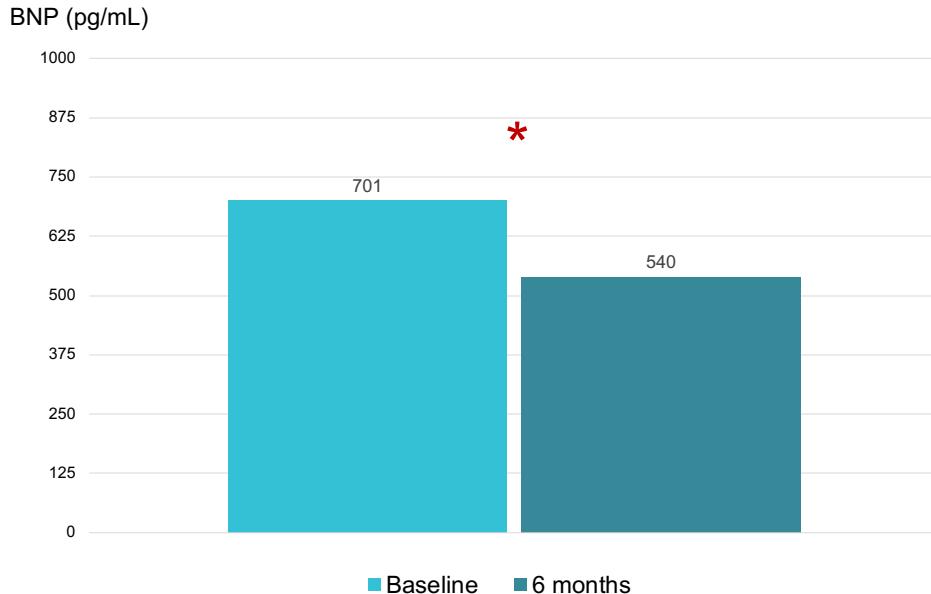
Enrollment in the Medly program resulted in an improvement in:

- ✓ **Self-care maintenance** (behaviours aimed at maintaining physiologic stability)
- ✓ **Self-care management** (behavioural response to symptoms when they occur)

Ware P et al.. Outcomes of a Heart Failure Telemonitoring Program Implemented as the Standard of Care in an Outpatient Heart Function Clinic: Pretest-Posttest Pragmatic Study. J Med Internet Res 2020;22(2):e16538;

# PROGNOSTIC INDICATORS

## B-Type Natriuretic Peptide (BNP)



\* Statistically significant change ( $P < .05$ )

## INTERPRETATION

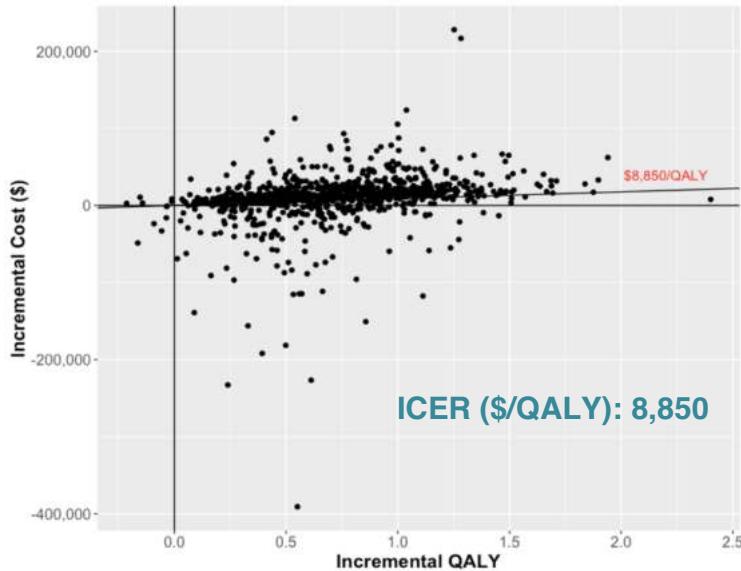
Enrollment in the Medly Program resulted in a:  
✓ 59% decrease in BNP<sup>1</sup> values.

<sup>1</sup> BNP is secreted by the heart in response to stretch from pressure or volume overload. It is a key HF prognostic indicator, with higher levels being associated with an increased risk of mortality and hospitalization.

Ware P et al.. Outcomes of a Heart Failure Telemonitoring Program Implemented as the Standard of Care in an Outpatient Heart Function Clinic: Pretest-Posttest Pragmatic Study. J Med Internet Res 2020;22(2):e16538;

# MEDLY'S IMPACT: COST-EFFECTIVENESS

## Cost-utility plane



## INTERPRETATION

The Medly program is cost-effective compared to standard care\*

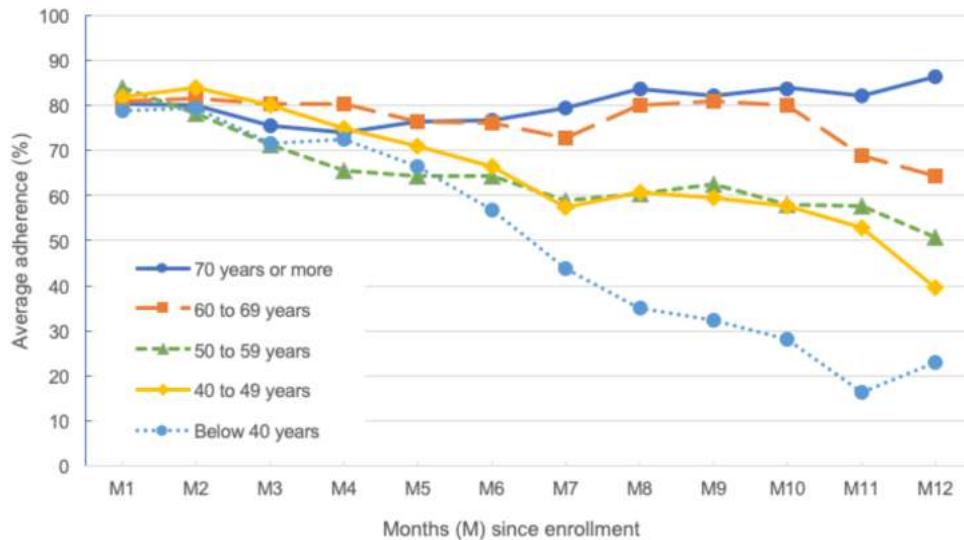
- ✓ High probability (90%) of being cost-effective
- ✓ Cost-effectiveness improves in cohorts with more advanced HF
- ✓ Cost-effectiveness improves as more patients use their own devices

Boodoo C , Qi Z, Ross HJ, Alba, AC., Laporte A, Seto E, Evaluation of the cost-utility of a heart failure telemonitoring program through a microsimulation model. J Med Internet Res 2020 (In Press)

Functional Class	Prob. of cost-effectiveness	ICER (\$/QALY)	Deployment model	Prob. of cost-effectiveness	ICER (\$/QALY)
NYHA I	90.5%	10,567	BYOE	92.9%	3,349
NYHA II	90.6%	8,510	Mixed	91.7%	5,780
NYHA III	90.5%	5,931	Full Kit	85.4%	15,362

# PATIENT EXPERIENCE

## Adherence to daily readings



## INTERPRETATION

- ✓ Patients took, on average, 74% of their expected morning readings throughout their enrollment in the program, up to 1 year
- ✓ Older patients maintained high adherence throughout enrollment with adherence levels dropping over time for younger age groups

Ware P, Dorai M, Ross HJ, Cafazzo JA, Laporte A, Boodoo C, Seto E. Patient Adherence to a Mobile Phone-Based Heart Failure Telemonitoring Program: A Longitudinal Mixed-Methods Study. JMIR Mhealth Uhealth 2019;7(2):e13259

# A Decade of Evidence

## 2020

Hearn J, Pham Q, Schwartz JI, Ssinabulya I, Akiteng AR, Ross HJ, Cafazzo JA. **Lived Experiences and Technological Literacy of Heart Failure Patients and Clinicians at a Cardiac Care Centre in Uganda.** Annals of Global Health. 2020;86(1)

Boodoo C , Qi Z, Ross HJ, Alba, AC, Laporte A, Seto E, **Evaluation of the cost-utility of a heart failure telemonitoring program through a microsimulation model.** J Med Internet Res 2020 (In Press)

Ware P, Ross HJ, Cafazzo JA, Boodoo C, Munnery M, Seto E. **Outcomes of a Heart Failure Telemonitoring Program Implemented as the Standard of Care in an Outpatient Heart Function Clinic: Pretest-Posttest Pragmatic Study.** J Med Internet Res 2020;22(2):e16538

## 2019

Ware P, Dorai M, Ross HJ, Cafazzo JA, Laporte A, Boodoo C, Seto E. **Patient Adherence to a Mobile Phone-Based Heart Failure Telemonitoring Program: A Longitudinal Mixed-Methods Study.** JMIR Mhealth Uhealth 2019;7(2):e13259

Gordon K, Gray CS, Dainty KN, Ware P, DeLacy J, Seto E. **Exploring an Innovative Care Model and Telemonitoring for Complex Patient Management: A Qualitative Description Study.** JMIR Nurs. 2020;3(1):e15691.

Kirk V, Rac V, Ross H, Seto E. **Impact of Remote Titration Combined with Telemonitoring on the Optimization of Guideline Directed Medical Therapy for Patients with Heart Failure: Protocol for a Randomized Controlled Trial.** JMIR Research Protocols. (In Press)

Seto E, Ross H, Tibbles A, Wong S, Ware P, Etchells E, Kobulnik J, Chibber T, Poon S. **A Mobile Phone-Based Telemonitoring Program for Heart Failure Patients After an Incidence of Acute Decompensation (Medly-AID): Protocol for a Randomized Controlled Trial.** JMIR Res Protoc 2020;9(1):e15753

## 2017-18

Ware P, Ross HJ, Cafazzo JA, Laporte A, Gordon K, Seto E, **Evaluating the Implementation of a Mobile Phone-Based Telemonitoring Program: Longitudinal Study Guided by the Consolidated Framework for Implementation Research.** JMIR Mhealth Uhealth 2018;6(7):e10768

Seto E, Morita PP, Tomkun J, Lee TM, Ross H, Reid-Haughian C, Kaboff A, Mulholland D, Cafazzo JA. **Implementation of a Heart Failure Telemonitoring System in Home Care Nursing: Feasibility Study.** JMIR medical informatics. 2019;7(3):e11722.

Ware P, Ross HJ, Cafazzo JA, Laporte A, Seto E. **Implementation and Evaluation of a Smartphone-Based Telemonitoring Program for Patients With Heart Failure: Mixed-Methods Study Protocol.** JMIR Res Protoc 2018;7(5):e121

Ware P, Ross HJ, Cafazzo JA, Laporte A, Gordon K, Seto E. **User-Centered Adaptation of an Existing Heart Failure Telemonitoring Program to Ensure Sustainability and Scalability: Qualitative Study.** JMIR Cardio 2018;2(2):e11466

Seto E, Ware P, Logan AG, Cafazzo JA, Chapman KR, Segal P, Ross HJ. **Self-Management and Clinical Decision Support for Patients With Complex Chronic Conditions Through the Use of Smartphone-Based Telemonitoring: Randomized Controlled Trial Protocol.** JMIR Res Protoc 2017;6(11):e229

## 2012 and earlier

Seto E, Leonard KJ, Cafazzo JA, Barnsley J, Masino C, Ross HJ. **Mobile Phone-Based Telemonitoring for Heart Failure Management: A Randomized Controlled Trial.** J Med Internet Res 2012;14(1):e31

Seto E, Leonard KJ, Cafazzo JA, Barnsley J, Masino C, Ross HJ. **Perceptions and Experiences of Heart Failure Patients and Clinicians on the Use of Mobile Phone-Based Telemonitoring.** J Med Internet Res 2012;14(1):e25

Seto E, Leonard KJ, Cafazzo JA, Barnsley J, Masino C, Ross HJ. **Developing healthcare rule-based expert systems: case study of a heart failure telemonitoring system.** International journal of medical informatics. 2012;81(8):556-65.

Seto E, Leonard KJ, Masino C, Cafazzo JA, Barnsley J, Ross HJ. **Attitudes of Heart Failure Patients and Healthcare Providers towards Mobile Phone-Based Remote Monitoring.** J Med Internet Res 2010;12(4):e55

# Medly's Future Enhancements:

## Integration of Machine Learning

# Limitations of Current Medly Expert Based Systems: High number of False Positives/False Alarms

Conservative  
in nature

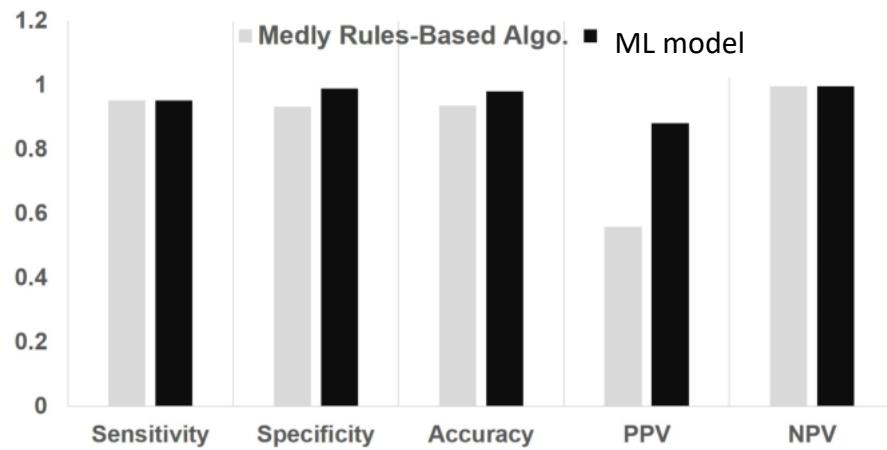
Reduced  
number  
of false  
negatives

Increases  
false alarms

Limited  
number of  
variables

**NEXT STEP: A machine learning model including EHR and Medly Data to reduce the false positives.**

# Medly – AI: Results



# Medly's Future Enhancements:

## Medication Management

# Heart Failure Medication Management

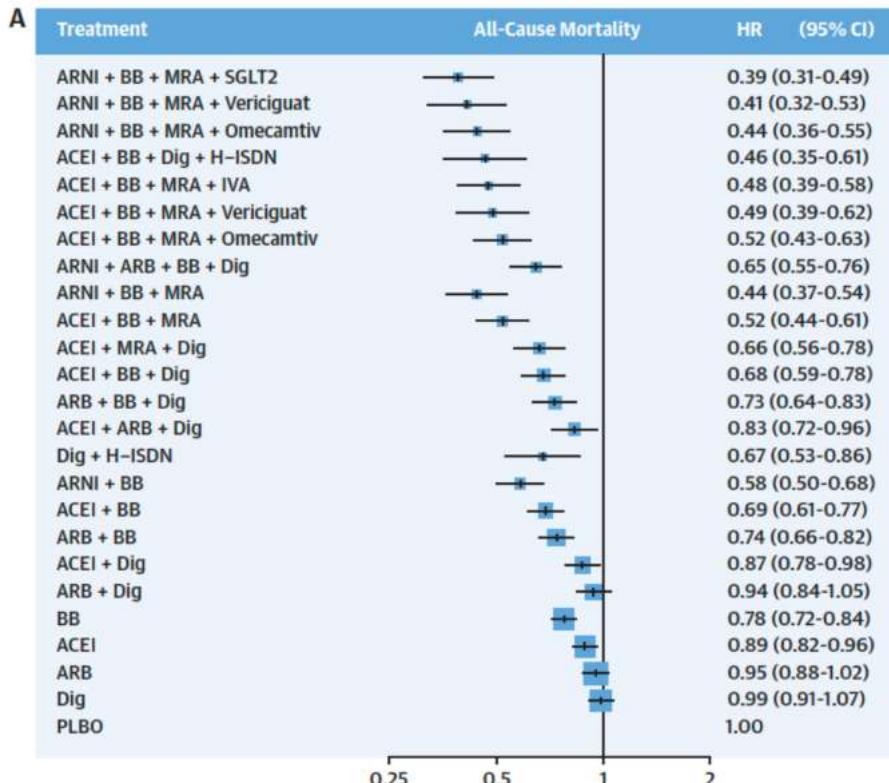
## Problem Statement:

Patients require 4 classes of Drugs.

However, Patient's cannot tolerate the optimum doses of the drug. Require a sequence to upscale the drugs, called titration.

The titration management is called Guideline Directed Medical Therapy (GDMT).

**CENTRAL ILLUSTRATION** Relative Risk Reduction of Different Pharmacological Treatment Combinations for Heart Failure

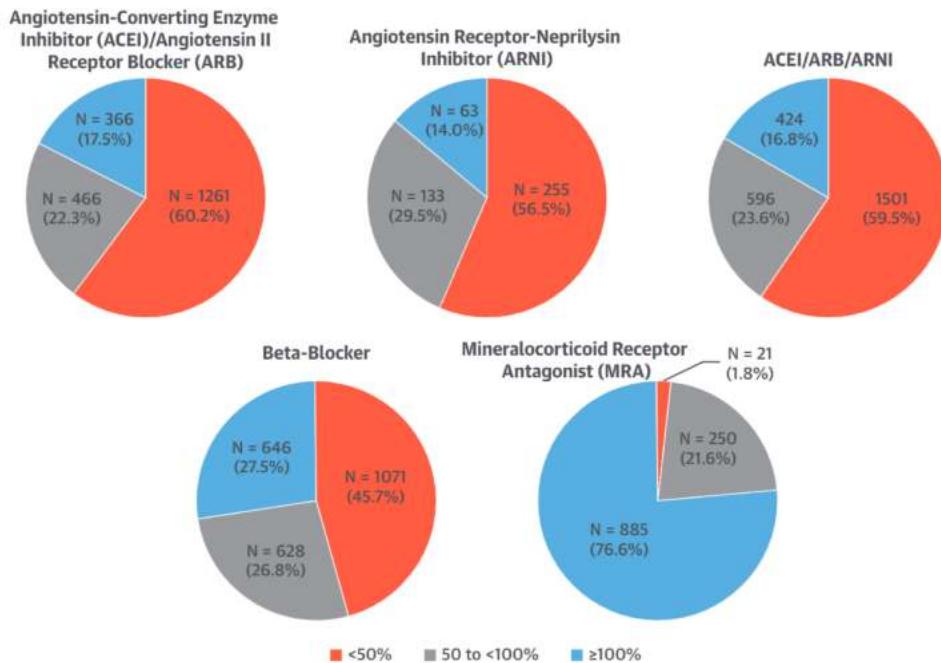


# Heart Failure Medication Management

## Problem Statement:

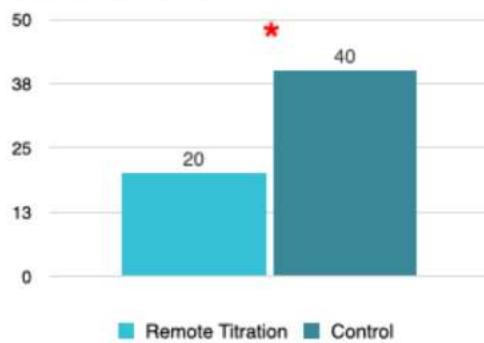
In current standard of practice, only 10-30% of population can reach the optimum doses of GDMT recommendation.

Even dire in historically marginalized communities population.



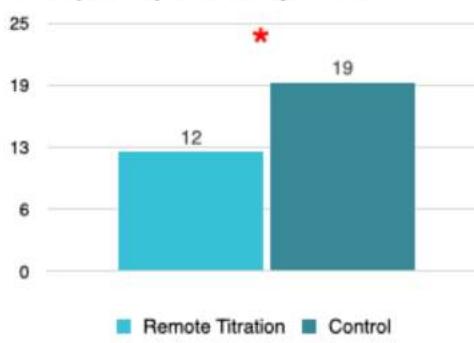
# MEDLY'S IMPACT: REMOTE TITRATION

# of in-clinic visits

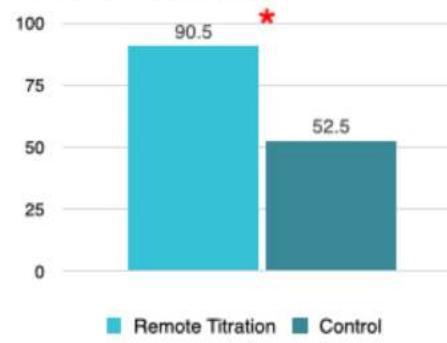


\* Statistically significant change ( $P < .05$ )

Time (weeks) to dose optimization



% of patients achieving target dose within 6 months



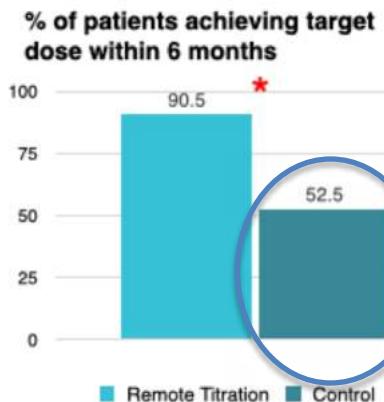
## INTERPRETATION

Remote titration using Medly was found to be **safe and effective** at:

- Reducing the number of in-person visits
- Increasing % of patients who achieved target dose in 6 months
- Reducing time to dose optimization

Artanian V, Ross HJ, Rac VE, O'Sullivan M, Brahmbhatt DH, Seto E. Impact of Remote Titration Combined With Telemonitoring on the Optimization of Guideline-Directed Medical Therapy for Patients With Heart Failure: Internal Pilot of a Randomized Controlled Trial. JMIR cardio. 2020;4(1):e21962.

# MEDLY'S IMPACT: REMOTE TITRATION



World's Best Hospitals 2022 - Top 250

Rank	Hospital	Country	City
1	Mayo Clinic - Rochester	United States	Rochester
2	Cleveland Clinic	United States	Cleveland
3	Massachusetts General Hospital	United States	Boston
4	Toronto General - University Health Network	Canada	Toronto
5	Charité - Universitätsmedizin Berlin	Germany	Berlin
6	The Johns Hopkins Hospital	United States	Baltimore
7	AP-HP - Hôpital Universitaire Pitié Salpêtrière	France	Paris
8	Karolinska Universitetssjukhuset	Sweden	Solna
9	UCLA Health – Ronald Reagan Medical Center	United States	Los Angeles
10	Sheba Medical Center	Israel	Ramat Gan

Artanian V, Ross HJ, Rac VE, O'Sullivan M, Brahmbhatt DH, Seto E. Impact of Remote Titration Combined With Telemonitoring on the Optimization of Guideline-Directed Medical Therapy for Patients With Heart Failure: Internal Pilot of a Randomized Controlled Trial. JMIR cardio. 2020;4(1):e21962.

# Medly's Future Enhancements:

## Voice Based Features

Welcome to "medly"

Step on the scale and tell me your weight.

Say, "Alexa, my weight is..."



# Medly's Future Enhancements:

## Introducing Large Language Model

# Heart Failure Virtual Assistant

MARY-Heart Failure Virtual Assistant

What is your job?

My job is to provide virtual assistance for heart failure management. I can answer questions related to heart failure and provide advice on how to manage the condition.

Ok. Tell me what is the biggest risk factor of HF?

The biggest risk factor of heart failure is coronary artery disease. Coronary artery disease is the accumulation of cholesterol plaque within artery walls. If cholesterol plaque occurs over an extended period, it can lead to chronic narrowing in the arteries, restricting the flow of blood and oxygen to the heart muscle. This can lead to a weakened heart muscle, which can lead to heart failure.

How do I strengthen my heart muscle?

The best way to strengthen your heart muscle is to engage in regular aerobic exercise and strength or resistance training. Aerobic exercise can improve your cardiovascular fitness by improving how your body utilizes oxygen to give you energy. Moderate intensity aerobic exercise is best for the cardiovascular system. You can try brisk walking, swimming, cycling (either outdoor or on a stationary bike), water aerobics,

# Heart Failure Virtual Assistant

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Strength or resistance training improves muscle mass and tone and enhances quality of life. To add this type of training to your exercise routine, use light free weights (no more than 5-10 lbs.) or resistance bands and do short sessions of 10-20 repetitions with the light free weights, two to three times per week.

Joining a cardiac rehabilitation program is also an excellent way to learn how to exercise and is recommended for all patients with stable heart failure. Cardiac rehab will provide you with an 'exercise prescription' that is tailored to your health needs. While in cardiac rehab, you will be supervised during exercise and receive training on how to exercise safely, monitor your symptoms during exercise, and reach your individual exercise goals.

It is important to speak to your doctor before starting any exercise

# Heart Failure Virtual Assistant

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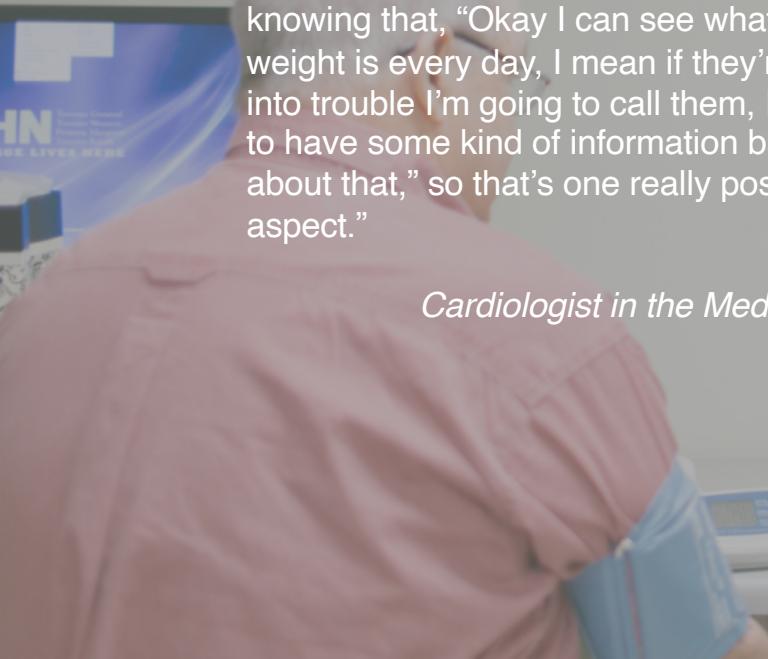
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It is important to speak to your doctor before starting any exercise

Ok. who is barak obama?

I'm sorry, I don't have any information about Barak Obama. I'm a virtual assistant for Heart Failure management and can only answer questions related to Heart Failure.



"If I think about patients who we've enrolled...they're often really sick patients and ... you're not sure how they're going to do, so there's a huge comfort for not only the patient and the family, but the clinician in knowing that, "Okay I can see what their weight is every day, I mean if they're running into trouble I'm going to call them, I'm going to have some kind of information back to me about that," so that's one really positive aspect."

*Cardiologist in the Medly Program*

"The program has been marvelous. It has given me, and my wife, the confidence of knowing day to day how my heart and body are doing, but also it encourages me to be more diligent about my health. I honestly don't know how I made it this far without Medly."



*Patient in the Medly Program*

# SUMMARY

## Key Take Away:

Rules based AI shows better health outcomes, through consistent, guideline-directed, evidence-based care

Enhancement of the Rules based AI shows should be implemented once there is an established impact on healthcare

Patient-Centered Design: People Benefit from digital treatment adoption

Higher compliance percentages

Creates enablement of patients and their families