

BML 300: INTRODUCTION TO HEALTHCARE ENGINEERING

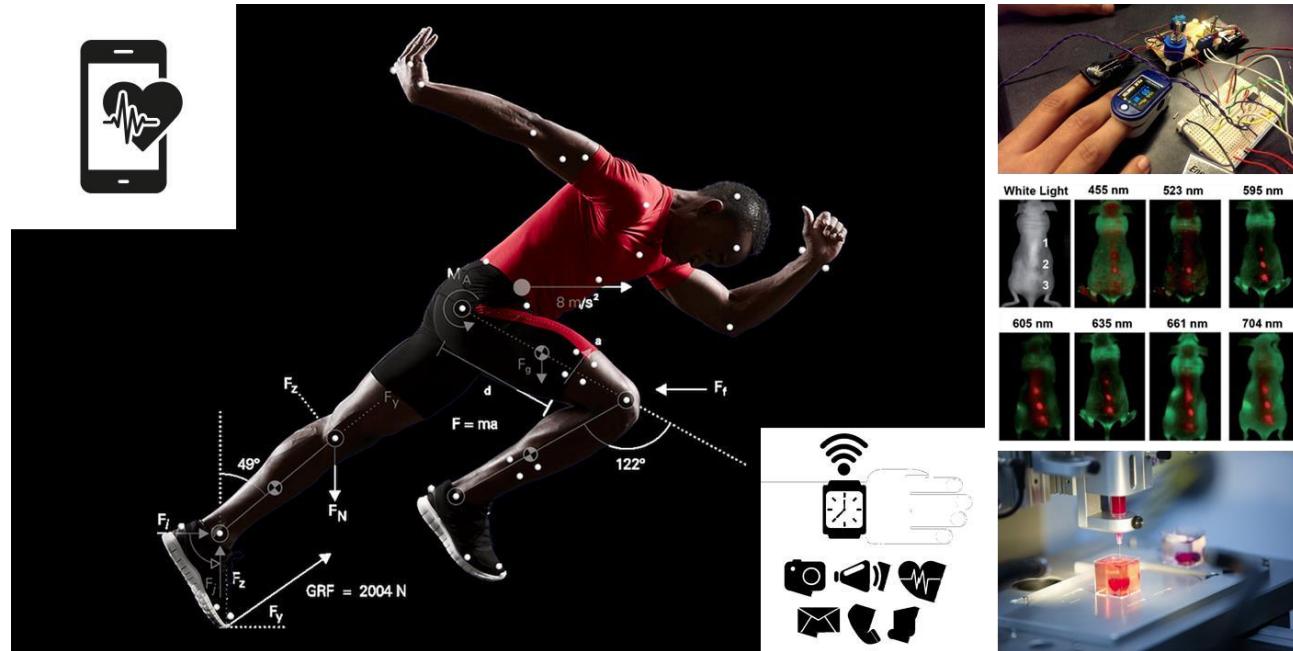
Coordinator: Dr. Arnab Chanda

Centre for Biomedical Engineering, IIT Delhi

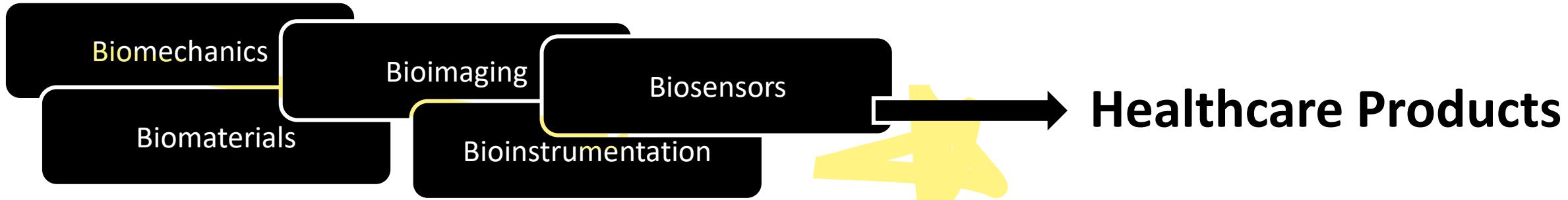
Department of Biomedical Engineering, AIIMS Delhi

Date: July 25, 2024

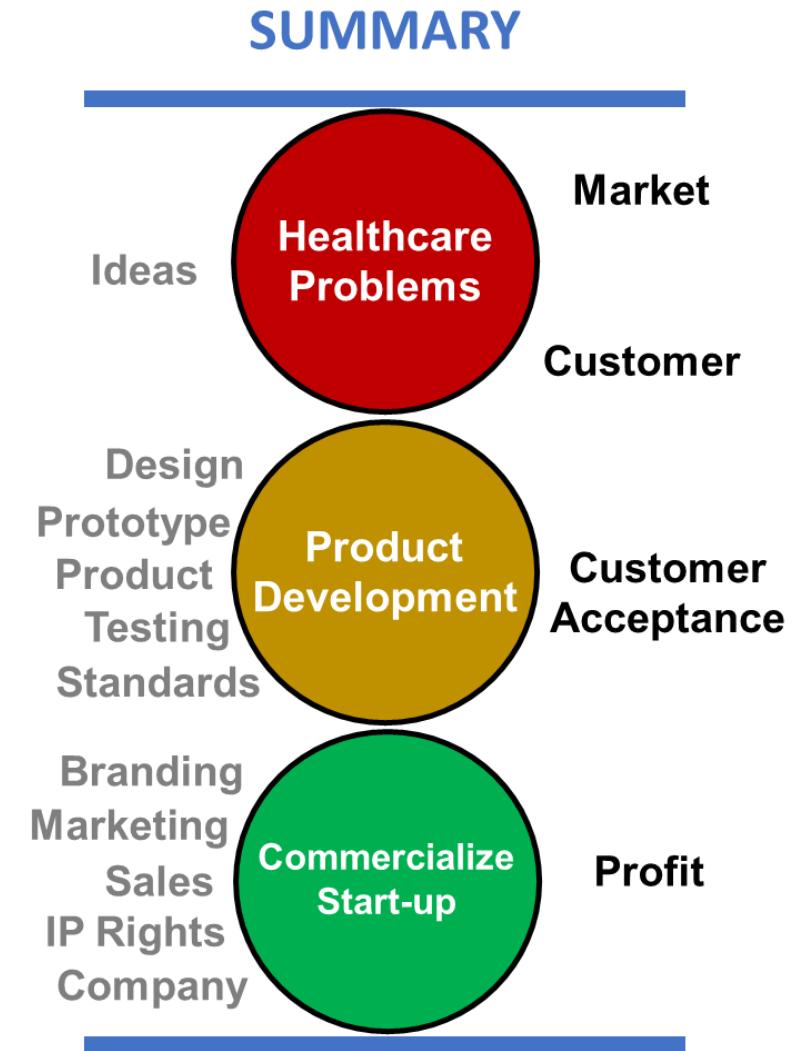
BML 300: INTRODUCTION TO HEALTHCARE ENGINEERING



The first-of-its-kind course in the institute to introduce students to healthcare engineering concepts, for development of products which can help in diagnosis, prevention, and treatment of injuries and diseases. Multidisciplinary topics will be covered ranging from biomechanics, biomaterials, bioelectronics, bioimaging, to bioimplants. The understanding of these areas will help identify current healthcare challenges in India, design and develop biomedical products for clinical and personal needs. Besides the study of important theoretical concepts, the students will also be exposed to experiments, simulations, and artificial intelligence (AI) based applications in research across labs in IIT, Delhi and AIIMS, Delhi working in different areas of healthcare engineering, which will lead to hands-on learning and equip them with the state-of-the-art skills to serve the ever growing healthcare and biomedical devices market.



Future Course: BML 401: HEALTHCARE ENTREPRENEURSHIP



SYLLABUS: Course Outline

Sr. no.	Topics	No. of hours
1	Introduction to healthcare challenges in India, which can be met with products for diagnosis, prevention, and treatment	3
2	What is Biomechanics, Different types of biomechanics, Gait Analysis, Tissue Mechanics, Computational and Experimental Modelling, Biomechanics of Device-Tissue Interactions.	4
3	PRACTICAL Gait Analysis: Biomechanical Measurements using In-shoe Pressure Insole	4
4	What are Biomaterials? Categories, and their use across implants, tissue replacements, medical devices, and other biomedical applications. Fabrication and Applications in Medical Device Development, Wound Healing, Tissue Engineering (Bioprinting).	4
5	PRACTICAL Soft Tissue Characterization: Uniaxial, Biaxial Testing, Digital Image Correlation (DIC), Fabrication of Biomaterials: Tissue Mimicking Polymers	8
Mid Sem Exam (12/9-18/9)		
6	Introduction to Robotics, Wearable devices, Bionic Prosthetics and Orthotics. Biosensors for Disease Diagnosis and Monitoring. Role of Artificial Intelligence (AI) and Machine Learning (ML).	4
7	PRACTICAL Biorobots and Hands-on applications	4
8	Introduction to Biomedical Imaging Techniques. Multiscale Imaging Modalities: From Cells to Organs (Microscopy). Overview of MRI, CT, and Ultrasound. Diagnosis of Key Diseases and Injuries. Latest Innovations in Medical Imaging.	4
9	Demonstration of Ultrasound Imaging, and Applications (BM)	4
10	Medical Devices and Implants. Different device Classes, their Fabrication, Testing, and Regulatory requirements. Mechanical Stability, Biocompatibility, Corrosion, Fatigue and Failure.	4
11	Additive Manufacturing and 3D Printing Lab	8
12	Recent Innovations in Healthcare Products, Clinical Testing and Role of Collaboration between Engineers and Doctors in Implementation of Valuable Biomedical Products (Case Studies).	4
15	Careers in Biomedical Engineering, Advanced Academic and Industry Research, Start-up, and Giving back to the Society.	1
End Sem Exam (16/11-23/11)		
Total hours		28+28 (56)

SYLLABUS: Course Outline

L-T-P structure: 3 Credits (2-0-2)

Prerequisite(s): APL100, ELL101, MCP100

Course Status: UG students in Semester I, 2024-25 (Slot B)

Class Day and Time: Lectures Mon Thu (10-11 AM) Labs (TBD)

Future Courses: BML401 Healthcare Entrepreneurship with BML 300 as Pre-requisite

COURSE EVALUATION CRITERIA:

50% Assignments, 20% Minor Exam, 20% Major Exam, 10% Attendance

GRADES:

As per department/institute rules, and to be curved as required

ATTENDANCE ISSUES AND LEAVES (IF ANY):

75% minimum as per institute norms. In case of health issues or emergencies, the course coordinator to be informed (flexible).

HEALTHCARE PROBLEMS & CHALLENGES IN INDIA

- India is the second most populous country in the world
- The death rate has declined but birth rates still continue to be high in most of the states.
- Health care structure in the country is overburdened by increasing population
- India faces the twin epidemic of continuing/ emerging infectious diseases as well as chronic degenerative diseases. The former is related to poor adoption of the public health programs, and the latter to demographic transition with increase in life expectancy.

Top 50 countries with largest population in 2022

| Top 50 countries 6.9B. Rest of world 1.1B. Total 8.0B



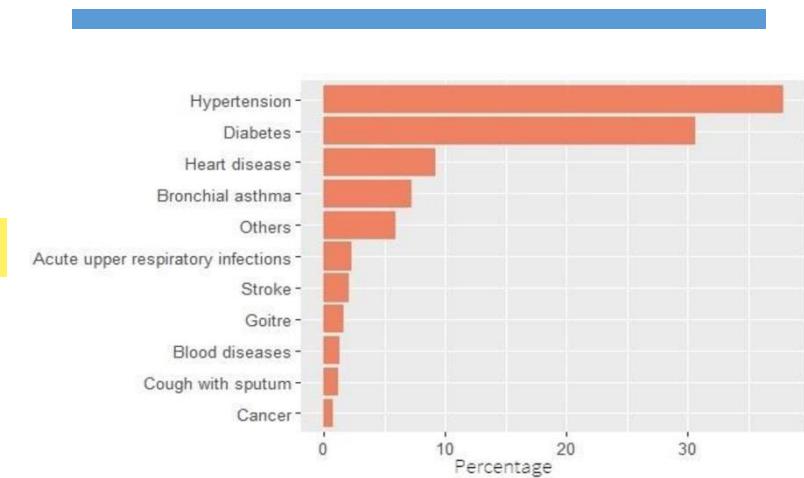
<https://www.visualcapitalist.com/cp/visualizing-the-changing-world-population-by-country/>



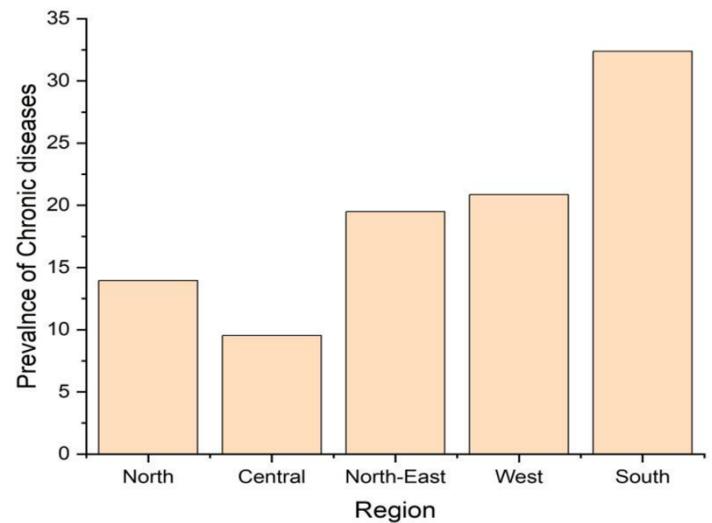
<https://www.thehansindia.com/posts/index/News-Analysis/2015-06-24/Healthcare-challenges-in-India/159113>

HEALTHCARE PROBLEMS & CHALLENGES IN INDIA

- About 21% of the **elderly** in India reportedly have at least one chronic disease.
- Hypertension and diabetes account for about 68% of all chronic diseases.
- The prevalence of chronic diseases is the highest in Kerala (54%), followed by Andhra Pradesh, West Bengal, and Goa
- The probability of having a chronic disease is 1.15 times higher among urban residents as compared to their rural counterparts.
- Differences in education and wealth status are the two most significant contributors to the urban-rural gap in chronic diseases



<https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0264937>



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Coordinator: Dr. Arnab Chanda

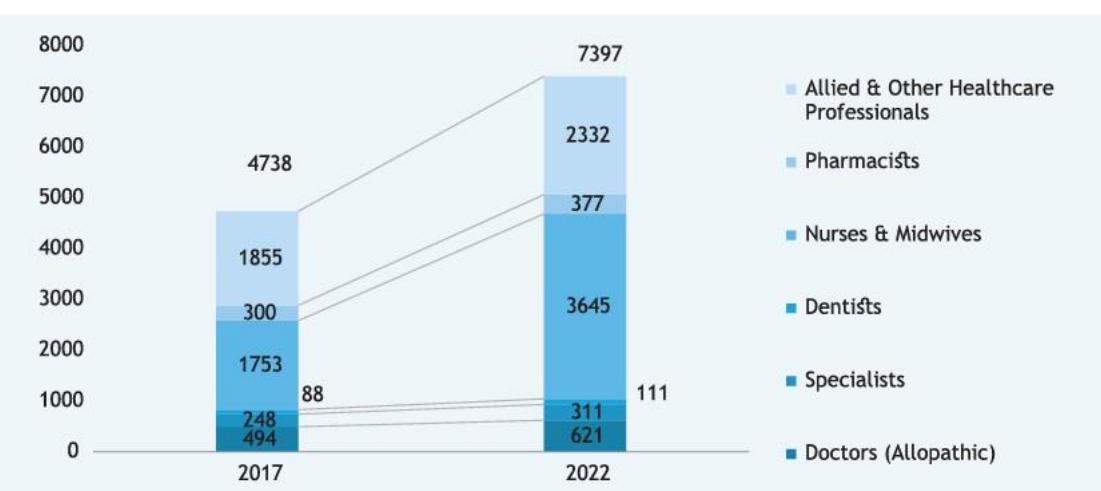
Centre for Biomedical Engineering, IIT Delhi

Department of Biomedical Engineering, AIIMS Delhi

Date: Aug 1, 2024

Healthcare in India: the good, bad and the ugly

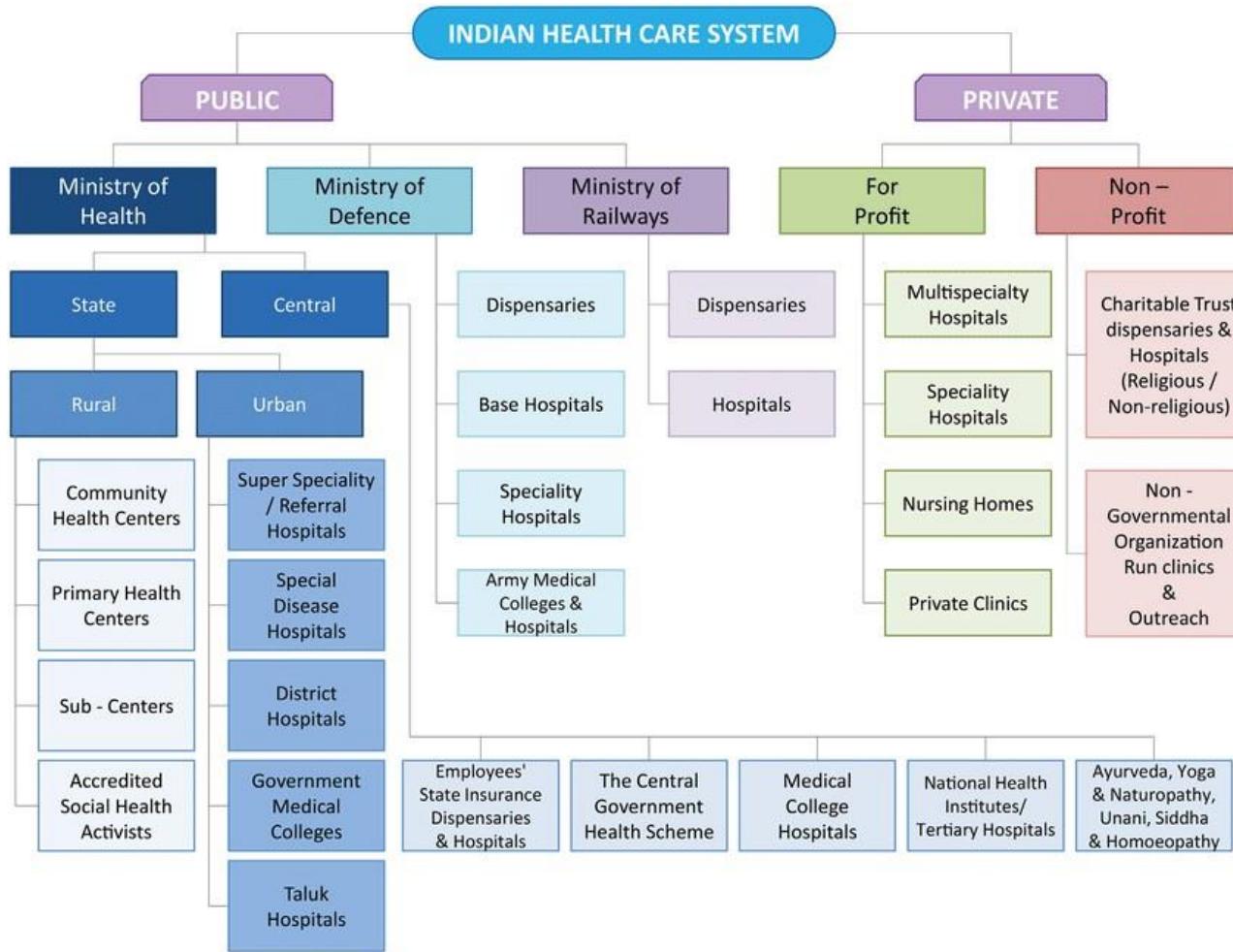
- India's healthcare sector has grown rapidly over the last 5 years, in particular, with a Compound Annual Growth Rate (CAGR) of approximately 22% since 2016.
- Broad proactive policies to encourage innovation and self-reliance in healthcare.



Healthcare in India: the good, bad and the ugly

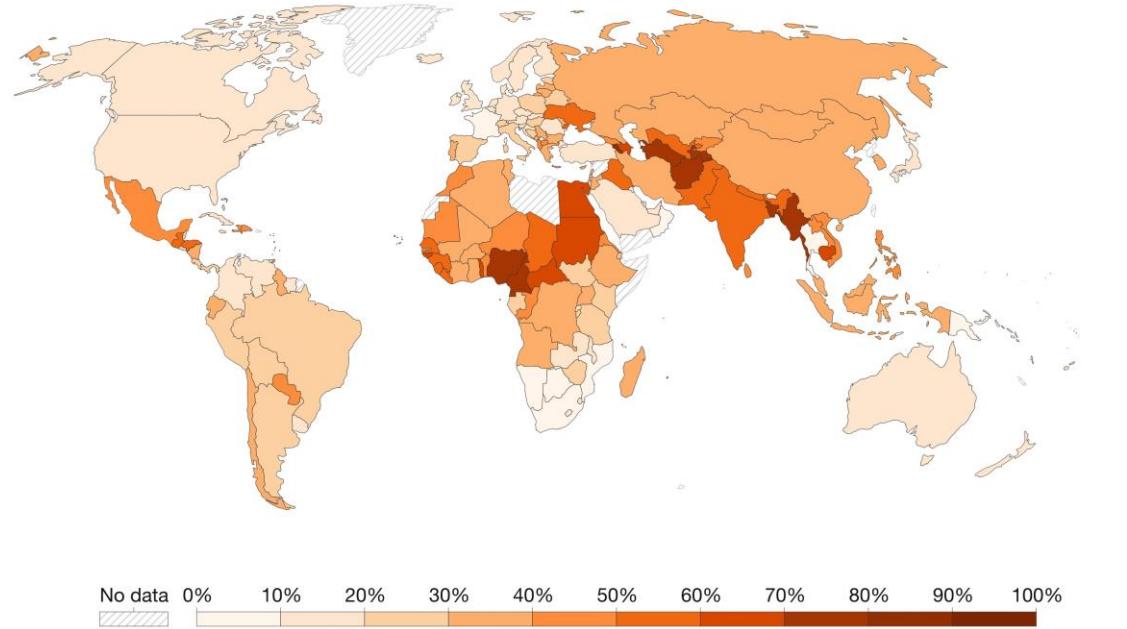


- Health-care infrastructure in urban and rural India is not evenly distributed.
 - Public services are free but often inaccessible due to proximity, socioeconomic restrictions.
 - Poor insurance penetration (government shifting towards payer vs provider) and high out-of pocket expenses.



Share of out-of-pocket expenditure on healthcare, 2019

Out-of-pocket expenditure on healthcare as percent of total current healthcare expenditure.



Source: World Health Organization (via World Bank)

Note: 'Out-of-pocket' refers to direct outlays made by households to healthcare providers.

OurWorldInData.org/financing-healthcare/ • CC BY

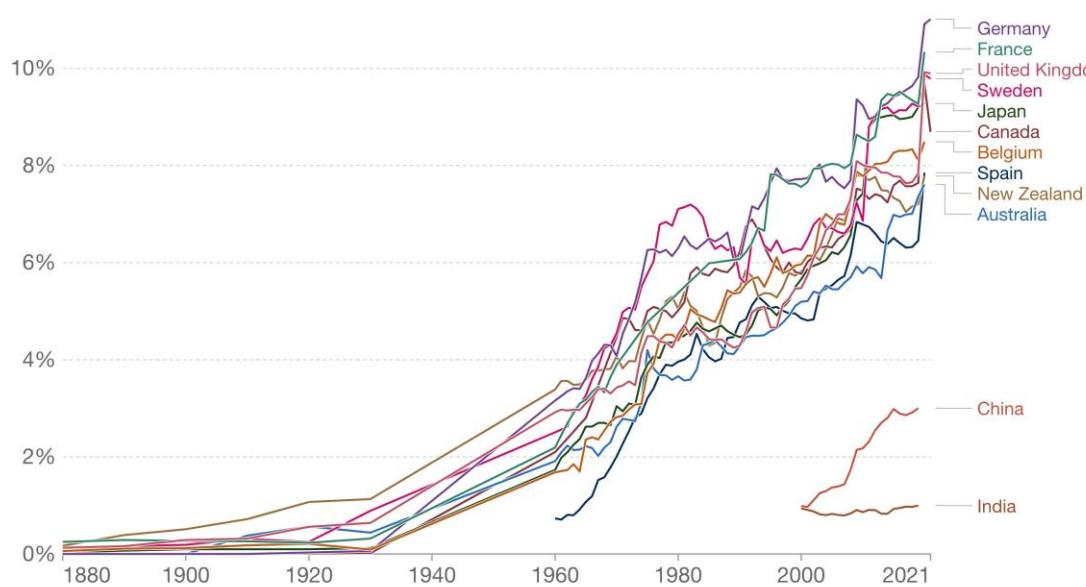
* Image adapted from Ramadas S. Is Indian Health Care System better than US ? A Sample Study... [Internet]. LinkedIn (2014). Available from: <https://www.linkedin.com/pulse/20140729152938-63974960-is-indian-health-care-system-better-than-us-a-sample-stu>

Healthcare in India: the good, bad and the ugly

- India's healthcare expenditure has not grown in proportion to GDP compared to other developing nations.
- Rapid population growth and urban migration likely to add stress to urban healthcare facilities.

Government health expenditure as a share of GDP, 1880 to 2021

This metric captures spending on government funded health care systems and social health insurance, as well as compulsory health insurance.



Source: Our World In Data based on Lindert (1994), OECD (1993), OECD Stat

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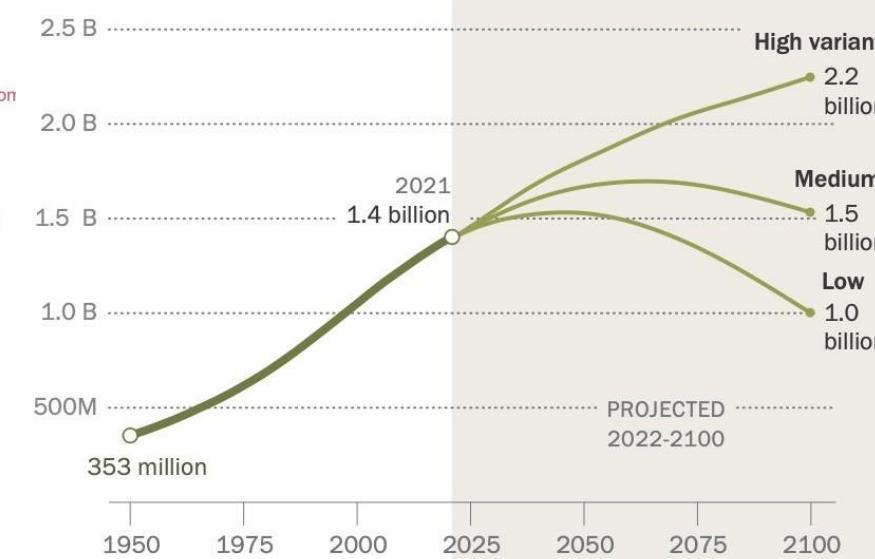
Note: Health spending includes final consumption of health care goods and services (i.e. current health expenditure). This excludes spending on capital investments.

<https://ourworldindata.org/grapher/public-health-expenditure-share-GDP-OWID>

Our World
in Data

India's population has more than doubled since 1950

Number of people in India, by variant



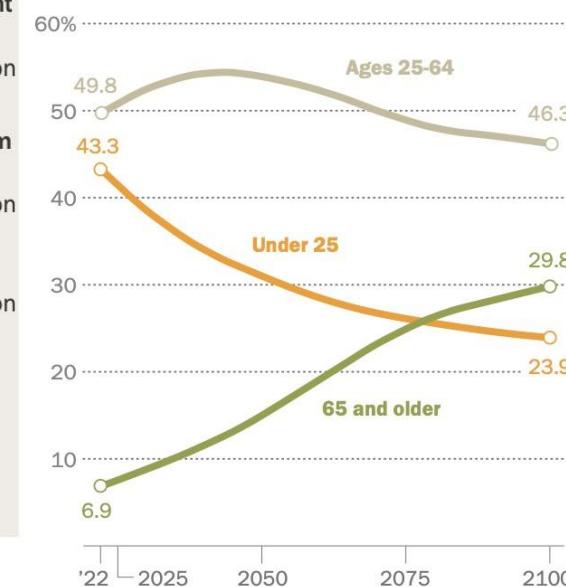
Note: May differ from national census figures. The "medium variant" is the middle-of-the-road estimate provided by the UN; "high" and "low variant" scenarios involve total fertility being 0.5 births above or below the medium scenario, respectively.

Source: UN Population Division's World Population Prospects: The 2022 Revision.

PEW RESEARCH CENTER

In India, people under 25 are projected to outnumber those ages 65 and older at least until 2078

% of Indian population, by age group



Note: The projection depicted is the UN's "medium variant" scenario.

Source: UN Population Division's World Population Prospects: The 2022 Revision.

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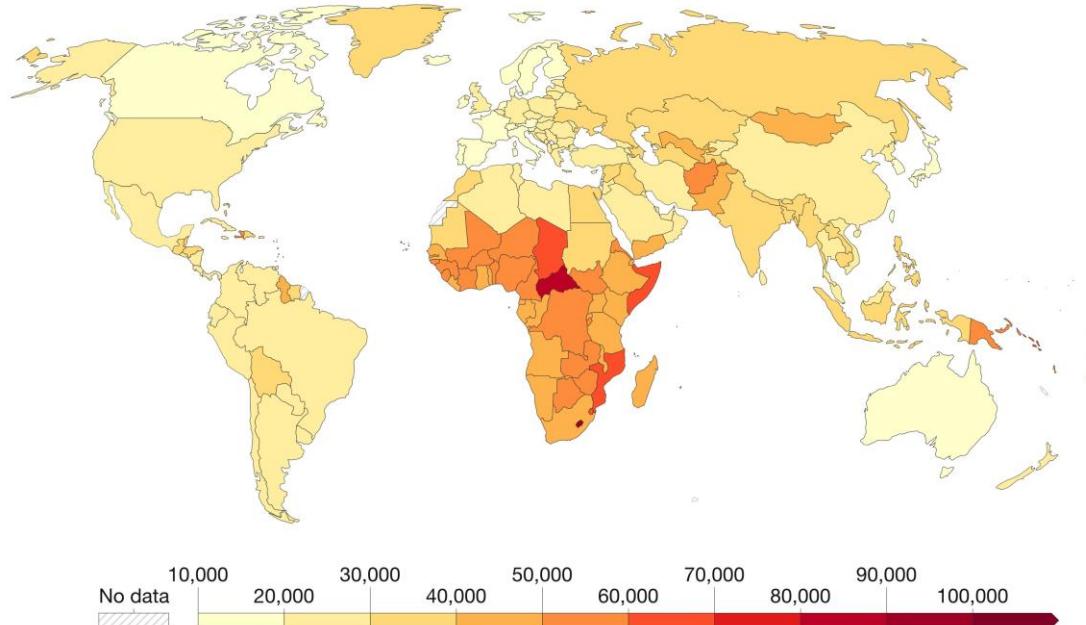
<https://www.pewresearch.org/short-reads/2023/02/09/key-facts-as-india-surpasses-china-as-the-worlds-most-populous-country/#:~:text=Under%20the%20UN's%20E2%80%9Cmedium%20variant,peak%20at%201.7%20billion%20people.>

Healthcare in India: the good, bad and the ugly

- India's disease burden is worse than other MICs such as Brazil and China.
- Over the last decade, India has reduced communicable, maternal, neonatal and nutritional related deaths.
- Rapid increase in non-communicable disease burden due to lifestyle, climate change, air and water pollution.

Burden of disease, 2019

Disability-Adjusted Life Years (DALYs) per 100,000 individuals from all causes. DALYs measure the total burden of disease – both from years of life lost due to premature death and years lived with a disability. One DALY equals one lost year of healthy life.



Source: IHME, Global Burden of Disease (2019)

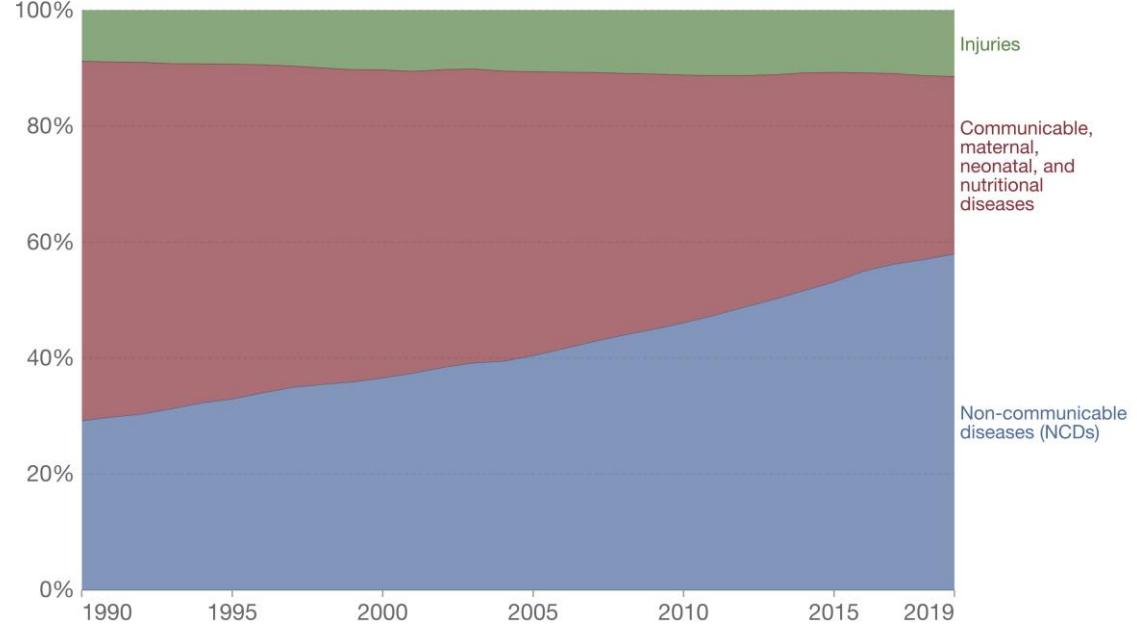
Note: To allow comparisons between countries and over time this metric is age-standardized.

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Our World
in Data

Total disease burden by cause, India, 1990 to 2019

Total disease burden measured as Disability-Adjusted Life Years (DALYs) per year. DALYs measure the total burden of disease – both from years of life lost due to premature death and years lived with a disability. One DALY equals one lost year of healthy life.



Source: IHME, Global Burden of Disease (2019)

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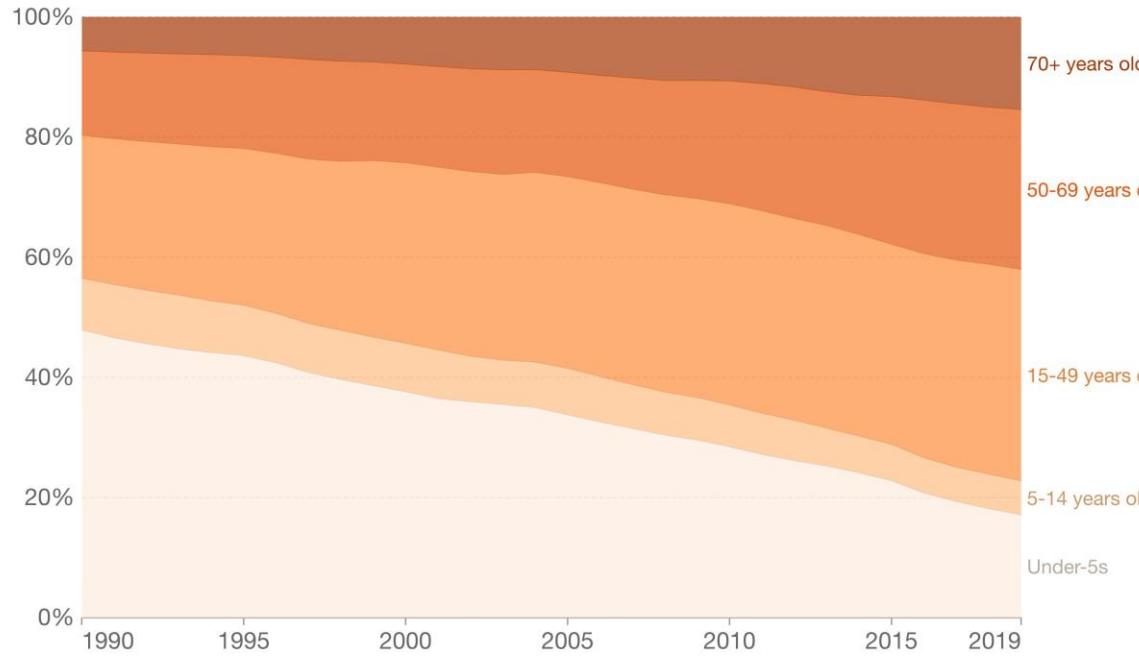
Our World
in Data

Healthcare in India: the good, bad and the ugly

- Cardiovascular diseases remains the top cause of mortality worldwide.
- Increasing burden of Diabetes, Cancer and Kidney diseases.
- Mental disorders are underreported and often treatment is never sought in formal settings but still contribute a large fraction to the overall NCD burden.
- Disease burden on the rise in the 15-49 age group indicating that chronic disease management will likely further stress the healthcare ecosystem as the demographic ages.

Disease burden by age, India, 1990 to 2019

Total disease burden by age, measured in Disability-Adjusted Life Years (DALYs) from all causes. DALYs measure the total burden of disease – both from years of life lost due to premature death and years lived with a disability. One DALY equals one lost year of healthy life.



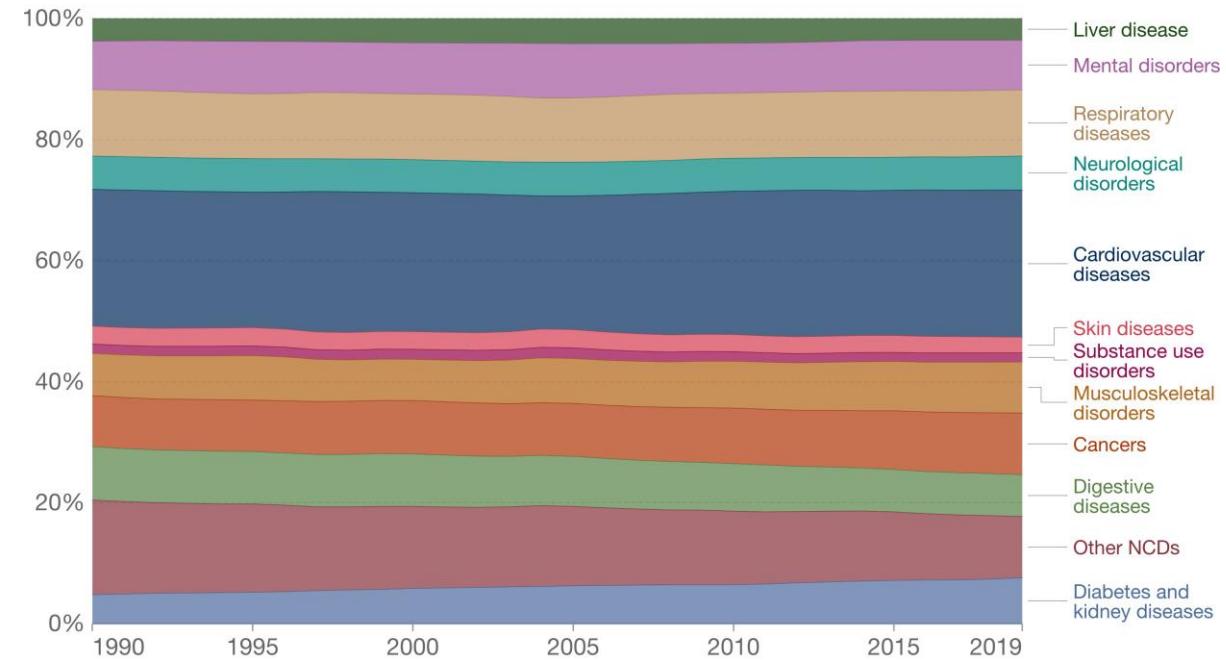
Source: IHME, Global Burden of Disease (2019)

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Disease burden from non-communicable diseases, India, 1990 to 2019

Total disease burden from non-communicable diseases (NCDs), measured in DALYs (Disability-Adjusted Life Years) per year. DALYs are used to measure total burden of disease - both from years of life lost and years lived with a disability. One DALY equals one lost year of healthy life.



Source: IHME, Global Burden of Disease (2019)

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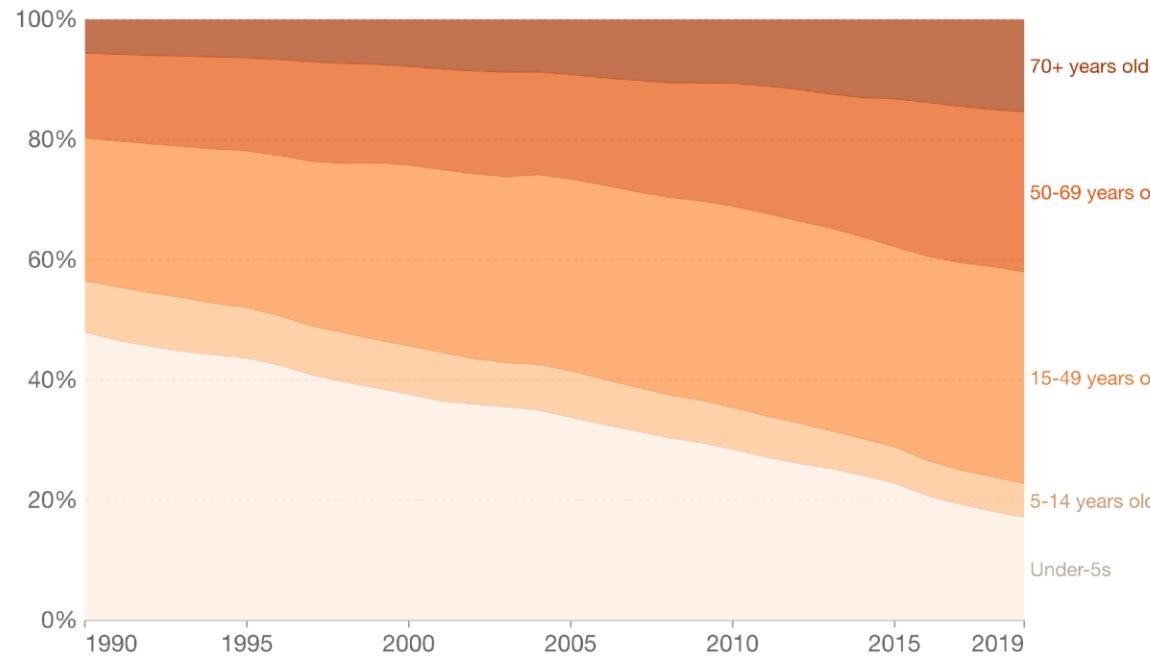
Our World
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Healthcare in India: the good, bad and the ugly

- Traumatic injuries due to road accidents steadily on the rise and likely to grow with increasing population.
- Preventable falls also on the rise and account for nearly 20% of injury related disease burden.
- Mental health and socioeconomic pressures are also driving up suicides and self-harm related incidents accounting of nearly 10 million incidences in India alone.

Disease burden by age, India, 1990 to 2019

Total disease burden by age, measured in Disability-Adjusted Life Years (DALYs) from all causes. DALYs measure the total burden of disease – both from years of life lost due to premature death and years lived with a disability. One DALY equals one lost year of healthy life.

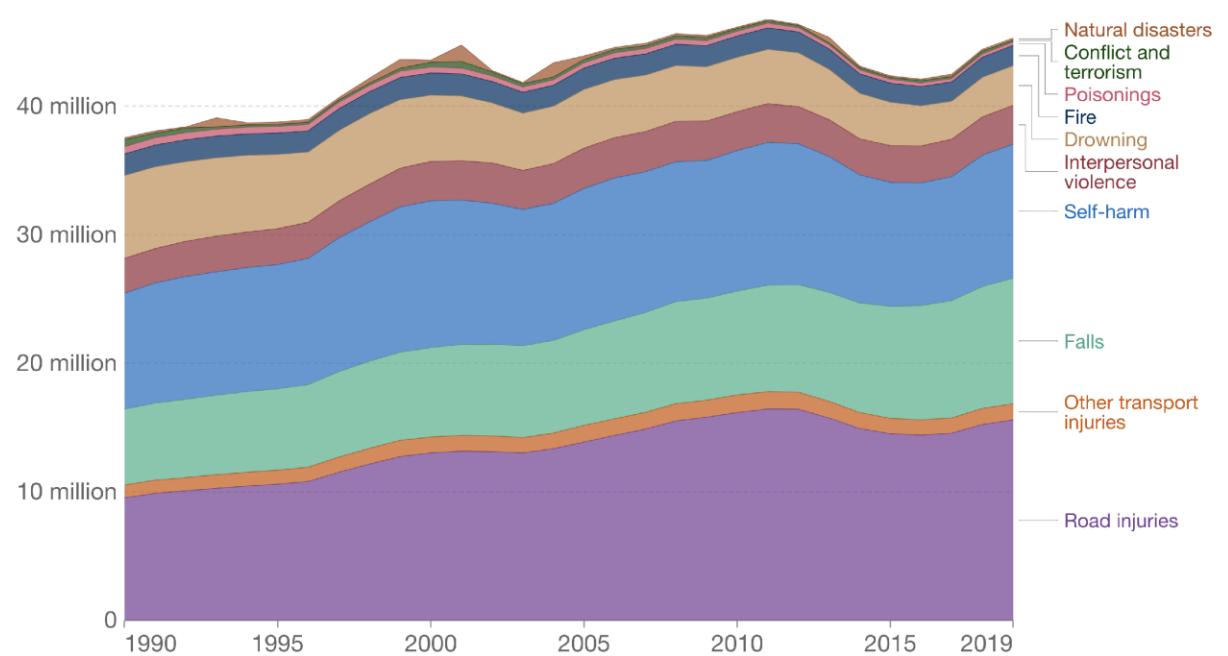


Source: IHME, Global Burden of Disease (2019)

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Disease burden from injuries, India, 1990 to 2019

Disease burden from injuries. Disease burden is measured in DALYs (Disability-Adjusted Life Years). DALYs are used to measure total burden of disease - both from years of life lost and years lived with a disability. One DALY equals one lost year of healthy life.

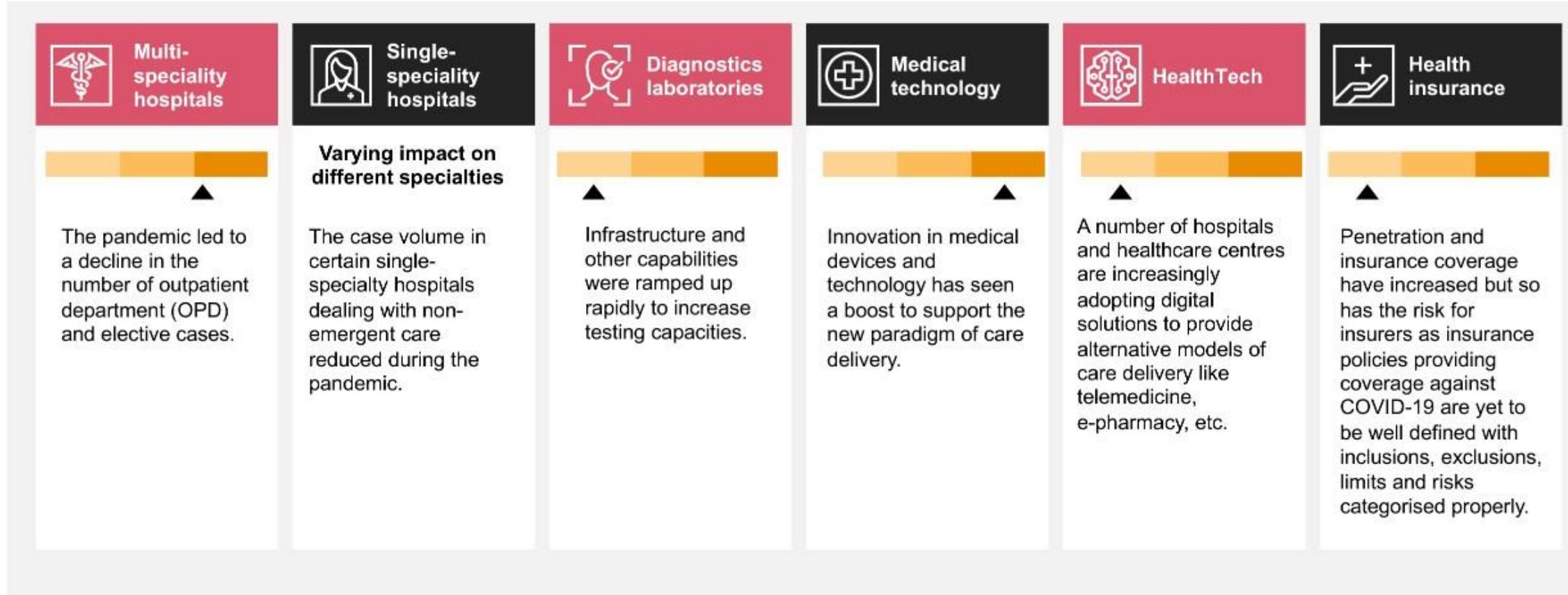


Source: IHME, Global Burden of Disease (2019)

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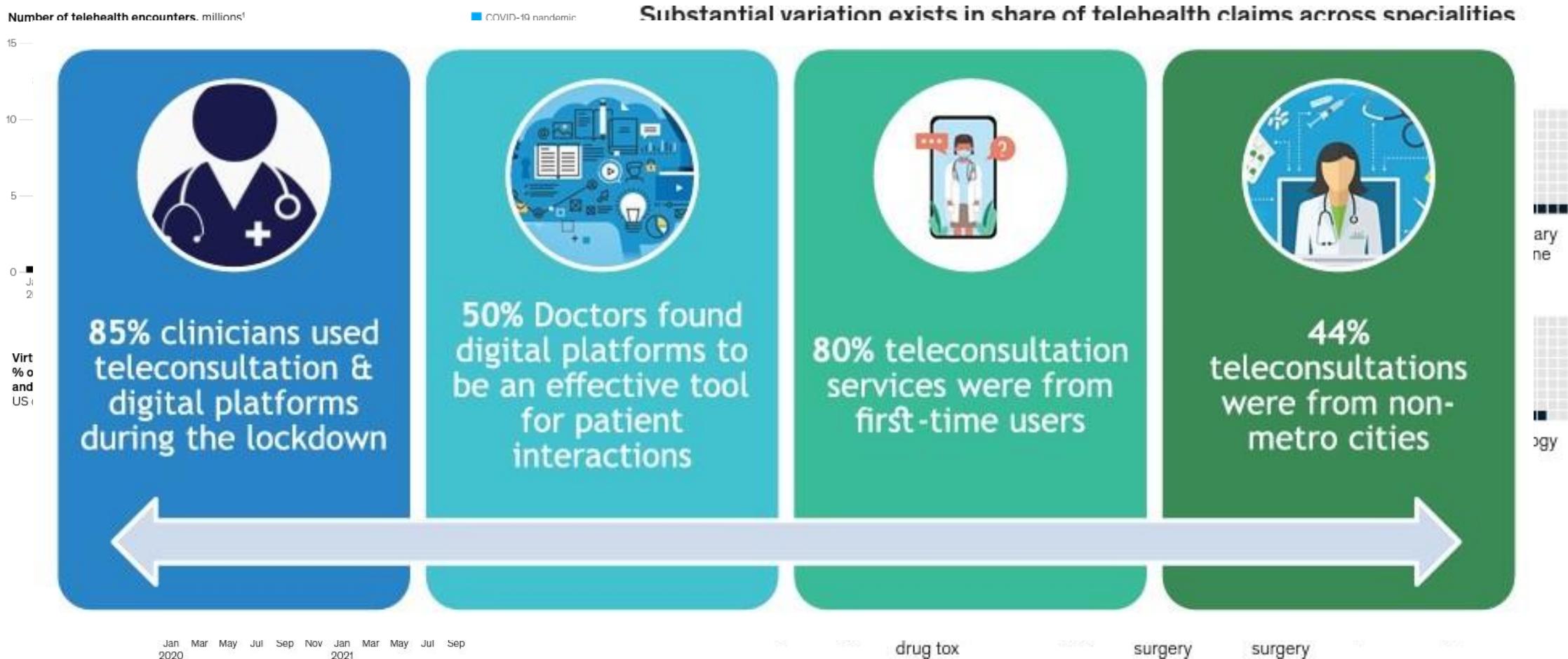
The healthcare catastrophe or an accelerated start to a new era?

- Differential and uneven impact across the healthcare system. Official figures suggest a large degree of resiliency to increased stress.
- Spur in medical innovation –
 - Vaccine and pharma innovations at record pace.
 - Devices - open-source medical ventilators, oxygen concentrators.
 - Democratization of health data – open-source dashboards.



The post COVID era: Redefining healthcare delivery and care

- A renewed interest in digital health solutions and personal health, wellness and fitness.
- The market size for telemedicine in India was around USD 830 Million in 2019. It is projected to increase to USD 5.5 Billion by 2025 growing at a CAGR of 31% during 2020-25.
- India's digital payment services is likely to be the catalyst for this growth, fueled by strong, sustained consumer demand.



Telehealth services—Across the continuum of care

Phase: Diagnosis

Archetype: Emerging risk

- 50 years old; has obesity and other risk factors potentially related to diabetes
- Doesn't drive; has a husband and a son

Current state

- Schedules routine in-person wellness appointment with primary care physician (PCP) in an office
- PCP orders urine sample and A1C test (blood test for glucose levels) to screen for diabetes

Potential future state

- Schedules routine telehealth wellness appointment
- Because of diabetes risk factors, urine and A1C tests shipped in advance to send back via mail
- PCP discusses results via telehealth visit

Patient: Mary



Care at Home interventions



At-home
diagnostics
via mail



Telehealth
PCP visit

Phase: Provider consultation

Archetype: Healthy/low risk

- 20 years old; has no chronic conditions
- Not married and has no children

Current state

- Wakes up with burning sensation during urination; goes to urgent-care center
- Picks up prescribed antibiotics at pharmacy for urinary tract infection (UTI)

Potential future state

- Connects with on-demand doctor through telehealth and drops off urine sample at urgent-care clinic
- Diagnosed with a UTI and is prescribed antibiotics
- Antibiotics are ordered and delivered to home by end of day

Patient: Laurie



Care at Home interventions



Medication
delivered to
home quickly



Telehealth
urgent-care
visit

Telehealth services—Across the continuum of care

Phase: Ongoing management

Archetype: Planned procedural

- 50 years old; has kidney failure
- Has a wife and 2 children

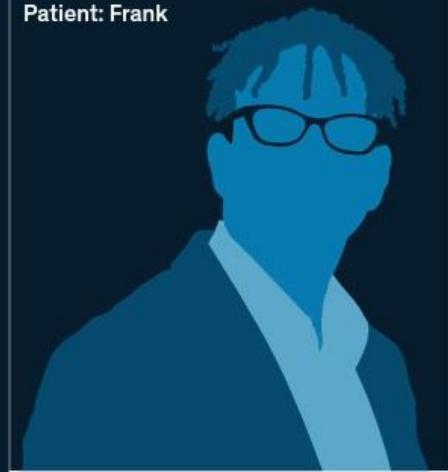
Current state

- Has kidney failure and receives dialysis 3 times a week at a nearby clinic

Potential future state

- Frank and his wife are trained on how to administer dialysis at home
- Able to administer dialysis at home with wife's support
- Set up with remote patient monitoring to prevent adverse outcomes

Patient: Frank



Care at Home interventions



Self-administer treatment (eg, dialysis) at home



Remote patient monitoring

Phase: Self-care

Archetype: High-risk chronic conditions

- 80 years old; has congestive heart failure, diabetes, and depression
- Divorced, with no children

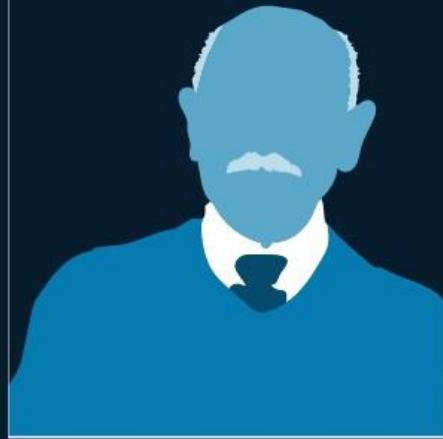
Current state

- Has difficulty remembering to take medications, making lifestyle changes, and keeping appointments
- No psychologist available nearby to treat depression

Potential future state

- Primary care provider (PCP) assigns a care manager and sets up remote patient monitoring
- PCP gives referral for telebehavioral-health providers

Patient: John



Care at Home interventions



Care-management support



Referral to specialist for telehealth visit



Remote patient monitoring

Telehealth services—Across the continuum of care

Archetype: Unplanned acute

- 75 years old; has coronary artery disease, chronic obstructive pulmonary disease, and diabetes
- Lives with husband, who has limited mobility; struggles to secure healthy nutrition

Current state

- Admitted to hospital with heart attack
- Discharged to skilled nursing facility because of concerns about staying safe and engaged at home

Potential future state

- Once recovered from heart attack, evaluated by a physician; sent home with assigned nurse and care manager
- Set up with remote patient monitoring
- Has daily telehealth visits with a physician coupled with in-person care from a nurse
- Community organization delivers meals to home

Patient: Bernadette



Care at Home interventions



Phase: End of life

Archetype: End of life

- 60 years old; has been undergoing chemotherapy for lung cancer
- Widowed and has a daughter

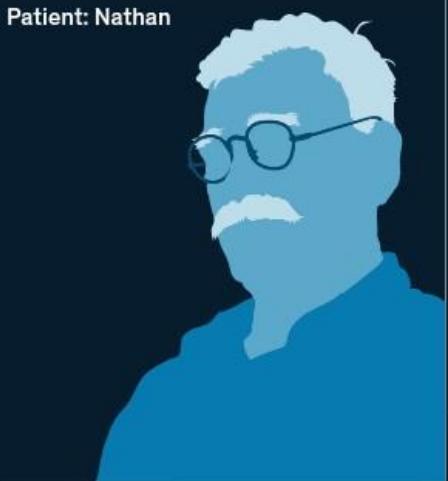
Current state

- Not responding to treatment so elects comfort care
- Oncologist helps select a nearby hospice facility

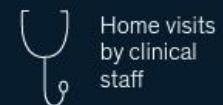
Potential future state

- Oncologist refers a hospice team who can provide Care at Home
- Daughter moves in to care for Nathan

Patient: Nathan



Care at Home interventions



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Date: Aug 5, 2024

Digital health innovations will drive at-home healthcare delivery

Consumer-centric digital health value pools in Asia are expected to grow by 22 percent per annum through 2025.

Over 75 percent of value in 2025 driven by digitalization of care delivery

Category	Value pool	Example technologies	Market size in Asia, estimated		
			Market size 2020, \$ billion	Market size 2025, \$ billion	CAGR 2020-25, %
Wellness and disease prevention	Improve wellness and prevent disease	Wearables, activity trackers, fitness	2.3	6.6	23
	Intercept diseases through screening	Genomics, other omics	3.5	11.7	28
Care delivery	Identify the right patient	Digital diagnostics, AI imaging	1.6	3.6	18
	Provide more effective therapies	CDM, digital therapies (CDS, cognitive games) ¹	6.1	7.6	4
	Provide remote patient support	Telemedicine, remote monitoring	16.8	37.1	17
Total		Digital pharmacies	37.4	100.4	21 (average)

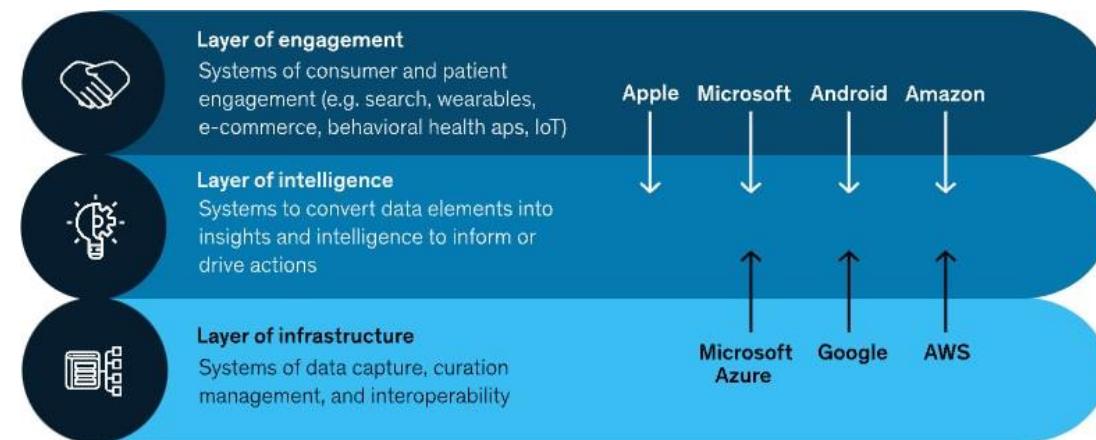
US consumers spend \$300 billion to \$400 billion per year across six dimensions on goods and services they consider important to improving health.

US holistic health and wellness market, \$ billions¹

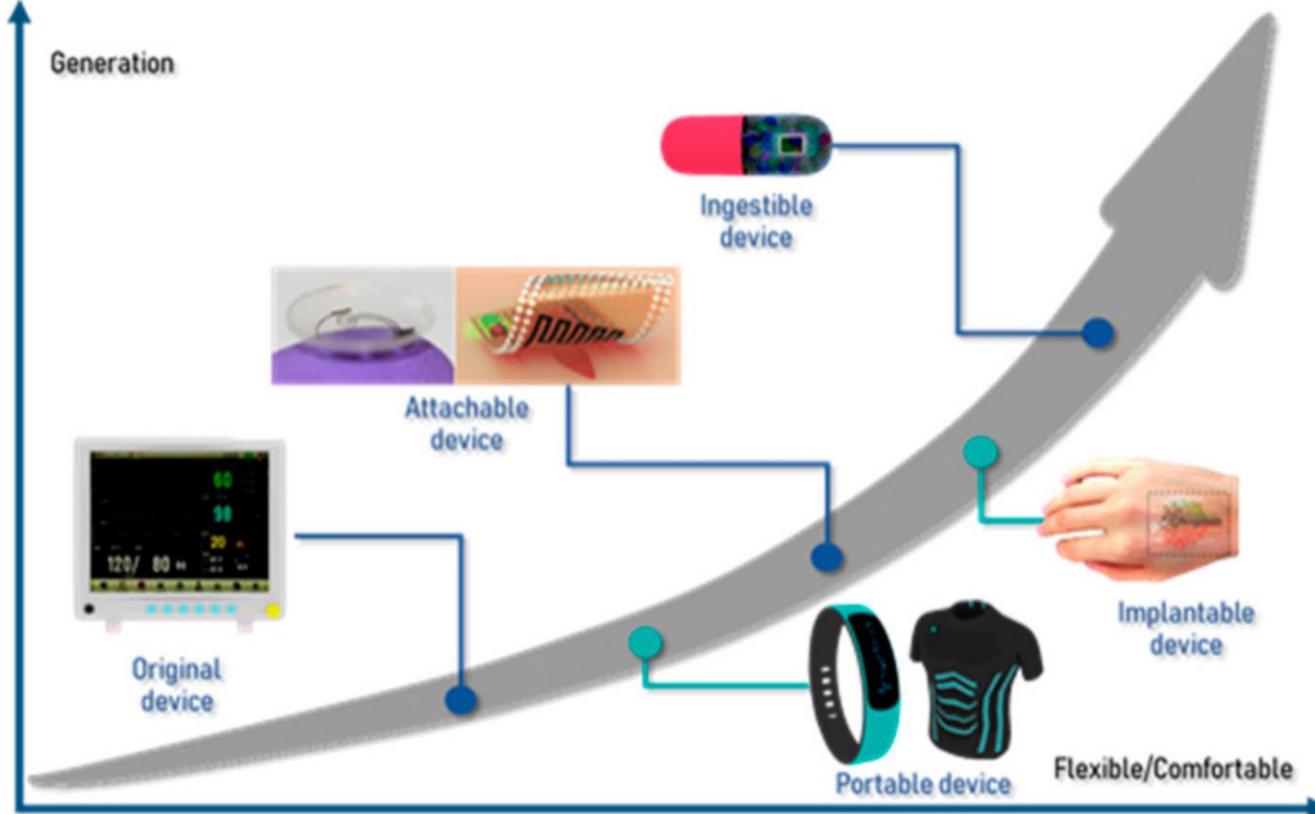


¹Figures may not sum, because of rounding.

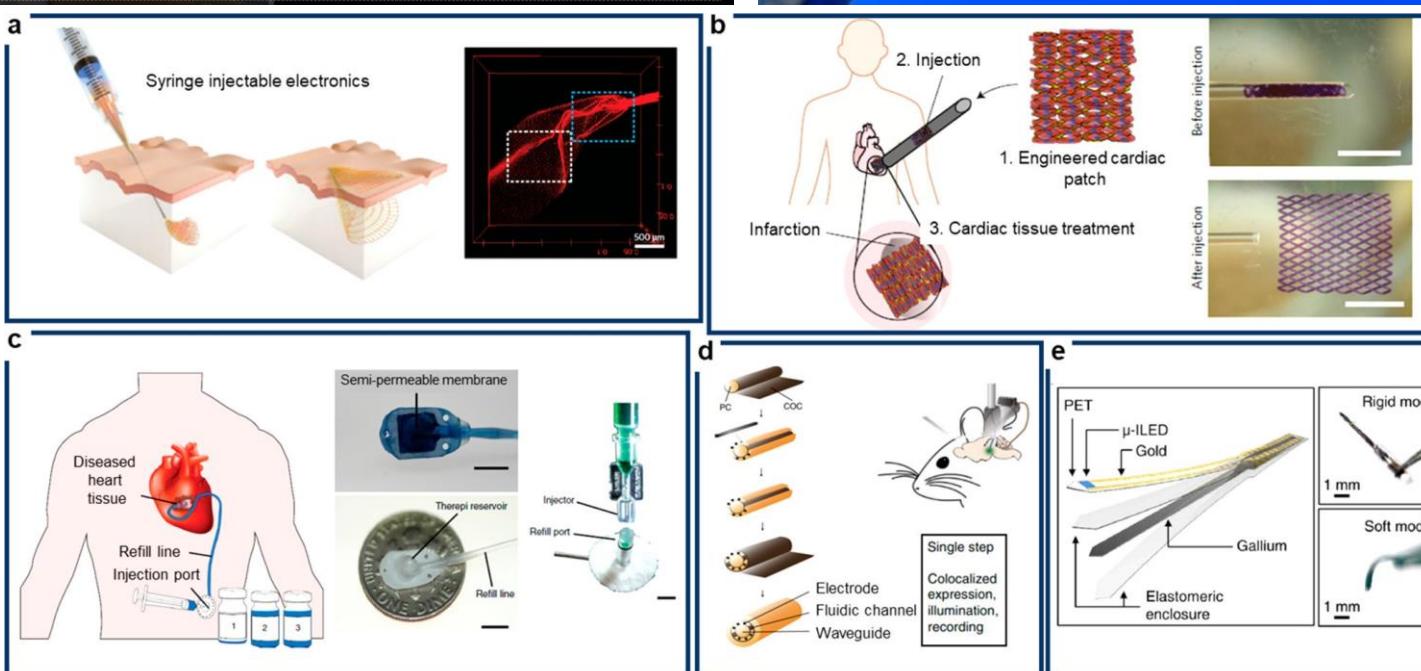
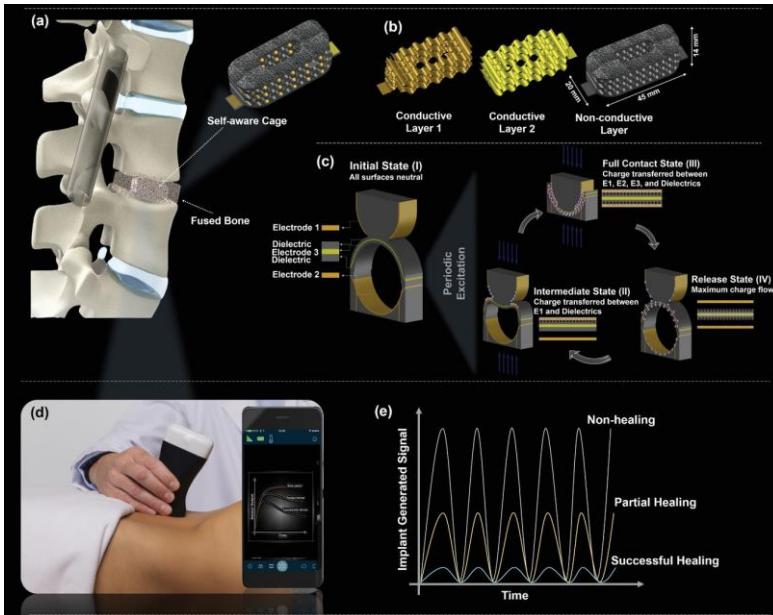
Source: Shaun Callaghan, Martin Löscher, Anna Pione, and Warren Teichner, "Feeling good: The future of the \$1.6 trillion wellness market," McKinsey, April 8, 2021; McKinsey Future of Wellness Survey (August 2020, n = 7,500); McKinsey Consumer Health Insights Survey (August 2021, n = 2,125); PatientPop



Digital wearable device deluge: Lab-on-Skin



Implantable, ingestible and injectable electronic revolution



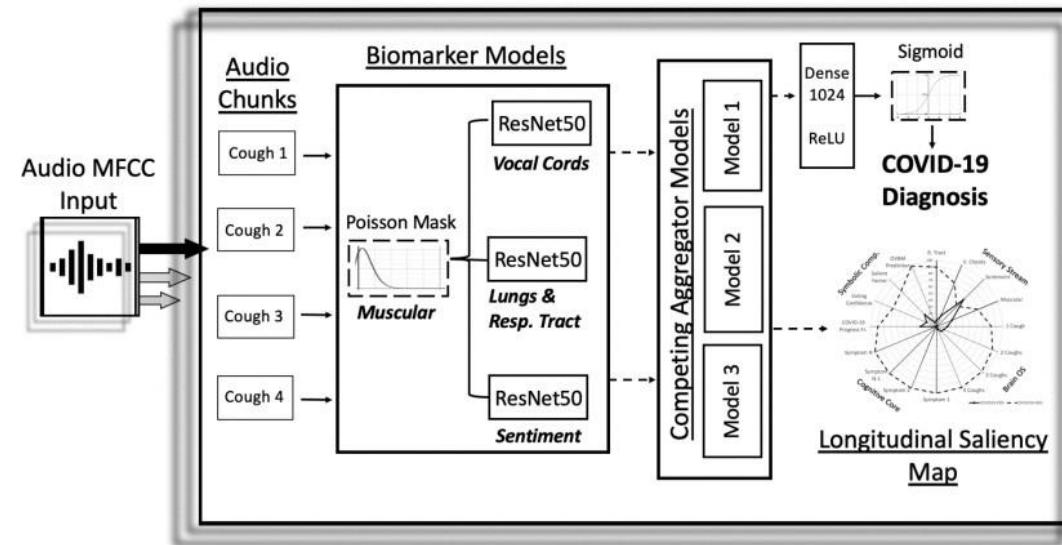
- Implantable devices refer to medical devices that have specific functions beyond passive mounting for fixation.

- Syringe-injectable implantable electronics is considered as the most ideal medical device for minimally invasive insertion of implantable devices.

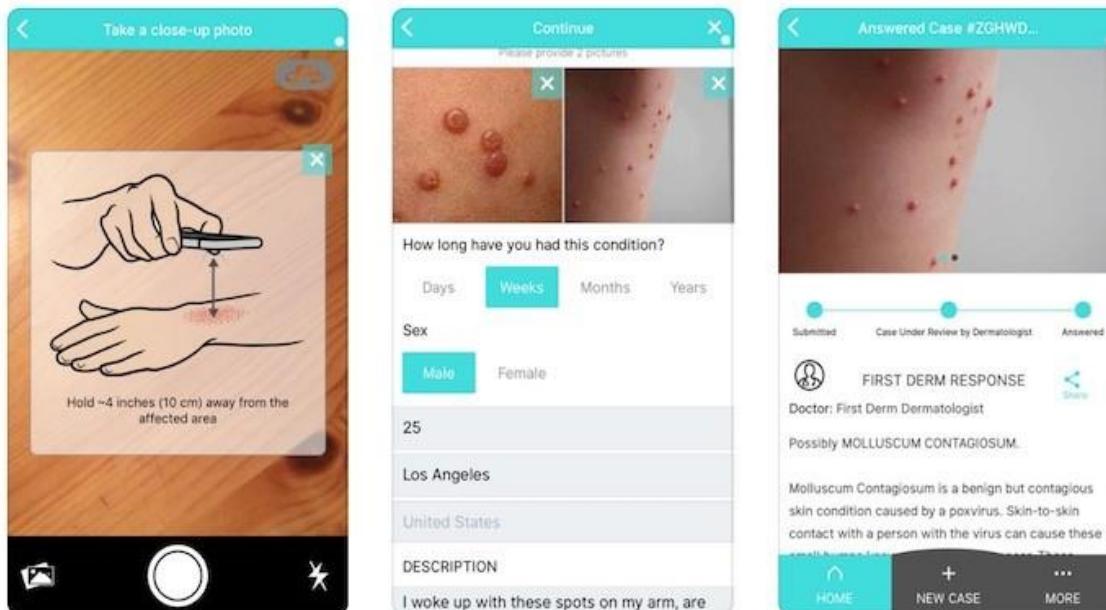
- Key technologies that will drive this innovation:

- Printable and flexible electronics
- Functional 3D printing
- Wireless energy transfer and harvesting
- Biomaterials - biocompatible, biodegradable and self-healing

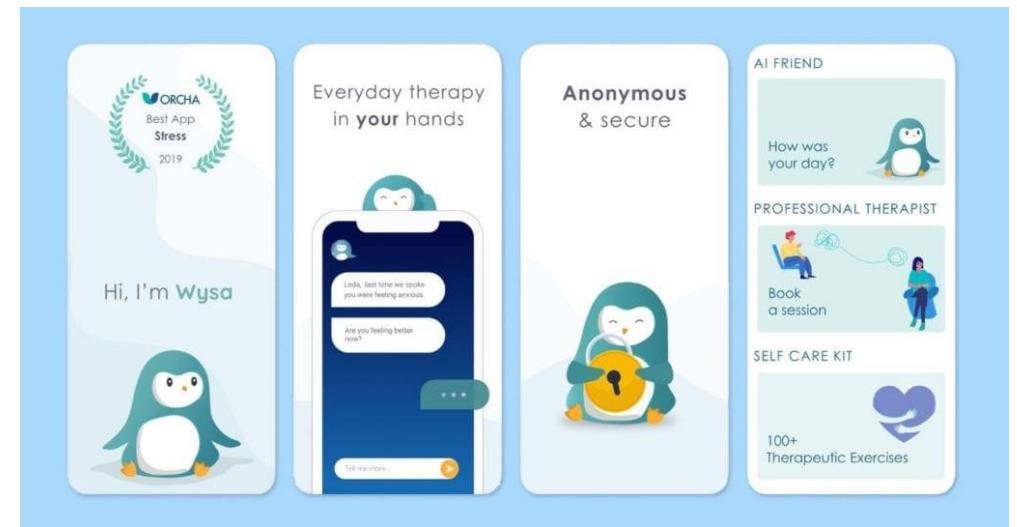
Leveraging mobile devices and embedded AI



Audiological examinations – Heart, lung sound, speech analysis



Camera-based analysis – Digital dermatology



Conversational bots – Mental health, chronic diseases



Whole-patient trackers – multi-modal approach



- Products are tangible.
- We can sell, buy, store, and transport products. When the sale is complete, we can move the product, or even replace it for another product.
- Products sold can be identical, but each delivery of a particular service is never exactly the same as the previous services or future services.
- Physical products usually come in many formulations. Clothes come in different styles, colors, sizes.

Products

Services

- Services are intangible
- We can define a service as a transaction that does not involve transfer of physical goods from the seller to the buyer. It is basically a work that a person/persons do for another individual.
- Services are difficult to identify because they are closely associated with a good; such as the combination of a diagnosis with the administration of a medicine.
- Services typically do not offer multiple formulations. As a doctor's visit is a doctor's visit, whether you are going for tennis elbow or diabetes.

Products

- Unless a product has protection under a patent, it's likely that many versions of it exist. For example, consumers may have thousands of choices when they want to generic medicine or a regular device (such as thermometer).
- Customers can often return products after purchase. This may allow them more freedom when making purchases, as they know it's possible to reverse the decision.
- While forming a relationship with a customer can help when marketing a product, it's often more important that the product appeals to the consumer's needs.

Services

- Companies that provide services may offer less variety, depending on the type of service. For example, seeing a doctor typically includes the same elements, whether you choose one provider over another.
- Some service providers offer a satisfaction guarantee, wherein the customer might get their money back if they have a negative experience of the service.
- Marketing services often require a strong relationship between the consumer and the business. This is because the customer might be more likely to return if they trust the company to do a good job with the service.

Medical Products

1. Diagnostics



Stethoscopes & Spare Parts



Sphygmomanometers & S...



Diagnostic Sets



Otoscopes



Ophthalmoscopes



Pulse Oximeters



Fetal Doppler



ECG Machine

Examples of Products



MRI Machine



Spirometer



Xray machine

2. Implants



Knee Implant



Hip Implant

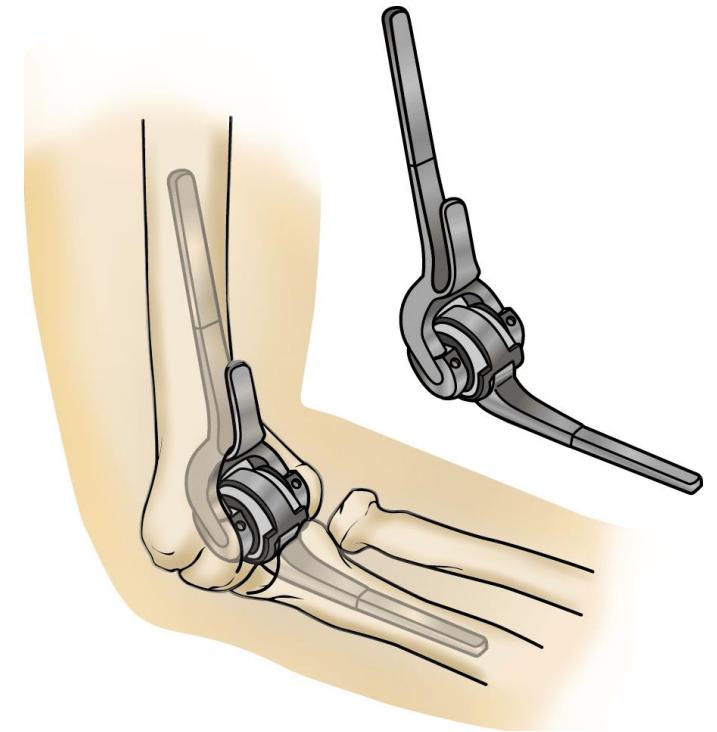
Examples of Products



Spinal Implant



Dental Implant



Elbow Implant

3. Assistive devices and Orthoses



Wheelchairs



Walkers

Examples of Products



Assistive
attachments



Hearing Aids



Adaptive writing
attachments

Examples of Products



Contracture Braces



Elbow Splints and Braces



Finger and Thumb Splints and Braces



Foot and Ankle Braces and Splints



Fracture Splints and Braces



Hand and Wrist Splints and Braces

Examples of Products



Hip and Thigh Splints and
Braces



Knee Braces and Knee Supports



Pediatric Orthotics



Plantar Fasciitis Solutions

Examples of Products



Diabetic Insoles



Diabetic Shoes



Diabetic Walker Boots



Orthopedic Supports & Braces

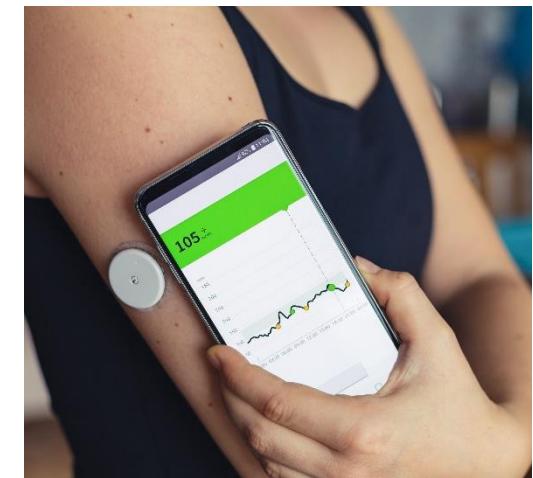
4. Wearables



Smart Glasses



Smartwatch



Glucometer



Activity Trackers

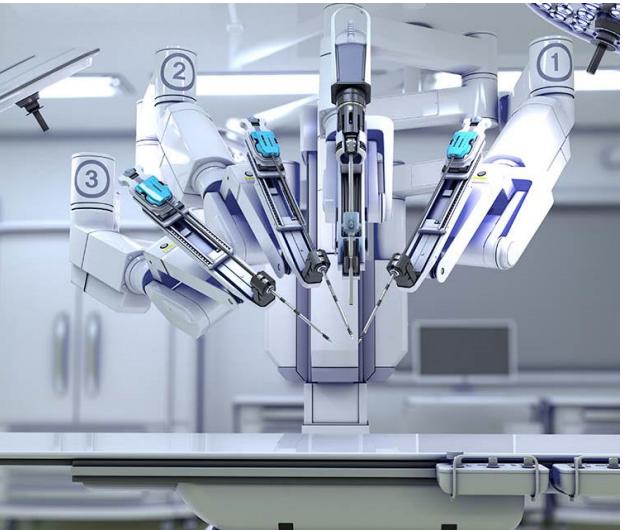


Hydration Monitors

Examples of Products



5. Robotics



Minimally Invasive
Surgical Robots



Neurosurgical
Robots



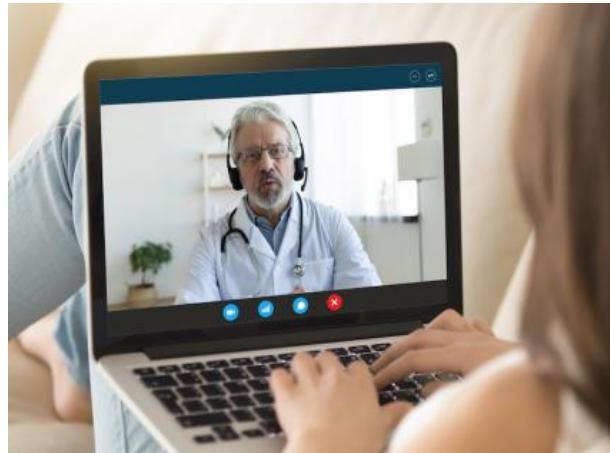
Robot Arms



Behavioural Therapy Robots

Healthcare Services

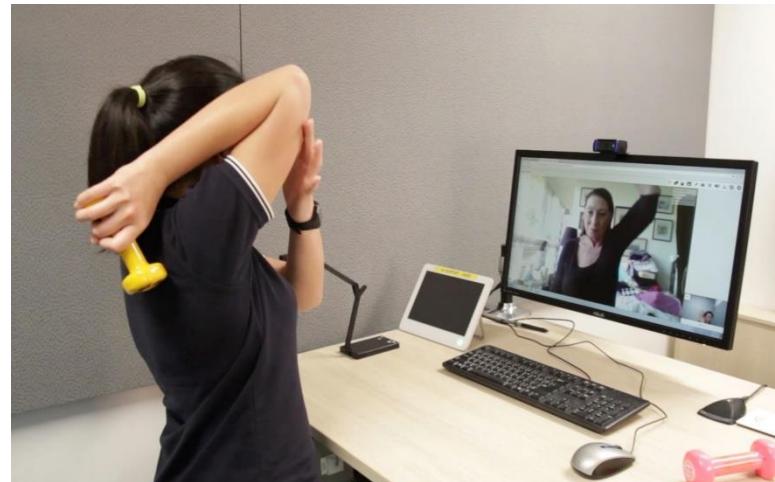
1. Telemedicine



Healthcare consultations



Telenursing



Telerehabilitation



Remote Monitoring

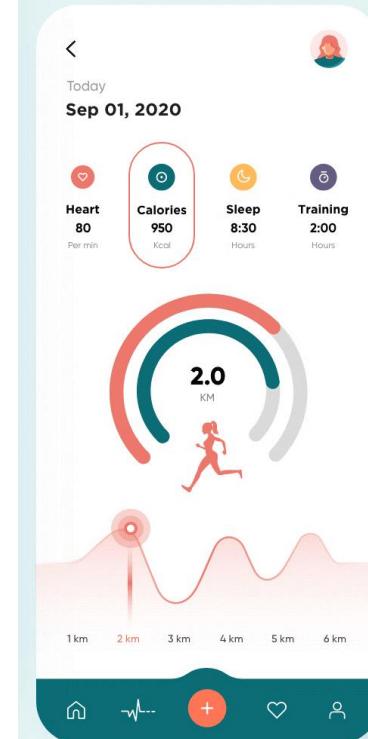
Examples of Services



2. App-based



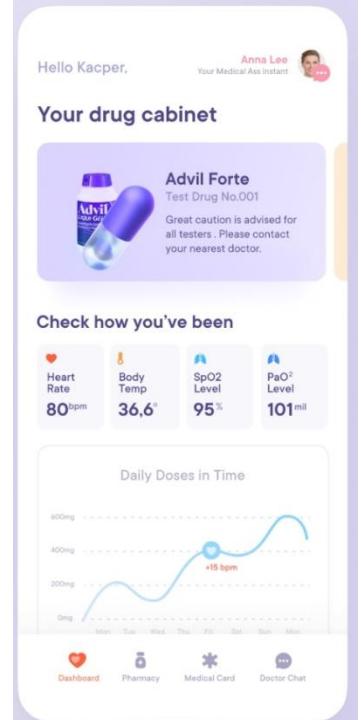
Sick Predictors



Fitness Trackers

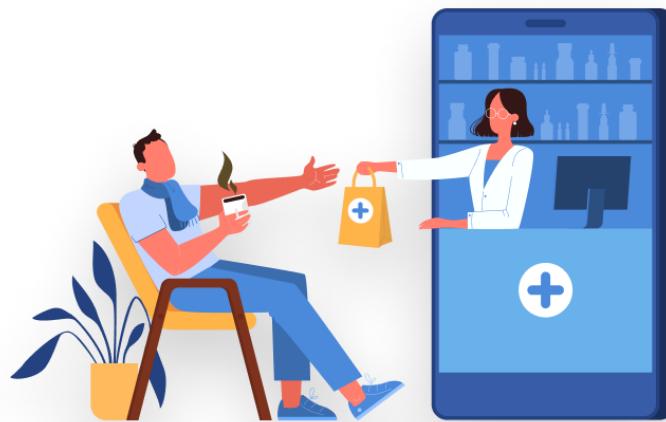


Glucose Trackers



Medicine
Reminder Apps

Examples of Services



3. Other Services

Online Pharmacy



Home Sample Collection for Lab Tests



Ambulance Services



Johnson & Johnson

Baby products, vaccines, ointments, daily use healthcare, cosmetics, disinfectants, implants

 **Abbott**

Diagnostic devices, nutrition supplements, medical-mechanical valves, implants, components (such as pedicle screws, guide wires, etc.), real-time glucometer, neuromodulation devices, medicines



Medical Imaging, lab diagnostics,
hospital IT solutions



Speciality, generic, over-the-counter,
active, and anti-retro viral
medications manufacturing expert



Orthoses, assistive devices, braces, injury mitigation wearables, wound protectors, etc.



Leader in prosthesis, orthoses, and wheelchairs

Real life Examples



Online Pharmacy



Telemedicine



THANK YOU
(Questions)