Remote Patient Monitoring
Hospital-at-Home and other settings

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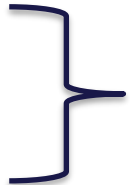Professor of Bioengineering and Biomedical Informatics

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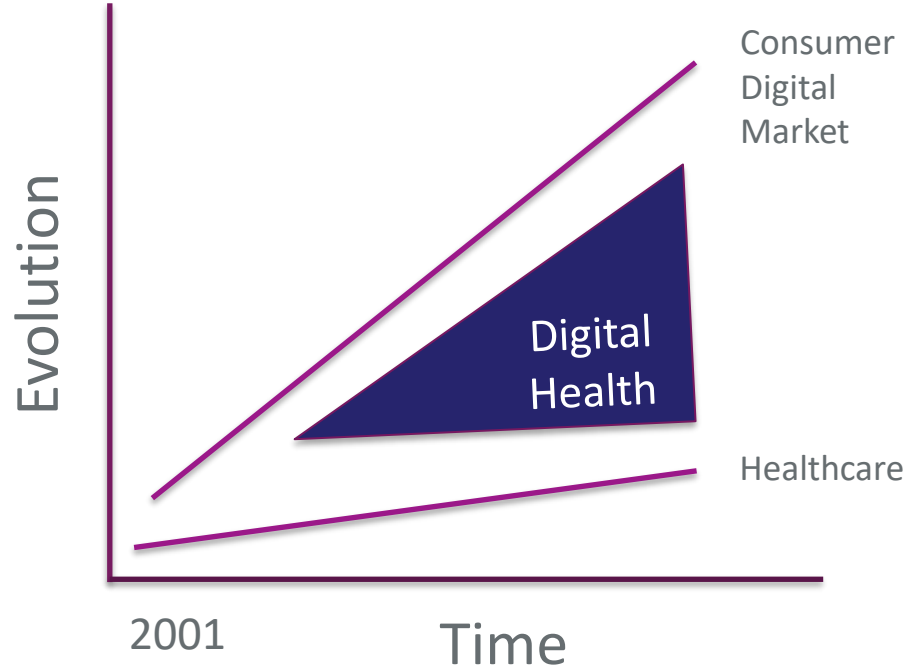
University of Pittsburgh and UPMC

Disclosures: Grants and Funding

- NIH R01-HL136836 (PI)
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- Sensydia Inc.
- EP Dynamics Inc.   Founder/Inventor/Board
- Hytek Medical Inc.

- Colle Capital Ventures, Venture Partner
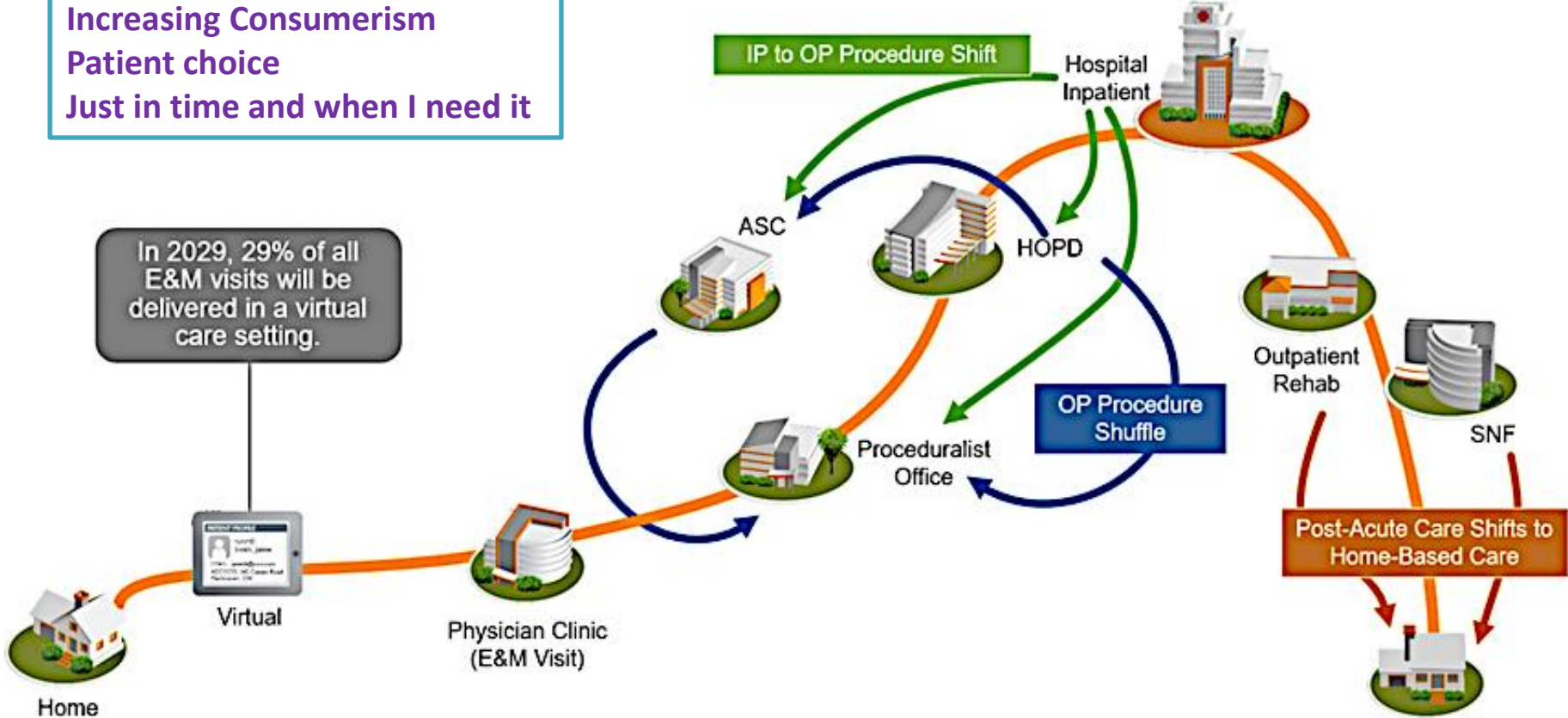- UPMC Enterprises (VC Investment Innovation group)

Technology revolution and Consumerism
Impact on Anesthesia, Surgery, Healthcare

Google Microsoft verizon

Are..

Wirelessly Connecting
Training
Speech enabling
Video linking
Analyzing

OUR VERY PATIENTS

Evolution

Consumer Digital Market

Digital Health

Healthcare

2001

Time

Digital Health: Telehealth, AI/Machine Learning, Robotics, Decision support systems, Wearables, *Remote Patient Monitoring*

Site of Care Shifts and Innovation Fuel Growth Trends Across Sites

**Increasing Consumerism
Patient choice
Just in time and when I need it**

IP to OP Procedure Shift

Hospital Inpatient

In 2029, 29% of all E&M visits will be delivered in a virtual care setting.

ASC

HOPD

OP Procedure Shuffle

Proceduralist Office

Outpatient Rehab

SNF

Post-Acute Care Shifts to Home-Based Care
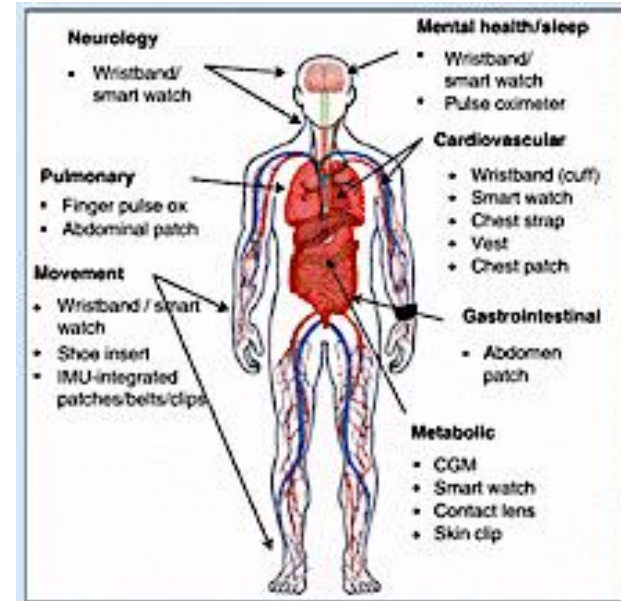
Virtual

Physician Clinic (E&M Visit)

Home

What is RPM?

In its simplest form, connected health electronic tools to record personal health and medical data in one location that is reviewed by a provider at a different location.

- Different from TeleHealth and Chronic Care Management (platform and patient Eligibility)

Sensors and Systems in RPM

Near future in Digital Tech: AI-Embedded Sensors for Advanced Monitoring and Care Delivery Improvement

## AI-embedded Wearable Biosensors for Hemodynamic and Cardiac Diagnostics

Automated Continuous Cardiac Diagnostics

Heart sound + ECG signals

↓

Machine learning algorithms

↓

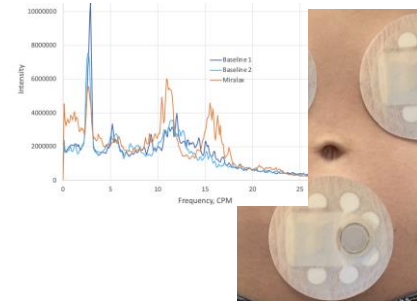| Ejection Fraction	Cardiac Output	Stroke Volume
Pulmonary Artery Pressure		Pulmonary Capillary Wedge Pressure

IEEE EMBS Proceedings. 2020 Jul:4067-4070

Cell phone enabled Blood Pressure for Remote and Ambulatory Monitoring
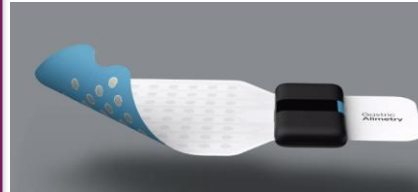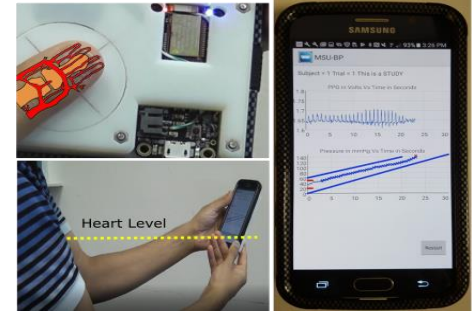
Gastric Alimetry for GI disorders

AI-enabled Voice Biomarker RPM for Mental Health

Cloud/5G and AI enabled miniaturized VR/AR smart glasses

Wearables and Remote Patient Monitoring Market Map

US Remote Patient Monitoring Users, 2020-2025
millions and % change

Legend: ■ Remote patient monitoring users ■ % change

Data:
- 2020: 29.1 (34.4%)
- 2021: 39.3 (35.3%)
- 2022: 45.1 (14.6%)
- 2023: 53.1 (17.8%)
- 2024: 60.6 (14.2%)
- 2025: 70.6 (16.4%)
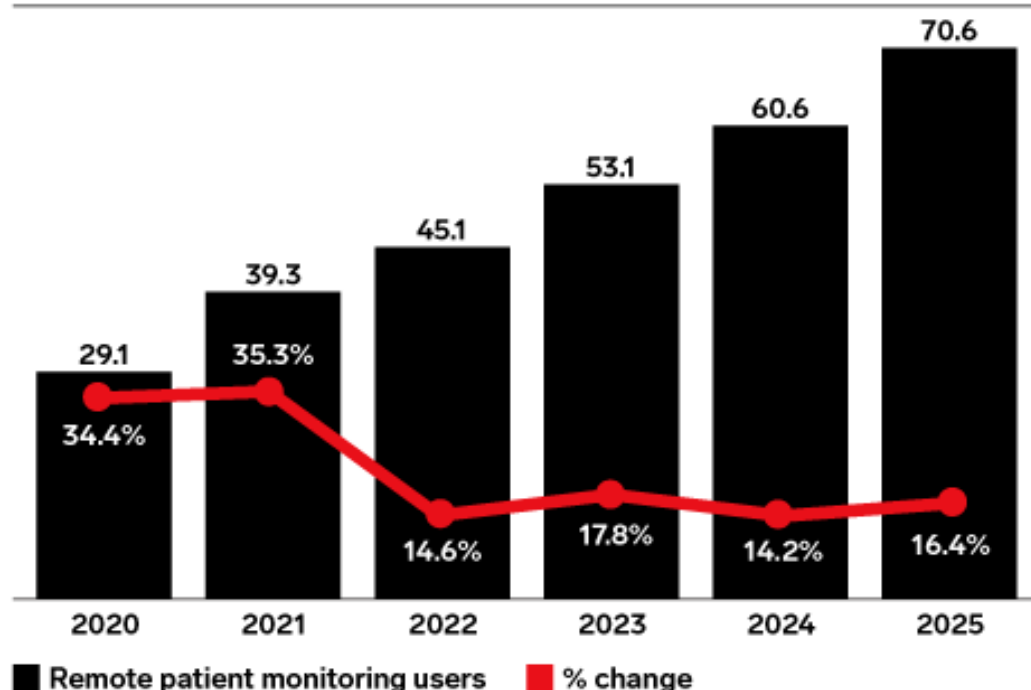
Note: individuals of any age who use wired or wireless devices that remotely track or collect well-being or medical data from the user outside a traditional healthcare setting at least once per month, and exchange it via the internet with electronic health records accessed by a medical professional or healthcare provider; includes wearable devices, home health devices, and sensors
Source: Insider Intelligence, Aug 2021

269585

InsiderIntelligence.com

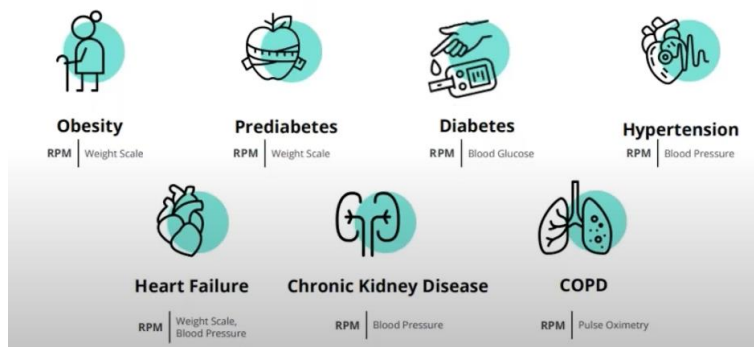**UPMC** LIFE CHANGING MEDICINE

Telehealth in 2020: Survey Data Show Widespread Use

Exhibit 1. Percentage of physicians whose practices have the following modalities and telehealth functions

	2018	2020
Any use of telehealth	25.1%	79.0%
Modalities used in the practice		
Videoconferencing with patients	14.3%	70.3%
Videoconferencing with another HCP	11.6%	26.2%
Store and forward of data	11.9%	13.1%
Remote patient monitoring (RPM)	10.4%	19.9%
Phone calls for patient visits	n/a	66.6%
Function of telehealth in the practice		
Second opinion from another HCP	6.9%	12.1%
Consultation with another HCP	11.3%	17.2%
Manage patients with chronic disease	9.9%	59.2%
Provide care to patients with acute disease	n/a	50.4%
Provide preventative care	n/a	34.3%
Diagnose or treat patients	15.6%	58.0%
After hours care or night calls	9.9%	22.4%

Source: Author's analysis of the AMA 2018 and 2020 Physician Practice Benchmark Surveys. Notes:

RPM used for both Chronic and Acute conditions that benefit from physiologic monitoring

Obesity
RPM | Weight Scale

Prediabetes
RPM | Weight Scale

Diabetes
RPM | Blood Glucose

Hypertension
RPM | Blood Pressure

Heart Failure
RPM | Weight Scale, Blood Pressure

Chronic Kidney Disease
RPM | Blood Pressure

COPD
RPM | Pulse Oximetry

COVID 19
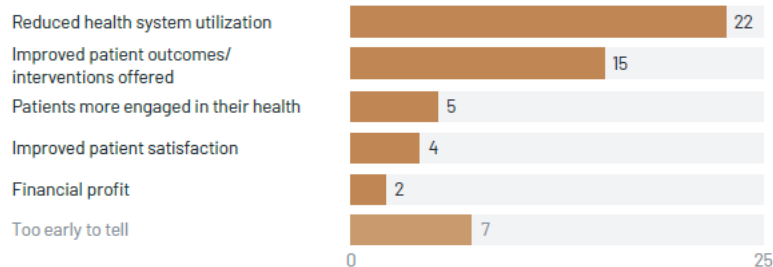
Other acute conditions
- Acute Heart failure
- infection
- Others

Post-ICU

Post-Surgical/Periop

Outcomes Achieved through RPM Organizations with a live RPM program; respondents could report multiple outcomes (n=37)

Outcome	Value
Reduced health system utilization	22
Improved patient outcomes/ interventions offered	15
Patients more engaged in their health	5
Improved patient satisfaction	4
Financial profit	2
Too early to tell	7

38% report reduced admissions
25% cited improved patient satisfaction
25% reported cost reductions.

https://klasresearch.com//962

UPMC LIFE CHANGING MEDICINE

Reasons for RPM Success

CONNECT.	**ENGAGE.**	**EDUCATE.**	**GUIDE.**	**MONITOR.**	**INTERVENE.**
Connect with patients using today's consumer and medical devices.	Engage with patients using captivating and intuitive programs.	Educate patients with current, relevant and informative content.	Guide patient behavior with outcomes-based clinical pathways.	Monitor and notify on patient biometrics, activity, and progress along prescribed pathways.	Intervene with patients using messaging, video or phone.

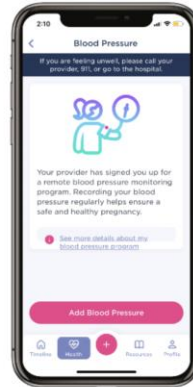|			
Patient Timely Diagnosis and outcomes; Satisfaction	Provider Satisfaction and Engagement	Hospital Capacity and Staffing	Interest from Payors, Costs and Outcomes

Significant Payor Interest in Promoting RPM

United Healthcare Launches Maternal Remote Patient Monitoring Program in Tennessee

STEP 1
Enroll

STEP 2
Monitor

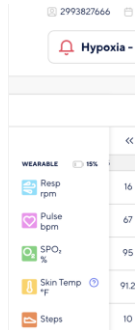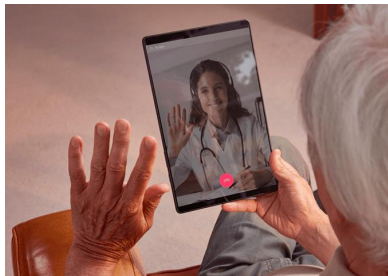STEP 3
Educate

STEP 4
Track

- Improve Quality Measures (i.e. HEDIS)
- Reduce the Cost of Maternity Care
- Avoid Complications for Mom and Baby
- Drive Better Compliance to Prenatal and Postpartum Care
- Target Social Determinants of Health

CMS Acute Care Hospital at Home Model (2020)

Patients admitted to the program from emergency departments and inpatient hospital beds

Hospital-level care at home with continuous and passive monitoring designed for high-acuity patients. Response to emergencies.
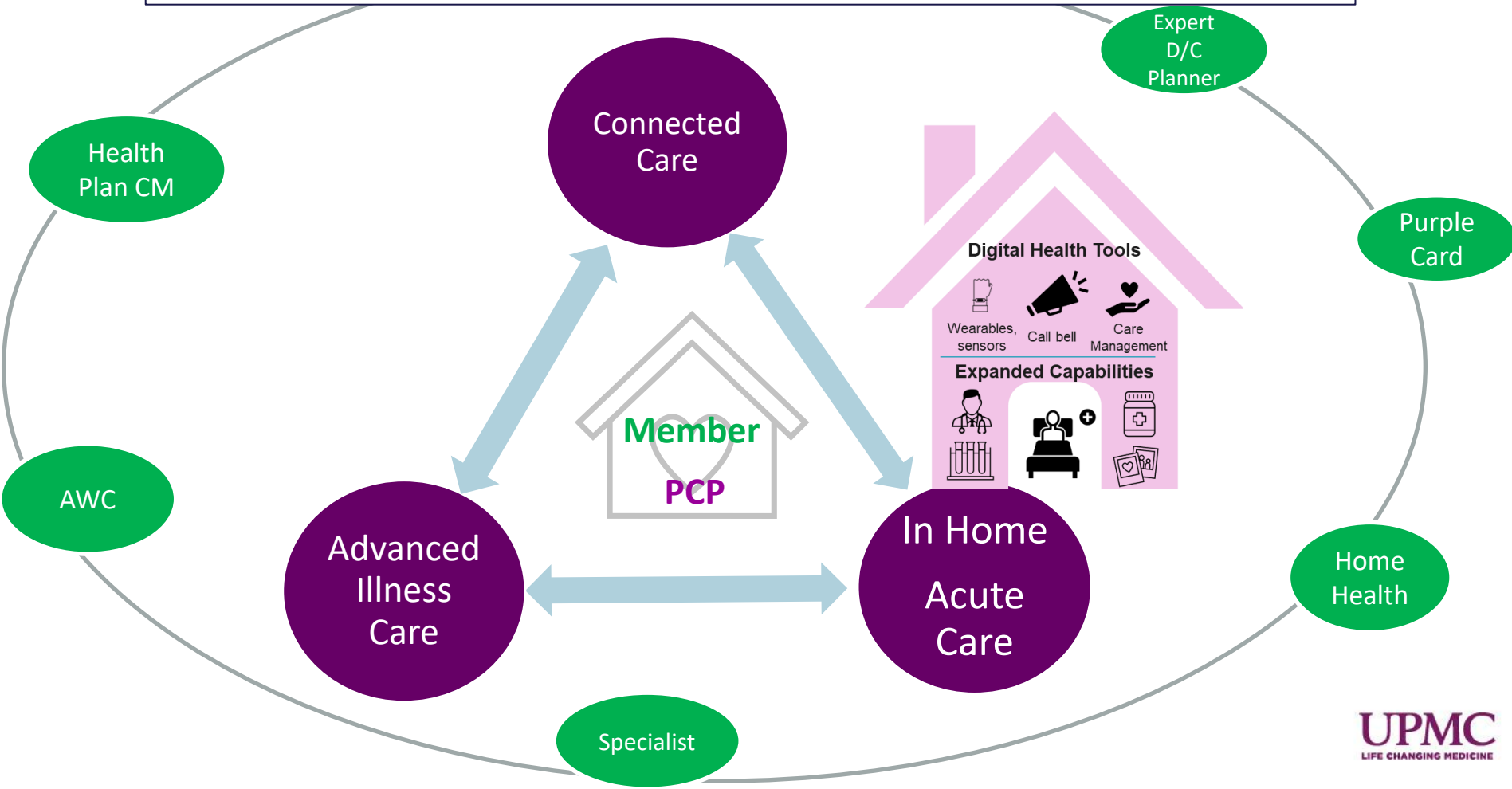

2993827666

🔔 Hypoxia -

WEARABLE ⬜ 15%

- Resp rpm — 16
- Pulse bpm — 67
- SPO₂ % — 95
- Skin Temp °F — 91.2
- Steps — 10

✔ **Pharmacy**

✔ **Infusion** (IV push and IV Piggyback infusions)

✔ **Respiratory care** (oxygen delivery, nebulizer treatment, etc.)

✔ **Diagnostics** (labs, radiology)

✔ **Monitoring with at least 2 sets of patient vitals daily**
(must include heart rate, blood pressure, respiratory rate, oxygen saturation, and temperature)

✔ **Transportation of patients**
(ambulance, non-ambulance medical transport, other)

✔ **Food services**
(including meal availability as needed by the patient)

✔ **Durable medical equipment**
(e.g., commode chair, walker, cane, hospital bed)

✔ **Physical, occupational, and speech therapy**
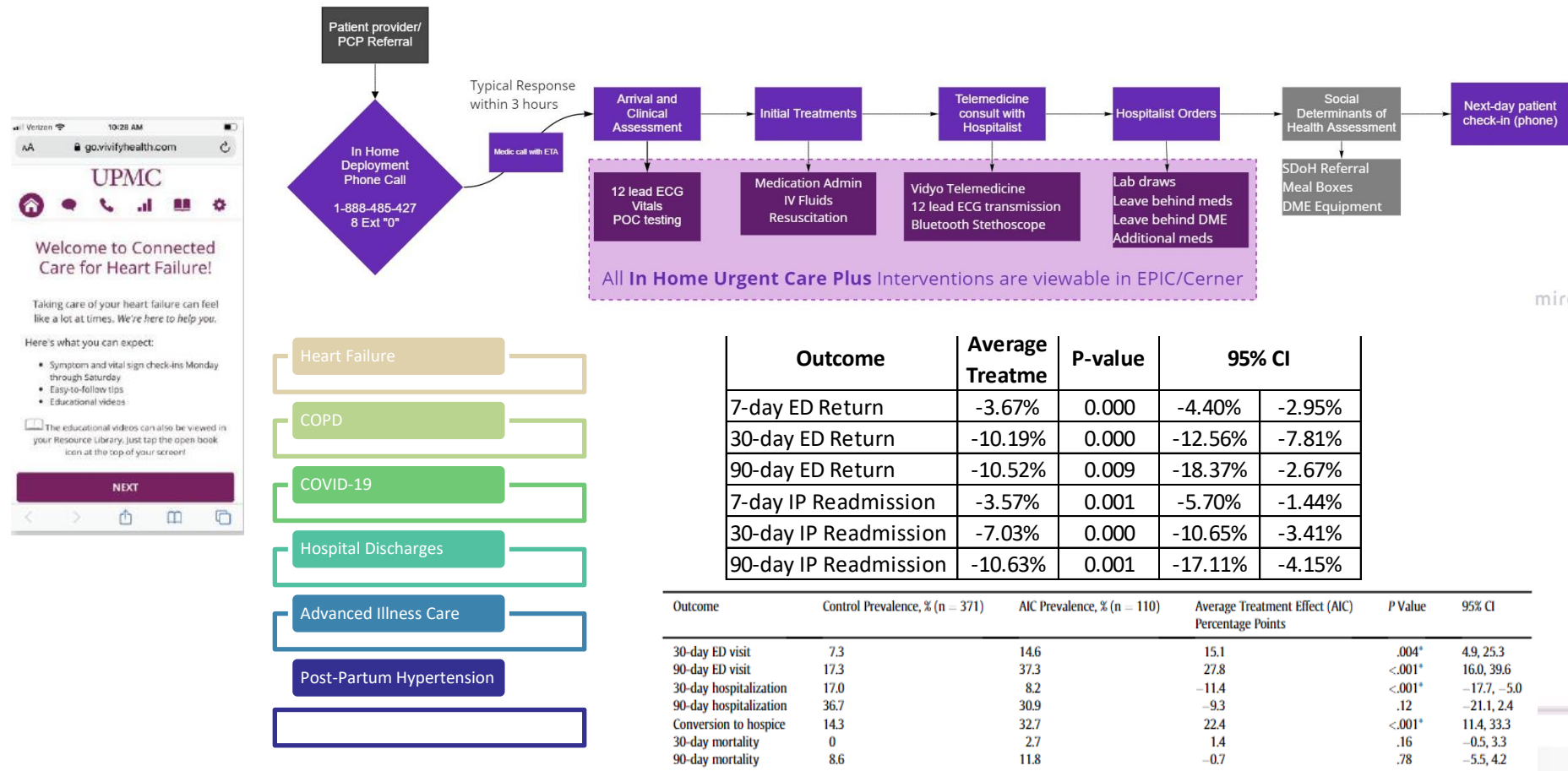
✔ **Social work and care coordination**

Deliver in-home services, as needed

Patients stay connected to their care teams with on-demand call/ video and messaging.

UPMC Innovative Homecare Solutions (UIHS) (501-3C)

Connected Care, AIC, In-Home Acute Care

Patient provider/ PCP Referral

Typical Response within 3 hours

In Home Deployment Phone Call
1-888-485-427 8 Ext "0"

Medic call with ETA

Arrival and Clinical Assessment
- 12 lead ECG
- Vitals
- POC testing

Initial Treatments
- Medication Admin
- IV Fluids
- Resuscitation

Telemedicine consult with Hospitalist
- Vidyo Telemedicine
- 12 lead ECG transmission
- Bluetooth Stethoscope

Hospitalist Orders
- Lab draws
- Leave behind meds
- Leave behind DME
- Additional meds

Social Determinants of Health Assessment
- SDoH Referral
- Meal Boxes
- DME Equipment

Next-day patient check-in (phone)

All **In Home Urgent Care Plus** Interventions are viewable in EPIC/Cerner

miro

Welcome to Connected Care for Heart Failure!

- Heart Failure
- COPD
- COVID-19
- Hospital Discharges
- Advanced Illness Care
- Post-Partum Hypertension

Outcome	Average Treatme	P-value	95% CI	
7-day ED Return	-3.67%	0.000	-4.40%	-2.95%
30-day ED Return	-10.19%	0.000	-12.56%	-7.81%
90-day ED Return	-10.52%	0.009	-18.37%	-2.67%
7-day IP Readmission	-3.57%	0.001	-5.70%	-1.44%
30-day IP Readmission	-7.03%	0.000	-10.65%	-3.41%
90-day IP Readmission	-10.63%	0.001	-17.11%	-4.15%

Outcome	Control Prevalence, % (n = 371)	AIC Prevalence, % (n = 110)	Average Treatment Effect (AIC) Percentage Points	P Value	95% CI
30-day ED visit	7.3	14.6	15.1	.004*	4.9, 25.3
90-day ED visit	17.3	37.3	27.8	<.001*	16.0, 39.6
30-day hospitalization	17.0	8.2	−11.4	<.001*	−17.7, −5.0
90-day hospitalization	36.7	30.9	−9.3	.12	−21.1, 2.4
Conversion to hospice	14.3	32.7	22.4	<.001*	11.4, 33.3
30-day mortality	0	2.7	1.4	.16	−0.5, 3.3
90-day mortality	8.6	11.8	−0.7	.78	−5.5, 4.2

Ernecoff, N. C., et al. Journal of the American Medical Directors Association 2021.

Effect of Remote Monitoring on Discharge to Home, Return to Activity, and Rehospitalization After Hip and Knee Arthroplasty
A Randomized Clinical Trial

POPULATION

53 Men, 189 Women

Adults scheduled to undergo hip or knee arthroplasty at intermediate risk after surgery of needing postdischarge facility care
Median age, 66 y (IQR, 58-73 y)

SETTINGS / LOCATIONS

2 Urban hospitals in an academic health system, Philadelphia, PA

INTERVENTION

242 Individuals randomized and analyzed

118 Remote mo
Activity monitori
text messaging a
patients prior to
initiated at disch.

PRIMARY OU
Percent of patient
care facility)

Mehta SJ, Hume E, Troxel AB, et al. Effect of remote monitoring on discharg
JAMA Netw Open. 2020;3(12):e2028328. doi:10.1001/jamanetworkopen.20

FINDINGS

No statistically significant difference in the rate of discharge to home between the usual care and remote monitoring groups

Table 2. Hospitalization/Discharge and Use Data

Variable	Intervention (n = 118)	Control (n = 124)[a]	P value
Discharge to home, No. (%) [95% CI]	67 (56.8) [47.9-65.7]	71 (57.3) [48.5-65.9]	.95
Length of hospital stay, mean (SD), d	2.5 (1.0)	2.5 (1.3)	.96
Time at home, median (IQR), d[b]	42 (34-43)	42 (33-43)	.64
Rehospitalization rate, No./total No. (%) [95% CI]	4/118 (3.4) [0.1-6.7]	15/123 (12.2) [6.4-18.0]	.01
Rehospitalizations, total No. (%) [95% CI]	5 (4.2) [0.6-7.9]	16 (13.0) [7.1-19.0]	.02
Observation[c]	1 (0.8)	1 (0.8)	
Inpatient[c]	4 (3.4)	13 (10.5)	
Patients with 2 rehospitalizations	1 (0.8)	1 (0.8)	
Admissions from ED	2 (1.7)	9 (7.3)	
Joint-related rehospitalizations	1 (0.8)	7 (5.6)	

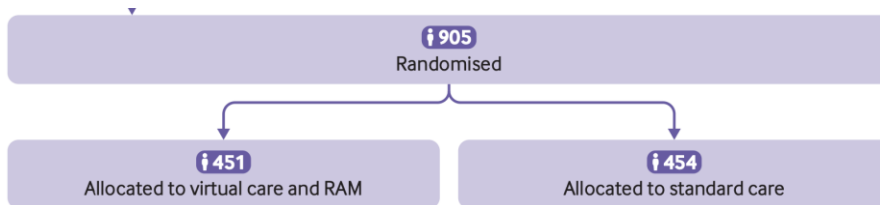# Can Remote Patient Monitoring Improve Post-Surgical Care and Recovery?

Table 2 | Outcomes within 31 days of hospital discharge by group allocation. Values are numbers (percentages) unless stated otherwise

Outcome	Virtual care and RAM (n=451)	Standard care (n=454)	Relative risk* (95% CI)	Absolute difference, % (95% CI)†	P value
Detection of drug error	134 (29.7)	25 (5.5)	5.29 (3.52 to 7.93)	24.2 (19.5 to 28.9)	‹0.001
Correction of drug error	128 (28.4)	18 (4.0)	7.01 (4.36 to 11.52)	24.4 (19.9 to 28.9)	‹0.001
Pain after randomisation (days)¶:					
7	227/386 (58.8)	309/425 (72.7)	0.81 (0.73 to 0.90)	13.9 (7.4 to 20.4)	‹0.001
15	193/402 (48.0)	248/414 (59.9)	0.80 (0.71 to 0.91)	11.9 (5.1 to 18.7)	‹0.001
30	144/411 (35.0)	184/413 (44.6)	0.80 (0.67 to 0.94)	9.6 (2.9 to 16.3)	‹0.008

Post-discharge after surgery Virtual Care with Remote Automated Monitoring-1 (PVC-RAM-1) technology versus standard care: randomised controlled trial. *BMJ* 2021

Remote Patient Monitoring and Decision Support in the Hospital

Vital Signs Monitoring with Wearable Sensors in High-risk Surgical Patients

Observational method comparison study in 25 high-risk adult surgical patients

Compared sensors' heart rate (HR) and respiratory rate (RR) measurements to ICU monitor
- 2 types of wearable patches
- Bed-based system
- Patient-worn monitor

Sensor	Bias (95% limits of agreement)	
	HR	RR
Patch #1	1.0 (-6.3, 8.4)	-0.8 (-7.4, 5.6)
Patch #2	1.3 (-0.5, 3.3)	4.4 (-4.4, 13.3)
Bed-based	-1.4 (-5.1, 2.3)	0.4 (-3.9, 4.7)
Patient-worn	-0.4 (-4.0, 3.1)	0.2 (-4.7, 4.4)

Wireless data loss varied from 6% to 27% for HR and 13% to 34% for RR.

- All sensors were highly accurate for HR.
- Patch #2's RR accuracy was outside acceptable limits; the other monitors were reasonably accurate.
- Trend monitoring with wearable sensors could aid in timely detection of deterioration.

Breteler MJM, et al. ANESTHESIOLOGY. March 2020.

A Remote Surveillance Platform to Monitor General Care Ward Surgical Patients for Acute Physiologic Deterioration

Anesth Analg 2021;133:933–9

Kyan C. Safavi, MD, MBA,* Hao Deng, PhD,*† William Driscoll, MA,* Milcho Nikolov, MA,* Kalpan Tolia, MA,* and Jeanine P. Wiener-Kronish, MD*

3,934 patients monitored

1,560,999 vital signs analyzed
16,635 laboratory results analyzed

151 alerts generated

Performance
- True Positive 143 (94.7%)
- False Positive 8 (5.3%)

Clinical Actionability
- Change in Care 133 (88.1%)
- No Change 18 (11.9%)

Alarm Fatigue
- Alerts / week 2.6
- Alerts / shift 0.4

- Change in Management 113 (67.7%)
- Diagnostic Test Ordered 26 (15.6%)
- Discharge Planning 20 (12.0%)
- Change in Level of Care 8 (4.8%)

Patch validation in an observational study protocol for the evaluation of a multisignal wearable sensor in patients during anaesthesia and in the postanaesthesia care unit
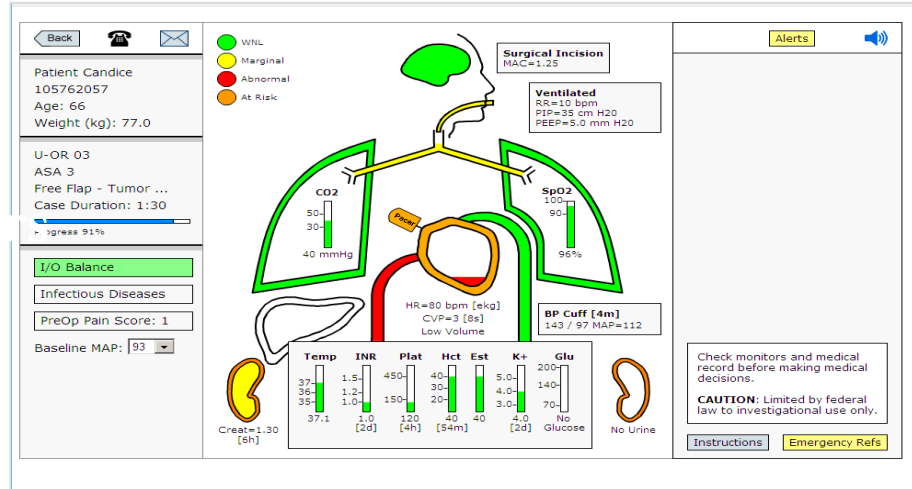
BMJ Open 2020;**10**:e040453

Morgan Le Guen,[1] Pierre Squara,[2] Sabrina Ma,[1] Shérifa Adjavon,[1] Bernard Trillat,[3] Messaouda Merzoug,[4] Philippe Aegerter,[5,6] Marc Fischler[1]

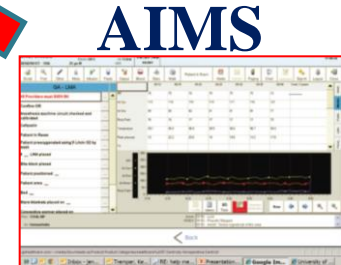Oxygen saturation, respiratory rate, heart rate, body temperature and blood pressure
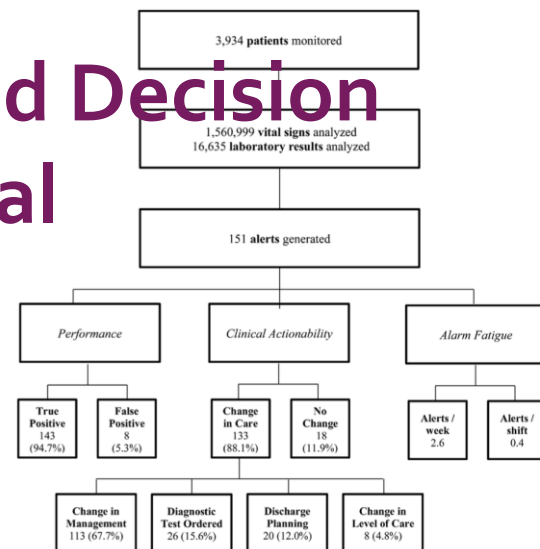
Monitoring and Surveillance Clinical Decision Support Systems: AW Multifunctional Monitor
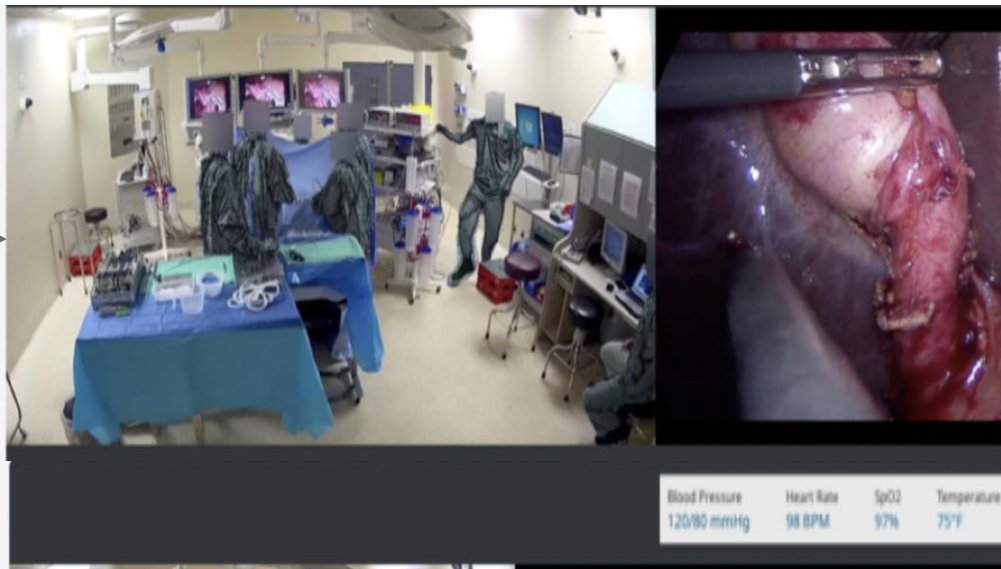

LABS

AIMS

Decision Support Engine

H & P

AI and Computer Vision Monitoring (and Guiding) Anesthesia and Surgery Performance

Surgical Safety Technologies
OR Black Box

oliance, Safety, Training, Efficiency

https://www.surgicalsafety.com

Challenges and Limitations to Overcome for RPM

- Accuracy

- Privacy and Security

- Oversight

- Accessibility

- Cost

- Acceptability

- Technological/ Form Factor

- Lack of Standards

- Scientific peer-reviewed evidence for safety and efficacy in all clinical settings NOT established

For Anesthesiology and its practices (Preoperative, Post-operative, Pain, post-ICU, others): Challenge to adapt to shifting healthcare landscape

Need for Evidence generation, Adoption, Training, in current and future clinical practice models

9/14/2022

Not yet, but maybe soon

"You can't list your iPhone as your primary-care physician."

Thank You