Capsules of Health in the City

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Abstract. The new vision and the strategy for the innovation of the healthcare systems rely upon prevention and territorial infrastructures. Digital technologies offer new systems for collecting, processing, and interpreting personal and community health data in an interoperable database. This action supports patient empowerment and the implementation of a new healthcare system closer to citizens, improving their quality of life, providing advanced and data-driven services. One emerging concept and solution is the new Capsules equipped with biomedical devices to support checkups and monitoring of citizens to enable advanced services in a personalized coaching. They are small private spaces that could be distributed over a territory to provide people entry point to healthcare services with a performing user experience and motivational engaging reward to sustain long-term adherence. Also triage procedures could be facilitated by the adoption of such technologies. This could be one of the new steps forward to tackle the challenge of a healthcare system reform and innovation to ensure a future healthcare that will be more and more accessible and equitable, and high performing.

Keywords: Territorial Health, Prevention, Digital Healthcare Technologies, Health Pod, Patient empowerment.

1 Introduction

1.1 The current Healthcare scenario

Health is our primary value and also one of the main engines for innovation: Also during critical and emergency time like the last years we lived we have experienced how true this situation is. In fact, the Coronavirus pandemic has changed everything in our lives: healthcare needs and sensibility too, social behaviours and also relationship with digital technology, it has forced organizations in every industry to flex and evolve, both in real-time and in the long-term. In this very complex scenario, a new awareness of the need of a structural reform of healthcare system of and for the future has arisen.

Health systems have relied on well-established disease management pathways and evidence- based care and person-to-person (e.g. patient-doctor) approaches in an effort to manage care demands and standard-ize practices to improve quality and safety. Digital health is emerging as a priority for many public and private healthcare systems as a way forward to drive value for every global citizen, to ensure healthcare is accessible and equitable, and high performing [1]. In fact, global health systems are at a crossroads, facing exponential growth in healthcare costs, coupled with aging populations and the rapidly growing preva-lence of chronic illness, that are collectively exerting strain on health systems that are already struggling to cope with demands for services. Together with this, today, the term HealthCare or Health describes a process that provides a clinical service no longer aimed exclusively at safety and the provision of care, but the treatment to the subject, which is and remains the main point, directs towards the quality of life for the patient, for his / her family and for all health professionals who interact with him / her every day.

It is increasingly evident that a modern healthcare system cannot ignore a profound overall restructuring of the system and environments, prod-ucts and services that must leverage the availability and development of new technologies, from telemedicine to digital health, from artificial intelligence to miniaturized monitoring systems [2]. To enable seamless integration within healthcare, the Internet of Things technology is being exploited to form closed-loop systems that remotely communicate with one another.

1.2 The new demand for Health

It is interesting to acknowledge that from the most recent scientific lit-erature findings, 84% of pathologies are direct correlation with lifestyle so that a new clinical branch is defined as 'Lifestyle Medicine' where definition, promotion and personalization of coaching interventions are the most promising strategies. To achieve this proactive healthcare promotion goal, the most important action is said to be the patient em-powerment that is defined as the process which people can gain a better control about decisions and actions related to his/her own Health through digital biomedical technologies [3]. This is also the vision adopted by the European Union in its key strategies for research and related exploitation: for Healthcare, we should push on Digital Trans-formation and trends towards Predictive, Preventive, Personalised, Par-

ticipatory Healthcare and Psycho-cognitive, the so-called P5 Medicine that is the target for 2030 [3, 4, 5]. Predictive Medicine founds on two pillars: one is genetics and genomics; the second is lifestyle as main factor to identify health related risks or pathology early signs. Preventive Medicine starts from these factors and thanks to a dedicated pro-activity by users and professionals can become a strategic action to improve our lives, free from pathology for a long time or with minimal effects [6]. These interventions must be transformed from actions performed on clusters of population to the single individual with tailored actions so to achieve the best effectiveness, efficacy, quality and acceptance. Personalization or tailoring to the individual user requires his/her participation, i.e. an active role of patients in the co-creation of systems, strategies, therapies and interventions to be really user- centered for their best results. Furthermore, Participatory Medicine means also to enable the subject to have an active role in the management of her/his own health, starting from awareness and knowledge of the current health status and personal lifestyle.

Lifestyle diseases share risk factors similar to prolonged exposure to four modifiable lifestyle behaviors, that are smoking, unhealthy diet, stress, and physical inactivity, and result in the development of chronic diseases, specifically heart disease, stroke, diabetes, obesity, metabolic syndrome, chronic obstructive pulmonary disease, and some types of cancer. It is worth considering that according to the related scientific literature lifestyle factors are responsible for about 60–65% in their development in comparison with the genetics that impacts only for about 30–35% [6, 7, 8, 9, 10, 11]. The cluster of common risk factors related to lifestyle (like high blood pressure, dyslipidemia, sedentary lifestyle, overweight, tobacco use, and alcohol abuse) affect our lives in term of loss of expectancy: the WHO estimates that each of these factors determines a loss of life expectancy ranging from 12 years for smoking to 3.3 years for a sedentary lifestyle, without considering the overlapping effects between several factors [12]. Fortunately, most of the risk factors mentioned above are reversible and, if corrected in time, so are the diseases they trigger. This new Lifestyle Medicine is an emerging discipline and strategy to have proactive interventions than reactive ones. The measurement of signals related to these factors allows for identifying and quantifying the risk so to produce the necessary awareness to promote a behavior change able to correct the situation. In this perspective an active role of the subject is needed before he/she becomes a pa-

tient. This action for the proactive healthcare promotion, is also called patient empowerment, in a multidimensional approach needed for a successful outcome [13].

In these last years, with the COVID-19 pandemic, the fundamental role of the personal responsibility in adopting safe behaviors was demonstrated, also for some digital services needed to assure continuity of care, surveillance/monitoring or remote assisted intervention, together with all the tools for population screening and personal protection in a territorial distributed care approach.

2 A territorial strategy for Personalized Preventive Medicine

Together with the crucial importance of digital technologies in our society and also in healthcare, the recent COVID-19 pandemic has highlighted that current healthcare systems needs a profound renovation of their service models, implementation infrastructures and related technologies with the adoption of modern technologies that could streamline the patient pathway, from identification of symptoms to treatment and long- term support [13]. This paradigm shift has the potential to widen access to healthcare provision, reduce costs, and provide services tailored to individual needs and increase their quality and efficacy.

Medical devices and in particular those ones dedicated to monitor patients' vital signs, are today being diffused as handheld and wearables objects that are able to support real-time, accurate diagnosis and treatment of disease. In the traditional model of healthcare, the general population tends to seek medical advice when new symptoms appear and they attend a check-up with a General Practitioner (GP). Nowadays this approach is changing because of the availability of those wearable sensors and Apps, which give patients direct access to information about their health status and trend by providing real-time clinical data. In this way, these devices can actually empower patients to gain direct awareness and self decision-making control over their care and make better-informed decisions about their health. Digital healthcare also offers new ways to facilitate prevention and management of chronic conditions at the population level [2].

Furthermore, in synergy with "wearable clinical monitoring", new models for a "middleware territorial medicine" is moving forward as a win-win model for healthcare systems and citizens. In fact, there a urgent demand for a territorial healthcare assistance, which has to be

close to citizens' needs, granting the population with effective equity of access to healthcare and social services, through the definition of homogeneous qualitative and quantitative standards, the strengthening of the network of district services, as well as through the consolidation of the hospital and the emergency network integrated within it.

More home and community-based care and long-term care are crucial in providing services and support to people, in particular for those with disabilities and other disadvantaged groups. Currently a reform is in progress towards strengthening the territorial network and ensure greater proximity to the citizen, to better distribute care activities while avoiding overloading the hospital network. Ensuring greater integration between hospital and local facilities is indeed a crucial element to provide a better access to care and a uniform provision of high-quality services at every level. To purse these objectives, the first action is to enhance the resources (infrastructural, structural, instrumental, human) essential to increase effectiveness of the prevention and response to communicable and non-communicable diseases according to WHO, international and European guidelines.

Such middleware structure has been identified and proposed in the so-called Community Health House. The Community Health House is an organizational solution that has the function of primary care hub and follows a model of delivery and use of services by promoting the proximity of the facilities to the local community, being able to filter access to acute care facilities and to coordinate and integrate all care services for chronic patients already present in the area (e.g. a light or not-severe pathology or event like small accident, the need for some tests, or the management of the caregiver for family situation, etc) [14]. In this perspective, its main mission is to improve territorial health assistance, specifically for those chronic diseases that in 2019 affected almost 40% of the Italian population and expected to increase in the coming decades. Just for understanding the current dimension of the problem, in 2020 in Italy there are 24 million people with chronic diseases, of which 12.5 million have multi-chronicity, for a healthcare expenditure of nearly 67 billion euro. The amount of chronically ill patients is also in progressive growth, with an impact on the future need to commit health, economic and social resources. To them there are other 3.1 million people with disabilities in the Country, i.e. 5.2% of the Italian population.

The Covid-19 emergency has made clear that there is the need for geographically widespread facilities, in order to avoid excessive use of hospital care, especially for non-urgent treatments that cannot be postponed.

In the Community Health House, citizens can:

- consult a general practitioner and a nurse throughout the day;
- consult a health professional who welcomes citizen's requests, guides the citizen to services and takes care of activating proper health paths;
- solve adequately most of citizen's problems in a single location;
- manage chronic diseases through shared and supervised care pathways.

In this scenario, to intervene effectively in the prevention and early treatment of the most common and diffused pathologies already mentioned, it is essential to move some processes also outside the healthcare facilities to the general population and specifically and hopefully in a self or automated mode - that implies the avoidance of the effort for the clinical operators and personnel like nurse, doctors, GPs, that are already at or over the threshold -, to identify those at risk or already affected, and to be able to treat them as soon as possible, thereby reducing the actual disease burden. Together with territorial facilities, a new generation of healthcare systems and devices are facing this opportunity.

3 Innovative technologies for territorial services: Capsulas of health in the city

In this scenario, to let people know and be aware of their current health level and to promote healthy lifestyle changes, so to enable the Participatory, Predictive, Preventive, and Personalised interventions, in the recent yeas several technological innovations were brought to the market bot at biomedical and at consumer level to remotely obtain and analyze clinically relevant information from individuals. Today, these new Digital Health Technologies (DHTs) have revolutionized several clinical processes and are playing a growing role in health care and because they are able to offer new important opportunities in clinical services and also in the related research [2, 14]. If compared to intermittent trial visits, the use of DHTs to remotely collect data from trial participants may allow for continuous or more frequent data collection. This may

provide a broader picture of how participants feel or function in their daily lives. On the contrary there is a production of large dataset that are requiring the development of new and powerful algorithm for data processing, mining, and extraction of the relevant clinical information bot for a personalized health service (prevention, diagnosis, monitoring, rehabilitation, etc.) and at community or societal level for a broader picture of the health status of the population too.

Wearable devices and Apps can be allocated to this category, i.e. DHTs able to record data directly from participants (e.g., performance of activities of daily living, sleep) wherever the participants may be (e.g., home, school, work, outdoors). Some DHTs also may facilitate the direct collection of information from participants who are unable to report their experiences (e.g., infants, cognitively impaired individuals).

Another key and enabling factor of today innovation is the so-called Internet of Things (IoT) technology. The Internet of Things is the network of physical objects that contains embedded technology to communicate and sense or interact with the objects' internal state or the external environment. Healthcare services based on the Internet-of-Things have great business potential. The revolution of Internet-of-Things is reshaping the modern healthcare model with promising economic and social prospects. Because of substantial advances in technologies, it is now possible to use connected sensing technology for health management. This is the base to Internet of Medical Things, where connected biomedical devices in a network and in the cloud exploit this concept. As technology has become such an important part of daily life, technology-based interventions (including wearable devices, environmental sensors, Internet-based biomedical parameters management tools, social media, apps for smartphones, and active video games) have been developed as methods for health management and health promotion opportunities. By using the personal computing devices (laptop, mobile phone, tablet, etc.) and mobile internet access (WiFi, 4/5G, etc.), the IoT-based healthcare services can be mobile and personalized and may significantly contribute to human health and well-being.

Currently, the state of available technologies for patient empowerment includes wearable technologies, un-obtrusive monitoring like environmental sensors, and several devices dedicated to specific measurements of physiological parameters. If wearable technologies offer continuous monitoring of some basic functional parameters, most of them are not reliable and certified as medical device, so just a general and behavioral

frame can be drawn in particular in the physical activity domain, while a deep insight into other and clinical-grade health parameters is often needed.

The continuous demand for new health services led to the recent development and deployment into the market of integrated solutions to enable the user to have a fast health check with respect to several human health domains, thanks to a set of easy-of-use measuring devices integrated into a standalone station. This led to the development of healthcare pod or kiosk where people can measure several physiologic parameters through 'non-invasive' techniques by an operator-assisted or self-based procedure [15, 16, 17, 18, 19, 20]. In most cases, the subject receives as output a report, including the measured data and a set of indicators related to associated risks for the most relevant pathologies. In some cases, other and secondary services (e.g., video or teleconsultation) can be activated by and through the same systems.

In more detail, a "health pod" or also a "health kiosk" is a small space, set in public or private environments, equipped with some medical devices where people can carry out check-ups, screenings, or follow-ups and eventually receive remote visits or clinical consultancy. They are a delimited space in the form of a capsule. where, with or without the presence of a healthcare operator, biomedical technologies are made available to measure different physiological parameters. In the case of a system without walls, in an open environment, and in a vertical configuration, the health pod has the shape of a totem, or, in its minimal configuration, placed onto a desk with some measuring devices for some health-related parameters or signal.

Among the most interesting systems in health pods, CAPSULA (https://CAPSULA.app/) has developed an innovative and disrupting solution [15, 20]. CAPSULA is an "Onlife Phygital" platform empowering people to build healthier behaviours concerning the wish of wellbeing and stay healthy through innovative and high added value products/services. Onlife is a neologism meaning the multifaceted dimension of life including health, relationships, social activity, work and wealth conditions. Phygital means that the user is living a digital experience through a physical interface. This physical interface is a health pod, a private space even in public environments, where people are led through a healthcare assessment pathway with a very performing user experience co-designed with a user panel and together with the Dept. of Design of Politecnico di Milano. The user is guided along all steps to

avoid procedural errors so to achieve the reliability of the system: 25 test-users have carried out parallel assessments to verify this aspect.

Design, and co-design activities in particular, was a crucial phase to obtain a great result in UX and engagement, not only to build a simple and 100% error free self procedure in the measurement of the biomedical signals, but specifically to create a high experience that engage the subject in a positive feeling more than a clinical mood to carry out a complex or demanding or anxious task. At the end of the tests sequence the user receives a printed label with a summary of the measurements and related indexes visually compared with the normalcy guideline provided by the scientific guidelines (such as ESH classification for BP) and a QRcode redirecting to the CAPSULA website where they can display their health dashboard and retrieve more detailed information and ask for further counselling services for their health and wellbeing (Fig. 1).
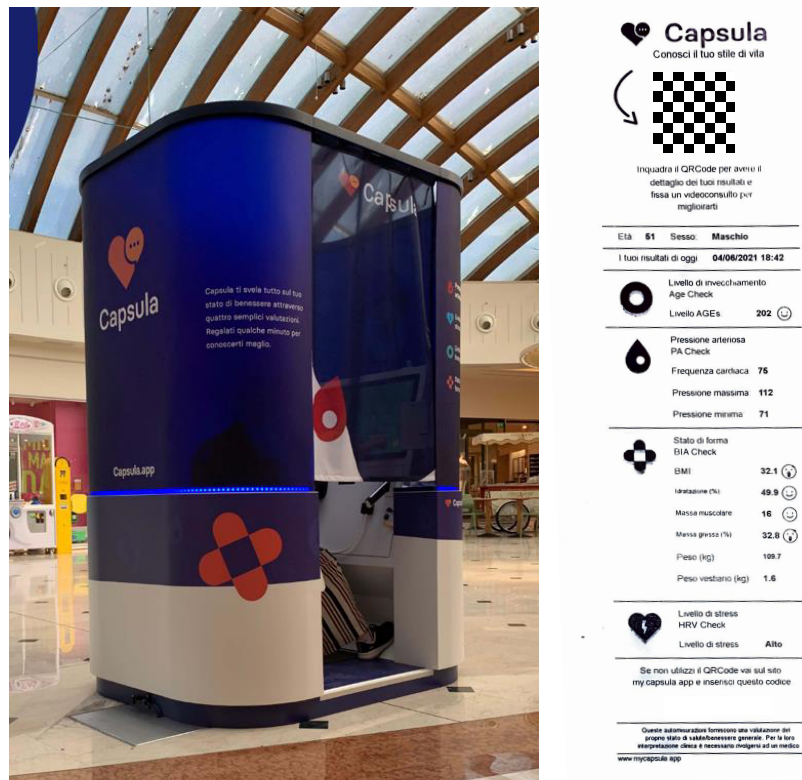

Fig. 1. The CAPSULA Lifestyle Health Pod and an example of the printout with the summary of the measurements and the QRcode redirecting to the landing page with the complete description and health positioning criteria.

CAPSULA platform is an open, scalable, cloud-based IoT software platform designed to easily connect devices and give them a voice in order to process, transform, organize and store sensor data, and connect them to mainstream messaging platforms to build and run IoT apps, capable to evolve and become the reference platform for all IoT connected devices (Table 1).

Thanks to and in light of the IoMT approach, the software has been optimized in terms of:

Modularity

- UX efficiency
- Fast and simple
- Customization (each pod can have a different customized procedure for matching specific needs in terms of brand identity but also in terms of healthcare service and domain).

Table 1. CAPSULA features, from requirements to implementation.

Requirement	Implementation
Easy to Integrate new services	An Open Webapp with API architecture shall allow for easy integration of services in different human domains.
Scalable	Multilingual Cloud Platform has to be easily manageable and customizable, and based on an API architecture integrating other services.
Internet of Things	The proprietary Software (IoT manager) must be capable to quickly and safely integrate external devices through dedicated plug-ins.
User-Friendlyness	The system must have an advanced UX to provide engagement and reliability in easy procedures.
Artificial Intelligence	From the consolidated background derived from more than 250.000 test in Italy, Spain and Portugal, every CAPSULA check-up is to be processed by robust algorithms to compute reliable individual indexes provided in the advanced final report.
Integrated Mobile App	The App implements the end-user management of data and services.

As said, CAPSULA exploit strategy that awareness is the entry step toward prevention. The CAPSULA Health Pod that let the user to carry out the individual check-up in self-mode, the CAPSULA cloud storing data and providing a further data processing and visualization for better comprehension to the user, and the CAPSULA APP, implementing the dashboard and the access to counselling for personalized preventive coaching towards healthier behaviors in lifestyle, i.e. in order to identify the best strategy for the prevention and improvement of one's life-

style, considered from a multifactorial point of view, defining specific suggested protocols (Fig. 2). The CAPSULA Lifestyle version integrates 1 ECG lead with HRV analysis, arterial blood pressure measurement, Advanced Glycation Endproducts measurement (AGE), weight and body composition for basic intervention in the main human dimensions driven by self and not-invasive measurements.

Several biomedical (CE marked) devices can be integrated but with a standard and unique patented sensory board, so that the morphology of the system is always the same.

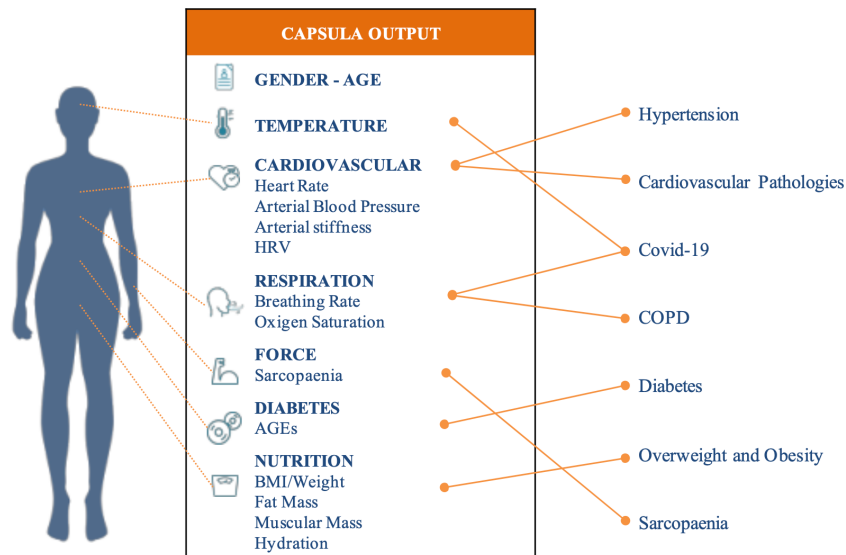## Personalized protocols for prevention

Fig. 2. The relationships between measurements in the CASPULA Lifestyle Health Pod and the most diffused and relevant pathologies to setup personalized monitoring actions.

The self-measurement of vitals sign is not only a good prevention tool, but it's very useful for hospital procedures efficiency. A pilot case conducted in a Clinic in the Milan area, through a 4 -steps pre-triage procedure composed by:

1. Mandatory hand sanification
2. Custom anamnestic questionnaire
3. Body temperature

  4. Results printout (date, time, privacy statement, temperature, overall output: 'entrance admission', 'need a swab', 'entrance not possible'),

This explorative case study demonstrated that such an approach, implemented by a simplified CAPSULA version in the morphology of a totem, provided a reliable and efficient process able to manage in average 347 patients per day, with an average procedure time of 22 seconds (Fig. 3). This Totem version of CAPSULA can be dedicated to speed up the triage procedure in crowed public environments to grant secure access and it can also become a relevant tool to protect employees dedicated to this task, for example the nurses at the entrance of hospital and emergency departments during the COVID pandemic so to divide the people fluxes in ordinary access (e.g. traumatic injured subjects) and people with signs of positive infection to the virus. This is another service that such system could offer in the healthcare system.

Fig. 3. The CAPSULA Triage Tome in two setups, without (on the left) or with the integration of the measurement of the Arterial Blood Pressure.

In fact, systems like CAPSULA can be considered tools for enabling further and added value services in several directions. Jointly with an App or Webapp, though a marketplace built in collaboration with selected partners clinical like hospitals or also technological like Artificial Intelligence startups to generate personalized data e contents and coaching, and even with other providers of services for prevention -

like pools or gyms or bike rent services for improving the physical activity, restaurants, food shops or malls for nutrition, up to organization to improve the engagement of people in social activities – they could offer in combination with the assessment specific call-to-action towards prevention (Fig. 4). They could open a new era where the healthcare system is able to provide differentiated and personalized services close to citizens and matching their actual needs and preferences. In a European initiative dedicated to the silver age, the NESTORE project [21] funded in the H2020 framework program explored with success the concept of personalized pathways of interest and an interesting and possibly winning strategy towards the wellbeing of citizens: starting from their preferences and beviours, measuring their health status through wearable and environmental sensors in the different human domains (physical activity, physiology, cognitive performance, social activity, nutrition) it is possible to build a data driven personalized coach that can reach a strong impact towards healthier lifestyles by implementing customized strategies and related activities with motivational reward.
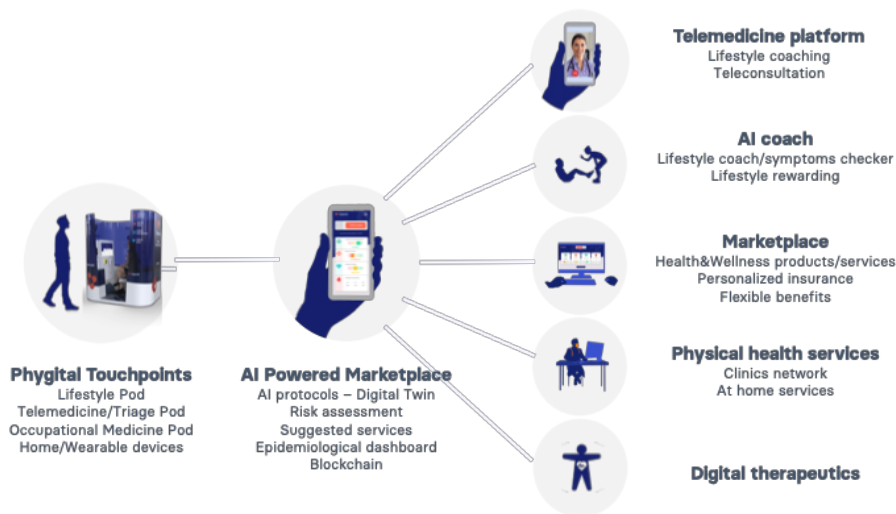

Fig. 4. The flow for service implementation from capsulas of health in the city to the citizen and stakeholders.

The next frontier is to make these territorial distributed systems also able to dispense digital therapeutics, even during all 24 hours in all the

days of the week. This will be a true implementation of the telemedicine concept: anyone, anytime, anywhere.

4   Conclusion

The global Covid-19 pandemic exposed the fragility of national healthcare systems all over the world, as preventive health stepped on the sidetracks to allow the treatment of urgent cases. While that impacted the healthcare domain in a largely negative way, it also allowed for the rise and growth of digital health, telemedicine, and AI. In this way the initial menace turned into an extraordinary opportunity to redesign our healthcare systems projected to the future and able to quickly answer to new emergencies and needs. This ambitious goal requires a new vision of organization supported by innovative technologies and systems (Fig. 5) distributed on a large territory and even at home - for the manageable services -.
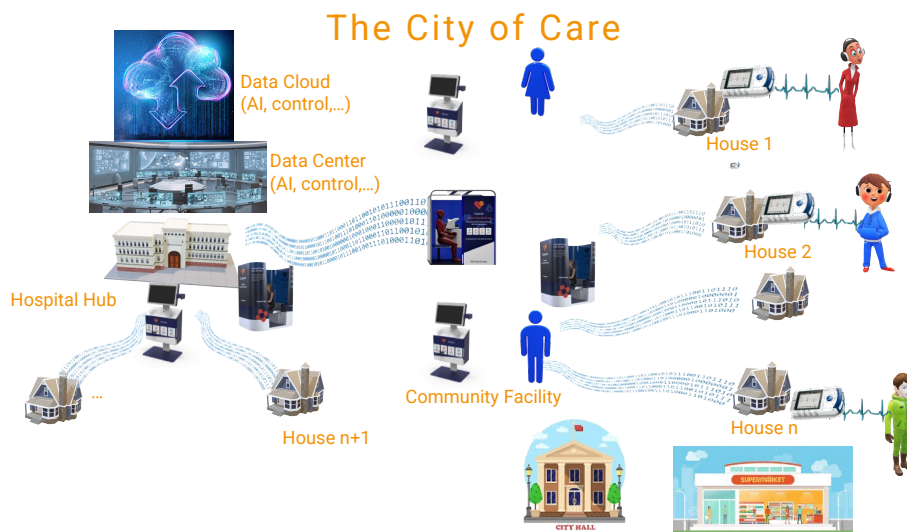

Fig. 5. A possible infrastructural and organizational model for the City of integrated Care with players, structures and technologies.

This reorganization will allow for pursuing three strategies to balance quality, access, and system's cost in the City of Care vision:
1. Large "regional hub" hospitals to increase volumes in specialised services to deliver high-quality care affordably;

2. Smaller hospitals (sometimes called local or community hospitals) forming networks to invest in infrastructure, share back-office costs, and attract and retain staff who want to undertake a range of clinical work;

3. Vertical integration amongst regional hubs, smaller local hospitals, community-based care and, in some cases, payer organisations to coordinate the full range of care services and provide care closer to patients' homes.

In this perspective, the introduction into the health market of a innovative IoT and cloud platforms can enable the development of new high-impact solutions to provide a large-scale set of services for of ubiquitous Health applications to:

- Empower patients' self-management of lifestyle and health, so implementing the first paradigm of prevention by awareness and reducing risk factors (through the personalized coaching delivered though the advanced level through cloud services);

- Provide personalized prevention programs, promoting health environments, encouraging physical activity and health nutrition through a gamified approach;

- Redefine the patient / care giver relationship, where care teams and consumers decide together when to visit live or virtually, reducing time and costs of the traditional healthcare delivery approach, providing immediate and geographically distributed tools for monitoring and evaluating the patients progresses;

- Empower patients' self-management of disease, helping patients to increase the level of adherence to their clinical Programs and to make the healthy choice the easiest one, in the right time.

The CAPSULA representative study aims at highlighting these developmental directions. In a certain sense the overall objective is to build a "City of Care" or even better a city of integrated citizenship and their care, where structures and services goes towards the individual needs in a friendly but safe and high-quality strategy. Better care services, high quality, resources optimization and cost reduction are the expected outcomes.

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