UNIVERSITAT DE BARCELONA

An adaptive case management approach to prevent unplanned hospital admissions in a care continuum scenario

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AN ADAPTIVE CASE MANAGEMENT APPROACH TO PREVENT UNPLANNED HOSPITAL ADMISSIONS IN A CARE CONTINUUM SCENARIO

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LIST OF ACRONYMS

ACM: Adaptive case management

ACP: Advanced care patients

AISBE: Área Integral de Salut de Barcelona-Esquerra

AMG: Adjusted Morbidity Groups

APIC: Assistance and Integration of Care Program

BSA: Badalona Serveis Assistencials

CCA: Cost-consequence analysis

CCM: Chronic Care Model

CCP: Complex chronic patients

CF: Core Features

CHS: Catalan Health System

COPD: Chronic obstructive pulmonary disease

CRG: Clinical Risk Groups

ED: Early discharge

EEG: Efficacy-effectiveness gap

EHR: Electronic Health Record

EIP-AHA: European Innovation Partnership for Active and Health Ageing

ENAPISC: National Primary Care and Health Strategy Community Program

EU: European Union

HaH: Hospital at Home program

HA: Hospital avoidance

HCB: Hospital Clínic of Barcelona

HC3: Regional shared electronic health platform

HRA: Health risk assessment

HSPA: Health Systems Performance Assessment

ICOPE: Integrated Care for Older People

ICT: Information and communication technologies

IDIBAPS: August Pi i Sunyer Biomedical Research Institute

JADECARE: Joint Action on Implementation of Digitally Enabled Integrated Person-Centred Care

KLW: Key Learning Workshop

KPI: Key performance indicator

LAP: Local Action Plan

LGP: Local Good Practice

MAFEIP: Monitoring and Assessment Framework for the European Innovation Partnership on Active and Healthy Ageing

MCDA: Multiple Criteria Decision Analysis

MSIQ: Moduls pel Seguiment d'Indicadors de Qualitat

NA: Next adopters

OC: Operational Committees

oGP: Original Good Practices

PADRIS: Data analysis program for research and innovation in health (PADRIS)

PDSA: Plan-Do-Study-Act

PHC: Primary healthcare center

PPAC: Chronic Prevention and Care Program

PREM: Patient reported experience

PROM: Patient reported outcome

RCT: Randomized controlled trial

SDOH: Social determinants of health

TERMCAT: Terminology center of the Catalan language

TW: Thematic Workshops

USA: United States of America

WHO: World Health Organization

THESIS IN COMPENDIUM OF PUBLICATIONS FORMAT

The thesis consists of 3 objectives and 4 articles.

Herranz C, González-Colom R, Baltaxe E, Seijas N, Asenjo M, Hoedemakers M, Nicolas D, Coloma E, Fernandez J, Vela E, Cano I, Mölken MR, Roca J, Hernandez C. Prospective cohort study for assessment of integrated care with a triple aim approach: hospital at home as use case. BMC Health Serv Res. 2022 Sep 7;22(1):1133. doi: 10.1186/s12913-022-08496-z.

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ABSTRACT

AN ADAPTIVE CASE MANAGEMENT APPROACH TO PREVENT UNPLANNED HOSPITAL ADMISSIONS IN A CARE CONTINUUM SCENARIO

Unplanned hospital admissions generate high economic, and organizational, burden on healthcare systems worldwide. Likewise, inpatient care has a deleterious impact on patients' quality of life and is a well-demonstrated causal factor of nosocomial complications. Moreover, multiple admissions have shown association with poor survival prognosis in chronic patients. Accordingly, there is a robust rationale to explore the potential of interventions aiming at preventing potentially avoidable hospitalizations, with an integrated, patient-centered, approach.

Chronic patients with multimorbidity, and frailty, are the most frequent candidates for unplanned hospitalizations, either due to episodes of exacerbation of a chronic condition, or during vulnerable periods, like transitions after hospital discharge.

The analysis of the literature on interventions to prevent hospitalizations in community-based chronic patients with episodes of exacerbation and on transitional care programs aiming at reducing early-readmissions after discharge provide inconclusive messages. This can be explained by several phenomena, namely: heterogeneities of the interventions, suboptimal description of the study protocols, poor comparability among sites, among others.

The unsolved efficacy-effectiveness gap seen between the positive results of a two-center randomized controlled trial, carried out in Barcelona (ES) and Leuven (BE) in 2006 and the lack of effectiveness observed when the same intervention was replicated in a pragmatic randomized controlled trial conducted in Barcelona during 2015, was explained by three intertwined factors: lack of personalization of the intervention, insufficient management change and immature digital support.

The current PhD thesis relies on the hypothesis that adoption of interventions properly addressing the three factors alluded to above, that is, personalization, management change and digital support, can generate value-based reductions of hospitalizations in chronic patients. The research reported in the thesis was undertaken in the context of the Catalan original Good Practice of the European Joint Action on implementation of digitally enabled integrated person-

centered care (*https://www.jadecare.eu/*), an initiative launched to address core aspects of health system transformation in the European Union. It includes four studies addressing three main objectives.

Objective 1 was the assessment of home hospitalization as a modality of care including transitional care after discharge. Home hospitalization was selected as a use case because it involves all stakeholders participating in prevention of hospitalizations and plays a principal role to foster vertical integration, between hospital and community-based professionals. The two studies carried out under the first objective cover a Triple Aim assessment with a Multiple Criteria Decision Analysis (MCDA) approach and a Cost-Consequence Analysis (CCA) of Home Hospitalization, respectively.

The second objective explored the potential of Adaptive Case Management (ACM) for digital support of collaborative work across healthcare tiers aiming at stimulating share care arrangements between specialized and primary care, as well as between health and social care. Two specific interventions were piloted: prevention of severe exacerbations in community-based chronic patients and prehabilitation of candidates for major surgical procedures. A commercial solution, Health Circuit, for digital support was successfully tested.

Within the third objective, a co-creation process using design thinking techniques and quality improvement methodologies, was undertaken, with participation of key stakeholders, including patients. The maim outcome was the design of a pragmatic study protocol for prevention of avoidable hospitalizations to be piloted within 2023 in a cohort of 200 multimorbid patients during a three-year follow-up period.

Main conclusions of the PhD thesis are threefold. The ACM approach seems to constitute a suitable approach to achieve mature digital support on integrated care services, already demonstrated for prehabilitation. After appropriate testing, the pragmatic study protocol, generated during the co-creation process, aiming at early management of exacerbations and prevention of hospitalizations could become the basis for the design of future mainstream collaborative interventions across healthcare tiers.

RESUM

UN ENFOCAMENT ADAPTATIU DE GESTIÓ DE CASOS PER PREVENIR INGRESOS HOSPITALARIS NO PLANIFICATS EN UN ESCENARI DE CONTINUUM ASISTENCIAL

Els ingressos hospitalaris no planificats generen una gran càrrega econòmica i organitzativa als sistemes sanitaris a tot el món. Així mateix, l'atenció hospitalària té un impacte nociu en la qualitat de vida dels pacients i és un factor causal ben demostrat de les complicacions nosocomials. A més, els ingressos múltiples han demostrat associació amb mal pronòstic de supervivència en pacients crònics. En conseqüència, hi ha una lògica sòlida per explorar el potencial de les intervencions destinades a prevenir hospitalitzacions potencialment evitables, amb un enfocament integrat i centrat en el pacient.

Els pacients crònics amb multimorbiditat i fragilitat, són els candidats més freqüents a hospitalitzacions no planificades, ja sigui per episodis d'exacerbació d'una malaltia crònica, o durant períodes de vulnerabilitat, com les transicions després de l'alta hospitalària.

L'anàlisi de la literatura sobre intervencions per prevenir les hospitalitzacions en pacients crònics de base comunitària amb episodis d'exacerbació i sobre programes d'atenció transicional que tenen com a objectiu reduir els readmissions precoces després de l'alta ofereix missatges no concloents. Això es pot explicar per diversos fenòmens: heterogeneïtat de les intervencions, descripció subòptima dels protocols d'estudi, poca comparabilitat entre llocs, entre altres.

La bretxa d'eficàcia-efectivitat no resolta observada entre els resultats positius d'un assaig controlat aleatoritzat de dos centres realitzat a Barcelona (ES) i Lovaina (BE) el 2006 i la manca d'eficàcia observada quan es va replicar la mateixa intervenció en un assaig controlat pragmàtic realitzat a Barcelona durant l'any 2015, s'explicava per tres factors entrellaçats: la manca de personalització de la intervenció, el canvi de gestió insuficient i el suport digital immadur.

L'actual tesi doctoral es basa en la hipòtesi que l'adopció d'intervencions que abordin adequadament els tres factors esmentats anteriorment, és a dir, la personalització, el canvi de gestió i el suport digital, pot generar reduccions basades en el valor de les hospitalitzacions en pacients crònics. La investigació que s'informa a la tesi s'ha dut a terme en el context de la Bona Pràctica original catalana de l' Acció Conjunta Europea sobre la implementació de l'atenció

centrada en la persona integrada digitalment habilitada (*https://www.jadecare.eu/*), una iniciativa llançada per abordar Aspectes fonamentals de la transformació del sistema sanitari a la Unió Europea. Inclou quatre estudis que aborden tres objectius principals.

L'objectiu 1 va ser l'avaluació de l'hospitalització a domicili com a modalitat d'atenció que inclou l'atenció transitòria després de l'alta. L'hospitalització a domicili es va seleccionar com a cas d'ús perquè implica la participació de tots els agents implicats en la prevenció d'hospitalitzacions i té un paper principal per afavorir la integració vertical, entre els professionals hospitalaris i comunitaris. Els dos estudis realitzats sota el primer objectiu cobreixen una avaluació de triple objectiu amb un enfocament d'anàlisi de decisions amb criteris múltiples (MCDA) i una anàlisi cost-conseqüència (CCA) de l'hospitalització a domicili, respectivament.

El segon objectiu va explorar el potencial de la gestió adaptativa de casos (ACM) per al suport digital del treball col·laboratiu a través dels nivells sanitaris amb l'objectiu d'estimular els acords d'atenció compartida entre l'atenció especialitzada i l'atenció primària, així com entre l'atenció sanitària i social. Es van pilotar dues intervencions específiques: prevenció d'exacerbacions greus en pacients crònics de base comunitària i prehabilitació de candidats a procediments quirúrgics majors. Es va provar amb èxit una solució comercial, Health Circuit, per al suport digital.

Dins del tercer objectiu, es va dur a terme un procés de co-creació utilitzant tècniques de design thinking i metodologies de millora de la qualitat, amb la participació de les parts interessades clau, inclosos els pacients. El resultat principal va ser el disseny d'un protocol d'estudi pragmàtic per a la prevenció d'hospitalitzacions evitables que es posarà a prova durant l'any 2023 en una cohort de 200 pacients multimòrbids durant un període de seguiment de tres anys.

Les principals conclusions de la tesi doctoral són tres. L'enfocament ACM sembla constituir un enfocament adequat per aconseguir un suport digital madur en serveis d'atenció integrada, ja demostrat per a la prehabilitació . Després de les proves adequades, el protocol d'estudi pragmàtic, generat durant el procés de co-creació, que té com a objectiu la gestió precoç de les exacerbacions i la prevenció d'hospitalitzacions, podria esdevenir la base per al disseny de futures intervencions col·laboratives generalitzades a través dels nivells sanitaris.

INTRODUCTION

HEALTH SYSTEMS TRANSFORMATION: INTEGRATED CARE

Due to the aging of the population and unhealthy lifestyles, the number of people with chronic diseases, and multimorbidity, has been increasing over the last decades and presents similar prospects in the medium term (1,2). It is usually associated with a lower quality of life, worse survival prognosis, and greater use of health resources. Moreover, it constitutes a source of dysfunctions and a very significant burden for health systems worldwide (3,4).

The epidemic of non-communicable diseases and the need for cost containment are triggering factors for a profound transformation of health systems, as well as in the way we approach the care of chronic patients. In this new scenario, conventional disease-oriented approaches focused on the treatment of acute clinical episodes are being replaced by integrated care services, as indicated by the World Health Organization's (WHO) Chronic Disease Program (5,6). Moreover, simultaneous, and continuous, progress in digital technologies for data capture and management, artificial intelligence, and the advances in medical sciences (predictive, preventive, proactive and personalized medicine, known as 4P Medicine or Precision Medicine) are shaping novel and stimulating scenarios for health promotion. It is of note that such paradigm changes in medicinal sciences (Precision Medicine) and practice (Integrated Care) share methodological commonalities, namely: i) a systems approach for the analysis of biological and clinical phenomena, ii) extensive use of information and communication technologies (ICT) leading to digital health transformation, with the consequent use of, iii) sophisticated computer modelling as supporting tools for analysis and decision making.

The WHO defines integrated care as *"an approach to strengthen people-centred health systems through the promotion of the comprehensive delivery of quality services across the life-course, designed according to the multidimensional needs of the population and the individual and delivered by a coordinated multidisciplinary team of providers working across settings and levels of care. It should be effectively managed to ensure optimal outcomes and the appropriate use of resources based on the best available evidence, with feedback loops to continuously improve performance and to tackle upstream causes of ill health and to promote wellbeing through intersectoral and multisectoral actions"* (5).

Integrated health services delivery, which aligns with the principles of the health-for-all agenda and the vision of primary health care (7), is an approach aimed at transforming the delivery of

health services and creating optimal conditions for strengthening people-centred health systems. It involves comprehensive delivery of quality services throughout an individual's life, based on the multidimensional patient's needs, but also with a population-based perspective. It requires a coordinated team of providers working across different settings and levels of cure and care, efficiently managed to ensure optimal outcomes.

Integrated healthcare services delivery comprises core interlinked processes that involve: i) designing care, ii) organizing providers, iii) managing services, and iv) continuously improving performance aiming at achieving value-based care (8). The framework of the REGIONAL COMMITTEE FOR EUROPE about strengthening people-centred health systems in the WHO European Region (5) utilizes these processes as key areas for optimizing services across various types of care, such as: i) health protection, ii) health promotion, iii) disease(s) prevention, iv) diagnosis, v) treatment, vi) disease(s) management, vii) rehabilitation, and viii) long-term care, as well as coordinating different settings: i) primary care, ii) community-based health and social care services, iii) patient's home, iv) specialized outpatient care, and v) in-patient care intermediate, secondary or tertiary care (9). The focus is on people and on prevention and relies on the health system to develop the institutional structure needed for implementing, scaling up, and sustaining the needed transformations.

Despite healthcare legal competences in Europe rely at state (and/or regional) levels, the European Union (EU) has gradually developed a consistent and integrated policy framework to respond to common challenges in the field of health that combines general directives, promotion of cooperation and financing.

The EU Health Strategy promoting digitally supported integrated care services was initiated with the Health Program "Together for Health: a Strategic approach for the EU" (4,10–13), launched within the Second Programme of Community action in the Field of Health 2008-2013. A highly relevant initiative under this umbrella was the European Innovation Partnership for Active and Health Ageing (EIP-AHA) (14) in 2011, promoting several working groups, as well as the identification of Reference Sites, as Good Practices. More recently, the Twining program has fostered collaboration between Good Practices and next adopters across Europe.

With the changing landscape of the last decades, the Health Systems Performance Assessment (HSPA) expert group was established in late 2014. Its purpose was to annually concentrate on

a specific policy area and provide national policymakers with tools and methodologies to enhance HSPA, in that domain. After publishing its initial report in April 2016, which examined the evaluation of care quality across Europe, titled *"So What? Strategies across Europe to assess quality of care,"* the expert group shifted its attention towards assessing integrated care (15). On the other hand, the Strategic Intelligence Monitor on Personal Health Systems (SIMPHS3, 2014-2015) (16), looked at integrated care services – including telehealth, telecare, and independent living solutions – for older patients with chronic conditions.

Since 2008, the different EU Framework Programs have supported a series of initiatives, Joint Actions, as well as a myriad of EU funded projects through different programs, for example, Horizon Europe (17), EIT-Health (18) and ERAPERMED (19), promoting health systems transformation toward digitally supported integrated care services.

By the end of the decade, a reasonable degree of maturity had been already reached which prompted a progressive alignment of policies developed by the EU and OCDE, also with WHO. Such a converge of strategies toward adoption of integrated care triggered the Market Place held in ISPRA (I) on 12-13 December 2018 to assess the maturity of approximately 20 Good Practices at EU level. The debates done in the two days meeting, supervised by EU officers and representatives of the Organization for Economic Cooperation and Development (OECD) and the European Bank of Investment fostered the design of the *Joint Action on Implementation of Digitally Enabled Integrated Person-Centred Care* (JADECARE) (20),running from the 1st of October 2020 to end of September 2023 which has been the umbrella of the current PhD Thesis.

The Joint Action JADECARE is an ongoing program launched to face the challenges of the transformation of health in the European Union. JADECARE intends to reinforce the capacity of health authorities to successfully address important aspects of health system transformation, in particular the transition to digitally enabled, integrated, person-centred care in the EU. To this end, four original Good Practices (oGP): Basque Country (ES), Catalonia (ES), Southern Denmark (DK) and Optimedis (DE) support the transfer of successful practices, and generate knowledge, into the healthcare systems of the partners from twenty-one regions (from 16 EU countries), participating in JADECARE as *"Next adopters"* (NA).

The activities of the Catalan oGP within the Joint Action have been fostered by the *Catalan*

Open Innovation Hub for ICT-support of Integrated Care for Chronic Patients coordinated by the Hospital Clínic of Barcelona - August Pi i Sunyer Biomedical Research Institute (HCB-IDIBAPS) team. The items transferred to the NA are clustered by the following three blocks (B) and Core Features (CF):

- B.1 - Risk Assessment
    - CF1.1. Determinants of adoption of population-based risk assessment & potential of the tools (Adjusted Morbidity Groups (AMG) (21,22) and Queralt (23) indices)
    - CF1.2. Multilevel predictive modelling in the clinical setting
    - CF1.3. Future developments of the AMG: Exploring disease trajectories
- B.2 - Adoption of integrated care services
    - CF2.1. Filling the efficacy-effectiveness gap
    - CF2.2. Co-creation strategies
    - CF2.3. Quality assurance after adoption: Key performance indicators & Dashboards
- B3. – Digital transformation (on top of the current mature Digital Health Network)
    - CF3.1. Open Electronic Health Record (EHR) strategies
    - CF3.2. Adaptive Care Case management in a collaborative work setting.

Since January 2021, the Catalan Open Innovation Hub has been collaborating with the *OECD Action to Support JADECARE*. This initiative had two main purposes: i) Develop a guidebook for policymakers, and ii) Generate case studies of best practice interventions targeting non-communicable diseases. The focus was on the economic analysis of best practice interventions using sophisticated modelling techniques to assess value generation and transferability. The work plan between the OECD team and the Catalan Open Innovation Hub was focused on three interventions: i) Hospital at Home (HaH), ii) Prehabilitation of candidates for major surgical procedures, and iii) Integration of health and social care in Badalona Serveis Assistencials (BSA).

Each of these interventions was assessed in terms of i) Effectiveness, ii) Efficiency, iii) Equity, iv) Evidence-base, and v) Extend of coverage. Moreover, Enhancement options and Transferability of the intervention were also evaluated. Each case study ended with formulation of conclusions on health value generation and perspectives of the intervention.

The prospects at the end of JADECARE (September 2023) are that the initiative will generate: i) A valuable picture of the heterogeneities of healthcare systems at EU level, ii) Properly evaluated methodologies for sustainable adoption and transferability of integrated care services across Europe, iii) some success NAs' stories to be validated over time, and iv) Guidelines on core areas of integrated care such as: Risk assessment, Assessment of Adoption and Digital transformation. The topics of the current PhD Thesis fall into Block 2 – Implementation of innovative services and Block 3 – Digital health transformation.

Novel EU Non-Communicable Diseases Initiative, under the 2022-2027 program named *Healthier Together* (24), aims to support EU countries in identifying and implementing effective policies and actions to reduce the burden of major non-communicable diseases and improve citizens' health and well-being.

Overall, there is consensus on the fact that health systems need to constantly evolve, and adjust, based on their specific circumstances, toward convergence between integrated care and precision medicine aiming at adoption of a Learning Healthcare Systems approach (25). Such changes are creating new demands for healthcare services that are proactive, preventive, comprehensive, continuous, and centred on long-term patient-provider relationships, rather than being episodic, reactive, and focused solely on specific diseases and led by providers as incidental care (5).

Research has shown that selecting a comprehensive package of services for health outcomes leads to better treatment success, increased uptake of preventive care, and improved care-seeking behaviours (26,27). Given the changing patterns of illness and disability, and the increased use of multiple drug regimens and parallel treatment plans (28,29), the ability to provide a wide range of services while tailoring care to the needs of both the population and individuals is particularly relevant (5).

Continuity across healthcare tiers ensures that care coordination should be achieved by creating the necessary conditions and relationships to enable smooth interactions among multiple providers within interdisciplinary teams or across different care settings or sectors. When continuity and care coordination are lacking, patients, caregivers, and families often experience fragmented and poorly integrated care from multiple providers, leading to

suboptimal outcomes and risks of harm due to communication failures, inadequate sharing of clinical information, medication errors, duplicated tests, and unnecessary hospital admissions or readmissions (30). This issue is particularly prominent among individuals with complex chronic conditions (CCP) (31), estimated 4% of the population, who require ongoing care and support, especially those with low income or complex circumstances. Such problems are common to both high-income (31) and low- and middle-income countries (32). Therefore, continuity and coordination of care are global priorities for improving health services to meet the needs of people, and they are crucial in all healthcare systems, for care providers across different settings and at all stages of life (6). However, understanding the complex interplay of barriers and facilitators modulating sustainable adoption of integrated care services becomes a crucial determinant of success, as analysed under the next subheading.

Since early 2000s, we are immersed in a profound transformation of health systems worldwide. Conventional disease-oriented approaches are being replaced by integrated care services (5,6)*. The paradigm changes in medical sciences (Precision Medicine) and in clinical practice (Integrated Care) share methodological commonalities, namely: i) a systems approach for the analysis of biological and clinical phenomena, ii) extensive use of information and communication technologies (ICT) leading to digital health transformation, and iii) incorporation of sophisticated computer modelling as supporting tools for analysis and decision making. Major international organizations are endorsing next generation medicine.*

LARGE SCALE ADOPTION OF INTEGRATED CARE SERVICES

However, the process of adoption of integrated care is long and complex. Both general and site-specific complexities for deployment and sustainable adoption of care continuum, need to be considered.

Care continuum involves two dimensions of integration. Firstly, horizontal integration across community-based health and social care services. It usually implies integration among primary care resources, health-social services (intermediate care), end-of-life programs and social support services. On the other hand, vertical integration refers to care continuum between the community-based services, alluded to above, and specialized care. The modality of organization of primary care is highly determinant of the strategies needed to achieve care

continuum.

Achieving integration across the entire health system requires different strategies: systemic integration through policies and regulatory frameworks, normative integration through shared values and culture, organizational integration through structures and relationships, administrative integration through back-office functions and budgets, and clinical integration through coordinating services and information within a single process (33). Last, but not least, digital strategies to achieve different levels of interoperability among health providers constitutes a major challenge to be addressed in the current research. It is of note that, digital health transformation is a key requirement for successful deployment and adoption of integrated care. Moreover, mature digital support should be robust, properly embedded into the services' workflow and user-friendly.

There is no single ideal model or set of guidelines for integrating care (34), which makes it challenging to deliver integrated care for aging populations. Therefore, the integration process necessitates multiple initiatives across various services and professions within the healthcare system involving complex top-down and bottom-up interactions fostering change management and engagement of all stakeholders, in particular patients and health professionals. However, integration efforts are often expensive, resource-intensive, and prone to failure (35). Planners and healthcare providers need to be aware of effective elements of integrated care, understand the specific needs in their own context, and apply implementation knowledge to address local integration strategies.

In this regard, the adoption strategy executed in JADECARE (**Figure 1**) is attractive and seems to provide highly acceptable outcomes. Forthcoming analysis of the adoption process in the Joint Action should provide key learnings useful to foster large scale sustainable adoption of integrated care across Europe.

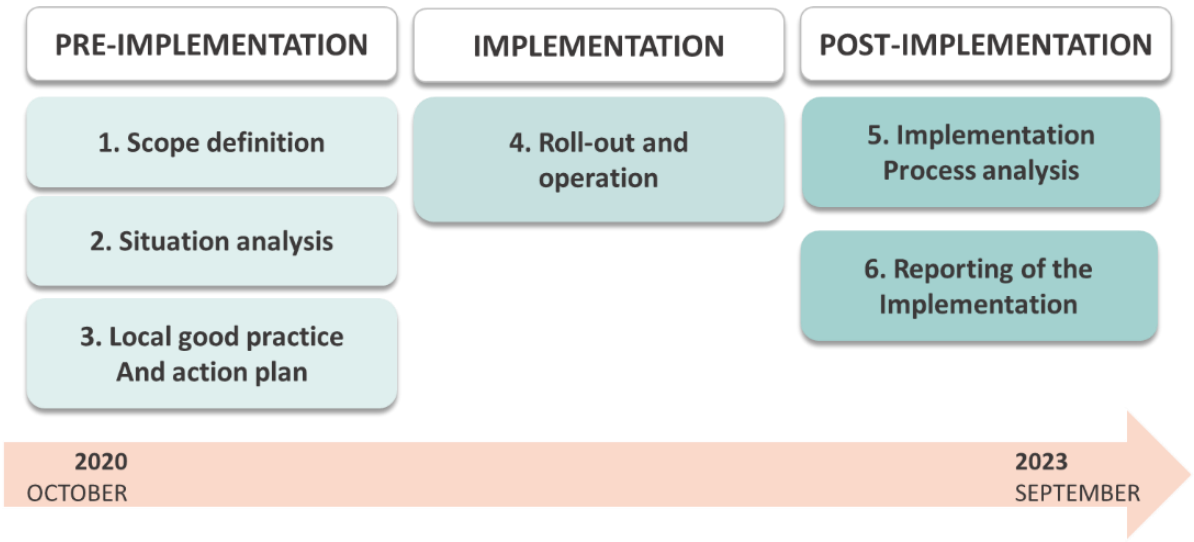

***Figure 1**. JADECARE three step Implementation Strategy.*
Source: JADECARE(20)

Pre-implementation *(October 2020 – May 2021)*

The objective of this phase was, for each NA, to elaborate the Local Good Practice (LGP) and the Local Action Plan (LAP) to be followed during the implementation by means of three activities:

- Scope definition: that implies selecting the CF of the oGP to be implemented and integrated in routine practice in each NA site. For this means, the NAs assessed the relevance and feasibility of the CF of the oGP(s) and selected those to be implemented at the local site.
- Situation analysis: whose purpose is to analyse the organizational position of the NA within the environment by conducting a SWOT analysis to then define its Strategic Intervention Areas.
- Definition of the LGP and LAP: including the detail of the intervention designed: name of the good practice, target population, setting, main aim, general description, needed inputs, main components and expected outcomes and the concrete actions to be taken to deploy it, including each SMART objective, specific activities, actors, resources, settings(s), timeline and key performance indicators (KPIs) (36).

Implementation *(June 2021 – January 2023)*

It consisted of the execution and monitoring of the implementation by means of 2 Plan-Do-Study-Act (PDSA) Cycles, where the report of each step includes:

- Plan: a detail of the activities broken down into actions, actors, timeline, and information on KPIs to assess them (target value and who/when and how will the data be collected).
- Do: information on the actual value of the KPIs compared to the planned target value, a summary of what was actually implemented, and description of deviations, problems or unexpected findings, if any, as well as the implementation progress achieved until the moment.
- Study: the reasons for the deviations, mitigation actions implemented and their impact, considering the planned and actual KPI values.
- Act: the decision to maintain, adapt or abandon each activity as well any new proposed action for the future.

At mid-term of the Implementation phase, two relevant events, the Thematic Workshops (TW) were held. The first TW was done in Viljanen county (Estonia) on 14-15 June 2022. It was devoted to Implementation of Health Risk Assessment Tools (37) Block 1 of the Catalan oGP. The second TW was held in Budapest (HU) addressing Implementation of Integrated Care Services taking Prevention and Care of Cardiovascular Complications of Type II Diabetes Mellitus as use case. The two TW generated relevant outcomes that were useful to modulate the second PDSA cycle aiming at achieving successful adoption at the end of JADECARE. A detailed description of the entire process, for the Catalan oGP and each NA, has been published in *D6.1 The Catalan Digitally Supported Integrated Care Services Approach: Original Good Practice and Transfer Process*.

Post-implementation *(February to September 2023)*

The whole implementation was reported by each NA by means of the SQUIRE 2.0 adapted guidelines. It contains SQUIRE 2.0 contains 18 items to respond 2 general sections and 4 key questions: title and abstract, why did you start?, what did you do? , what did you find?, what does it mean? and other information.

Two key steps during the post-implementation phase were: i) the Key Learning Workshop (KLW), and ii) the debate on application of the Consolidated Framework for Implementation Research (CFIR) (38) to evaluate the implementation process. The KLW of the Catalan oGP was

held in Barcelona on 12th May 2023. The summary results will be published in the September JADECARE's Newsletter, whereas the analysis of CFIR assessment is still underway.

Regarding the process of adoption of integrated care services, the analysis of the status in the United States of America (USA) is of high interest. Despite spending nearly double its gross domestic product on healthcare compared to the average country in the OECD, the US has the highest rate of chronic diseases, preventable deaths, and the lowest life expectancy among high-income nations. This disparity has led to a series of policy reforms over the past decade, including innovative initiatives aimed at reducing fragmentation, enhancing coordination between systems, and addressing the social determinants of health (SDOH) (39).

Traditionally, healthcare in the USA has operated under a fee-for-service model, where providers are paid separately for services, office visits, tests, procedures, and treatments. This structure incentivizes the quantity of services rather than the quality of care. In 2010, President Obama enacted the Affordable Care Act, which stands as one of the most comprehensive health reform policies in USA history. The law sought to achieve universal healthcare coverage, control costs, and improve care quality through new payment structures (40). The Affordable Care Act introduced new payment models based on value, linking payment for health services to their quality and cost instead of volume (41). Examples of value-based payment models include allocating health systems global budgets to serve patient populations, rather than requiring payments for individual services per patient, and making payments contingent on compliance with specific quality measures (42). These value-based payment models offer providers and insurers financial flexibility to develop creative solutions that enhance access, coordination, and integration across different environments and sectors.

Innovative approaches to integrating health and social services have rapidly expanded with the shift to value-based payment models, driven by growing evidence that adverse social determinants of health (SDOH) significantly contribute to poor health outcomes. Over the past decade, three notable policy initiatives have aimed to advance integrated care and improve the health of populations covered by Medicaid Health Insurance (39):

1. *Responsible Health Communities*: This demonstration program integrates health, social, and federally funded community organizations, facilitated by the government, specifically targeting Medicaid recipients in select regions.

2. *Medicaid innovation program:* Medicaid agencies fostered flexibility to explore innovative approaches to improve care delivery, and access to services, to meet the needs of their recipients.

3. *Health and social care integration*: There is growing evidence that linking coverage of unmet social needs with healthcare has led Medicaid agencies to enhance prevention efforts to reduce costs and improve health outcomes.

There are successful experiences of adoption of integrated care services across the world like the Singapore's program (43) or different pilot initiatives in Australia (44). A recent narrative review (45) analysed the lessons learnt from early adopters, up to 18 teams, of the WHO's guidelines for implementation of a new Integrated Care for Older People (ICOPE) framework in 2017-2019. Such report could be useful for future ICOPE adopters, as well as for other sites interested in large scale deployment and adoption of integrated care.

All of them illustrating that adoption of integrated care is a complex and lengthy process, involving both general and site-specific complexities. Care continuum requires horizontal integration among community-based health and social care services and vertical integration between community-based and specialized care. Achieving integration across the health system necessitates strategies like systemic policies, normative, organizational, administrative, and clinical integration, as well as digital transformation.

Over the last decade, substantial progress has been done in terms of identifying barriers and facilitators for deployment integrated care services, as well as on the site transferability constraints. We are also learning from evolving comprehensive frameworks aiming at guiding large scale adoption of the new model of care. However, all the experiences illustrate that adoption of integrated care is a complex and lengthy process, involving both general and site-specific complexities. Care continuum requires horizontal integration among community-based health and social care services, as well as vertical integration between primary and specialized care services. The ongoing analysis of JADECARE's post-implementation phase will likely generate a significant step towards the refinement of future adoption strategies.

THE CATALAN SCENARIO

The Catalan Health System (CHS) (46), through a single public payer, ensures universal coverage and free access at the point of use. Healthcare expenditure represents approximately 8% of the gross domestic product paid by taxes. Since 1981, the region is fully responsible for policy formulation, organization, management, service delivery, and financial aspects of the health services in the region of Catalonia (ES), with 7.7 million citizens. The Health System has a robust tradition of regional health planning. The latter has an essential role in triggering key sustainable changes at the regional level, as recently assessed by the 2020 WHO report on the "*Thirty-year Retrospective of Catalan Health Planning: Driver of Health System Transformation"* (47).

The territorial organization of the CHS consist of three levels: i) the Health Regions, a total of seven across the territory, provide all levels of care, ii) Within each Health Region there are the Health Districts wherein care continuum among the different modalities of care and social services is organized, and iii) the Primary Care Areas each of them covering approximately 20,000 citizens. Since the early 1980s, two organizational aspects have facilitated the adoption of integrated care in Catalonia within the 2011-2025 Catalan Health Plan (48–50). Firstly, the structure of the primary healthcare centres (PHCs) being the first point of contact for individuals seeking healthcare services. PHCs are staffed by general practitioners (GPs), nurses, paediatricians, and other healthcare professionals. Citizens are assigned to a specific PHC based on their residence, such that each PHC is responsible for serving a defined population within its catchment area.

The second major component were the socio-health services and the end-of-life program, born in 1986 under the seminal program "Vida als Anys" (Life to Years) (51),that further evolved toward a myriad of interconnected service modalities.

After successful integrated care pilot experiences carried out during the first decade of the century, the 2011-2015 Catalan Health Plan fostered key achievements in digital health transformation, the progressive implementation of person-centred integrated care services, as well as the adoption of an initial population-based health risk assessment (HRA) strategy transiently based on the commercial solution "Clinical Risk Groups" (CRG) (52). This initial HRA

had a case-finding approach focused on preventing adverse health events, managing complex chronic patients (CCP) and early detecting advanced care patients (ACP) (31,53).

The HRA approach acknowledged the close relationship between frailty and multimorbidity while recognizing their distinct nature as independent risk factors. Additionally, it introduced specific scales for the evaluation of each factor individually. The clinical complexity level was assigned based on multimorbidity scoring and the clinical judgment of primary care physicians. As mentioned, high risk chronic patients were classified into two groups**:** CCP (31), approximately 4% of the population, and ACP (31), representing approximately 1% of the population with limited life expectancy. Specific community-based management plans, aiming at integrating health and social care, were defined for these two categories of patients (53). An overall description of the care model for people with frailty and multimorbidity in Catalonia, tested during the 2011-2015 Health Plan, has been recently reported in (31).

The refinement of the assessment of the multimorbidity burden was achieved with the creation of the AMG a new morbidity grouper that reflects patients' disease burden in terms of the number and complexity of concomitant disorders through a disease-specific weighting deduced from statistical analysis based on mortality and the utilisation of healthcare resources. A significant achievement was the development of a dashboard to monitor the population's multimorbidity burden and the use of healthcare known as Modules for Monitoring Quality Indicators ("Moduls pel Seguiment d'Indicadors de Qualitat" (MSIQ)) (54), which generates and displays customised KPIs with aggregated data to inform health policy decisions, benchmarking, and governance. On the clinical side, the AMG scoring of the patient is currently displayed in the workstation of the primary care physicians and the shared clinical history (55) as a support tool in the clinical setting. During the 2016-2020 Catalan Health Plan (49), the utilisation of AMG for HRA purposes was validated in different regions of Spain, covering a population of approximately 38 million citizens, and showing good transferability in all cases (22).

Table 1 corresponds to the summary report submitted to the EU Commission on August 2018 to participate in the Marked Place held in ISPRA (I) on 12-13 December 2018. As alluded to above, this was the seminal event triggering the Joint Action JADECARE (20). The report reflects the characteristics and main achievements in terms of adoption of integrated care in Catalonia during the period 2011-2015.

It is of note that the Catalan Health Plans 2016-2020 (49) and 2021-2025 (50) further endorsed maturity of the regional Integrated Care approach. The two Health Plans indicating both goals and achievements toward mature digital health transformation, as well as the adoption of integrated care services encompassing both vertical (specialized vs primary care) and horizontal (community-based and social care services) integration. Likewise, key ongoing regional developments are reported in the following documents: i) 2022 EIP-AHA Reference Site (14) , ii) 2021 Information Systems Master Plan (56), and iii) Health Plan 2021-2025 (50).

Evolution of HRA strategies - During the 2016-2020 Catalan Health Plan, the utilisation of AMG in several studies testing the contribution of the AMG in different HRA settings, such as: i)the identified risk factors during the SARS-CoV-2 pandemic (57,58), 2) the refinement of tools for resources allocation (59–62), 3) the analysis of the effect of the multimorbidity burden in patients with chronic obstructive pulmonary disease (COPD) (63), and 4) assessing the use of AMG in complex clinical predictive models for short-term clinical outcomes predictions after hospital discharge (37,64). In summary, the HRA has profoundly evolved from the initial case finding approach toward towards sophisticated predictive modelling wherein the AMG, and other indices (i.e. Queralt index for characterization of hospitalizations) play a highly relevant role as covariates. Moreover, efforts are devoted to the practicalities of adoption of such predictive modelling tools in real-world settings, involving: 1) training and continuous evaluation of clinical decision support systems embedded into integrated care services, 2) pragmatic use of implementation science tools to foster engagement of health professionals, and 3) ethical and regulatory aspects including refinement of the regional data analysis program for research and innovation in health (PADRIS) (65) for secondary use of health data.

Frailty and multimorbidity - The Catalan model of care for chronic patients has been extensively developed through the accumulation of knowledge, dedicated work, and the incorporation of insights gained since the 1980s from various sources, mainly through primary care and socio-health programs. Different initiatives like the Chronic Prevention and Care Program (PPAC) (66), within the 2011-2015 Health Plan, and the National Primary Care and Health Strategy Community Program (ENAPISC) (67) established in 2017 have been crucial to formalize the CCP (4% of the population) and ACP (1% of the population) management.

According to the consensus of experts gathered by the terminology center of the Catalan language (TERMCAT) (68), complexity refers to a situation that reflects the challenges in

managing the care of an individual and the necessity of applying a specific individualized plan. This complexity arises from the presence or co-occurrence of diseases, the individual's utilization of services, or their environment. While concepts such as fragility, multimorbidity, complexity are interconnected, and commonly experienced by professionals in Catalonia, they are not synonymous concepts, as displayed in **Figure 2**. Accordingly specific scales should be used to assess each of these terms.

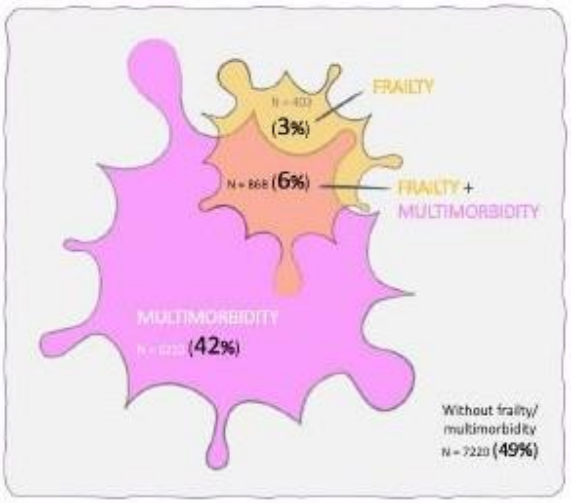

Figure 2. *Intersection between frailty and multimorbidity:* According to a meta-analysis that analyzed studies on multimorbidity and frailty in people living in the community, 42% had only multimorbidity, 3% only frailty, and 6% had both multimorbidity and frailty. There exists a disconnect between frailty and multimorbidity. Generally, individuals who are more fragile tend to have multimorbidity, but not all people with multimorbidity are frail (69).

Source: Catalan model of care for people with frailty, complex chronic (CCP) and advanced chronic (ACP) conditions (31).

Table 1.- Template fiche for Good Practice on digitally enabled, integrated, person-centred care prepared on August 2019 to participate in the Market Place held in ISPRA(I).

Title of the practice	Catalan open innovation hub on ICT-supported integrated care services for chronic patients
Location of implementation	Region of Catalonia (7.5M citizens), Spain (ES)
Target group	Chronic patients with focus on multimorbidity management and on coordination with social support and dependence
Number of people served by the practice	Whole population, focus on Complex Chronic Patients (CCP) and Advanced Care Disease (ACD): 210.000 patients, 66% coverage. Full coverage in 2020.
Short description	Core targets of the Catalan Health Plan 2016-2020 are: *i)* maturity of comprehensive digital health services, *ii)* consolidation of achievements of the period 2011-2015; and, *iii)* multilevel clinical risk assessment with a preventive approach considering Adjusted Morbidity Groups (GMA) as the population-health tool. Within this umbrella, innovative practices continuously emerge both for testing and large scale deployment. Five selected examples are: - Collaborative self-management services promoting healthy lifestyles. - Programme for complex chronic and frail patients. - Complex patient management linking tertiary care and community. - Healthcare support programmes for nursing homes. - Integrated care for admission avoidance of subacute and frail patients.
Level of care integration	Encompasses both vertical (specialized vs. community-based care) and horizontal (healthcare vs. social support) integrations. Combines a population-health orientation with a collaborative adaptive case management approach.
ICT technologies used	Fully deployed: *i)* regional Health Information Exchange platform (HC3), *ii)* Personal Health Folder (La Meva Salut); *iii)* ePrescription; and, *iv)* Population-based registries & GMA scoring system. In development: Multi-level clinical predictive modelling & Clinical/Patient Decision Support Systems (CDSS/PDSS).
Evidence of impact (2011-2015)	- Health-preserved expect. survival to expect. survival ratio: from 78 to 82.1% - Percentage reduction of referrals to specialized care: - 50% - Reduction of hospitalisations: - 7,500 admissions - Reduction of 30-d re-admission rate in chronic patients: -9% (13% cases) - Reduction of emergency room admissions in chronic patients: -40% - Reduction in mortality rate of cardiovascular and respiratory disorders: -15% - Improvement of activity of home hospitalization: + 53% (12,600 cases/yr.) - Improvement of activity of palliative care: 100% coverage - Improvement of coverage of ePrescription: 97% population
Lessons learnt	- Promote ICT-supported value-generating services with a preventive focus. - Develop & apply innovative evaluation methods in real world settings. - Develop multilevel subject-specific risk predictive modelling feeding CDSS/PDSS. - Develop & implement cloud-based computing environments. - Refine application of the regulatory frame for evaluation in real-world settings.
Links for detailed information	**NEXES/MECASS**: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC93931/lfna27056enn.pdf http://ec.europa.eu/research/innovation-union/pdf/active-healthy-ageing/how_to.pdf (p. 100-104) **NEXTCARE** (deployment programme of five initiatives, COMRDI15-1-0016, 2016-2019). http://www.nextcarecat.cat/publications.htm **Catalan Health Plan 2011-2015**: http://salutweb.gencat.cat/web/.content/home/el_departament/pla_de_salut/documents/arxius/health_plan_english.pdf **Catalan Health Plan 2016-2020**: http://salutweb.gencat.cat/web/.content/home/el_departament/Pla_salut/pla_salut_2016_2020/Documents/Pla_salut_Catalunya_2016_2020.pdf

Digital support to integrated care services - ICT plays a crucial role in the implementation and management of comprehensive care processes, ensuring two important aspects. Firstly, they allow all professionals involved in the care process to access essential shared information. Secondly, they provide these professionals with a technological environment that facilitates collaborative work, allowing them to carry out joint comprehensive assessments, develop comprehensive care plans, carry out periodic monitoring and evaluations, and incorporate more advanced support functionalities in the care process. Moreover, the intensive use of the personal health folder, La Meva Salud (My Health), by patients and caregivers facilitates proactivity of users. It is of note that the current ICT support at regional level allows health information exchange among healthcare providers across the system through the regional shared electronic health platform (HC3). Despite the extensive use of robust digital support during the last two decades, the setting is showing unmet needs for optimal support to integrated care services.

The Catalan Health Information System Master Plan published in 2019 (56), currently under deployment, is establishing the basis for the transformation to a new digital-health paradigm based on a knowledge-driven platform and adopting the Open-EHR standard as a reference. Moreover, ongoing developments fostering collaborative work across healthcare tiers following an adaptive case management (ACM) approach (70), as well as patients' empowerment for self-management, may contribute to achieve mature digital support to integrated care services.

INTEGRATED HEALTH AREA OF BARCELONA ESQUERRA

The city of Barcelona, one of the seven Health Regions, includes four Health Districts. One of them is the Integrated Health District of Barcelona-Esquerra (Área Integral de Salut de Barcelona-Esquerra (AISBE)). AISBE serves a population of 524,000 residents, accounting for 35% of Barcelona city's population and 6% of Catalonia. The citizens living in AISBE show a mean age above the overall population of Catalonia. Up to 22% of individuals are above 65 years, with 19.8% of them being above 85 years, whereas in Catalonia as a whole, 17.3% of individuals are above 65 years, with 17.3% of them above 85 years.(71)

AISBE was created in 2006 after an analysis of the characteristics of the services provided at

Health District level carried out by the Catalan Health Service (CatSalut), the single-public payer, and the HCB. Several dysfunctions, listed below, were identified, as well as significant opportunities for improvement through adoption of an integrated care approach (71). Briefly, three main dysfunctions were identified:

Heterogeneity among providers with lack of coordination - There were public bodies and private institutions with public funding, each having different strategies, cultures, and information systems.

Absence of shared goals and lack of a territorial vision in terms of reimbursement modalities

Poor definition of roles of each provider - The responsibilities of each provider in caring for basic diseases and medium-high complexity cases were not clearly defined.

The analysis identified a huge potential for improvement based on the definition of shared clinical processes across providers and healthcare tiers. Two main unmet needs were: i) Foster coordination between specialists and primary care, that is vertical integration, through well-defined clinical processes leading to enhance problem-solving capabilities at community level, ii) Re-engineering of unplanned emergency visits to prevent avoidable overload at the emergency room of the HCB. The objective was potentially achievable through two specific actions. Firstly, a better coordination of scheduled appointments and, secondly, a re-distribution of points of attendance of unplanned visits across the territory.

However, the lack of knowledge on key aspects of change management, as well as a rather poor understanding of the potential resistances to change across entities and professionals involved due to fear of losing, were main challenges to be faced in the process of integration.

In this context, the pivotal actions undertaken to face the challenges described above, were:

1.- Prioritize the integration of care pathways (clinical processes) to reduce the boundaries between hospital and primary care, and to improve population health outcomes.

2.- The HCB examined the impact of chronic diseases and multimorbidity in the Health District, as well as issues related to therapeutic adherence (72–74). This initial picture of the situation at territorial level was useful to define the priorities for action aiming at increasing coordination

among the various providers and their professionals to generate healthcare efficiencies.

3.- Definition and consolidation of the governance of the process of change based on participation of health professionals. To this end, a supervisory body was created, along with separate working groups to define the organizational structure, information system requirements, and care processes. The key component of the AISBE's organization is the Operational Committees (OC), which were established based on priorities defined in the Catalan Health Plan, prioritized projects identified by AISBE management structures, or needs recognized by professionals themselves (71).

4.- The process of development and re-engineering followed a patient-centered approach. Later in the process, the Patient Experience Unit was created in the HCB aiming at directly incorporating the patients views into the process of integrations.

5.- During the process, it was crucial to determine the role of HCB, a teaching, high-tech, and research-focused hospital, within an integrated care network. The challenge for HCB was to function simultaneously as a dual hospital; that is: a high-tech facility acting as a top reference center, and, in certain cases, acting as a community hospital with a catchment population of approximately 300,000 inhabitants (71). The concept of a "dual hospital" was clearly defined within the managerial structure, but it required an iterative strategy to progressively involve all frontline clinicians.

6.- Devote energies to provide digital support to healthcare services aiming at fostering care continuum at territorial level. To this end, the HCB developed a health information exchange platform to foster communication among providers. Over time, such digital developments at AISBE level, as well as specific successful pilot experiences, have contributed to enrich regional developments.

Since 2006, AISBE has consolidated a care continuum environment at health district level including several different healthcare providers, wherein the HCB is the reference centre. encompassing horizontal (across community-based services) and vertical (between primary and specialized care) integration of health and social care services. The AISBE program promotes professional engagement and active citizens participation, as well as innovative digitally supported integrated care services with a value-based approach covering several

different fields.

Despite the initial process of care integration was hospital-driven, it has progressively become a bidirectional operation towards maturity of vertical, as well as horizontal, integrations. **Figure 3** presents a 10-year timeline, 2006-2016, highlighting key milestones in the development of the AISBE project.

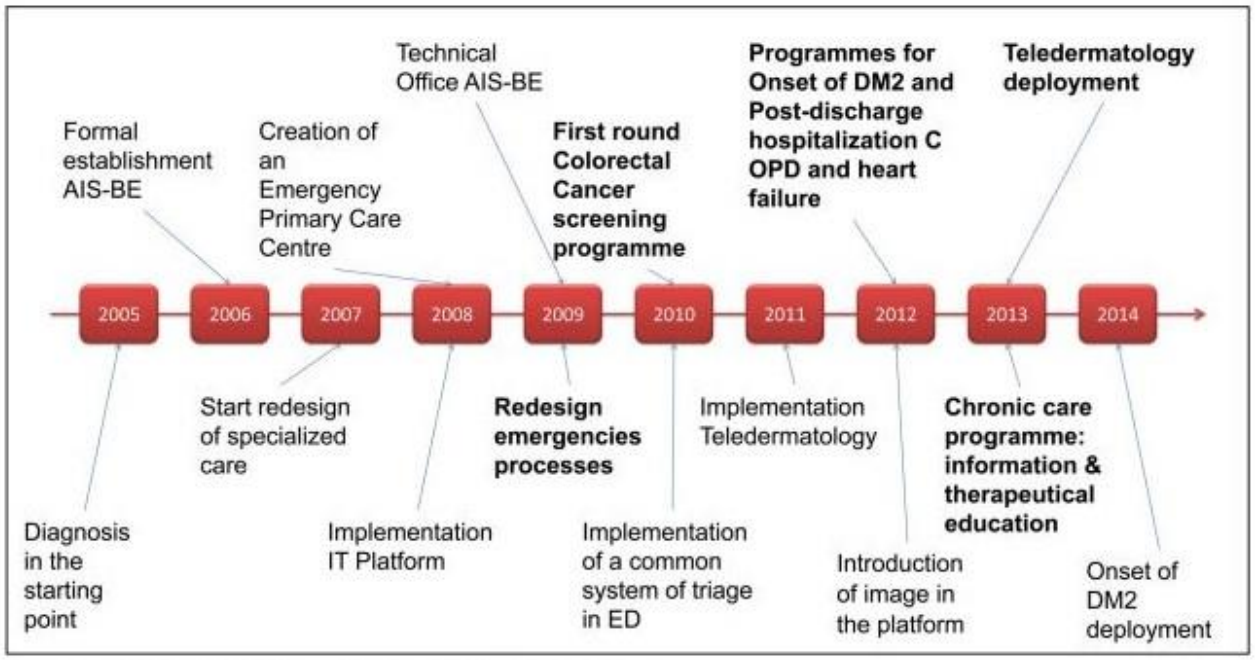

***Figure 3**. AISBE 2005-2016. 10-year timeline key milestones.*

Source: Integrated Health Care Barcelona Esquerra (Ais-Be): A Global View of Organizational Development, Re-Engineering of Processes and Improvement of the Information Systems. The Role of the Tertiary University Hospital in the Transformation (71)

The organizational model adopted to foster change management in AISBE deserves specific attention because one of its pivotal traits. One of them is the heavy promotion of professional participation. Doctors and nurses contribute improvements to the care programs with support from the Technical Office. A second fundamental element of AISBE is the strategic alignment of different institutions, particularly through the Standing Committee, where representatives from each institution align the strategy and needs of AISBE with those of their respective entities. Adopting a territorial and patient-centered mindset that facilitates this alignment (71). The third element modulating the change is the emphasis on the need to deploy programs for prevalent and community-based pathologies in collaboration with different institutions in the territory and beyond the hospital walls. In this regard, the HCB fully embraces the strategy of

breaking down boundaries between hospital and primary care, aligning with the concept of a "hospital without walls" (71).

The following four programs exemplify the progresses done in AISBE over the last fifteen years. Also, they point out key aspects to be developed in the current PhD thesis:

Enhanced management of Type 2 Diabetes Mellitus – The screening of pre-diabetes condition was one of the initial programs implemented. The main aim was to improve the management of type 2 diabetes from its inception. To this end, a structured therapeutic educational program based on structured group education was implemented (75). The program was progressively expanded towards community-based of Type 2 Diabetes Mellitus aiming at preventing and treating the disease complications. In 2013, the percentage of patients with HbA1c levels below 7 increased from 50% to 82%. The percentage of smokers decreased from 22% to 17%, while triglyceride levels decreased from 167 to 124 mg/dl, and HDL cholesterol levels increased from 46 to 48 mg/dl. Participants also reported reduced alcohol consumption and increased physical activity. The program led to a maintenance of attention in primary care and a reduction in hospital visits (76). Further evolutions of the program have led to mature vertical integration of the Diabetes Clinic at HCB that is currently fully working with a territorial orientation with proven value-based approach.

The Tele-dermatology program aimed to expedite dermatological diagnosis and reduce unnecessary consultations. The program involved the design and implementation of a protocol for diagnosing dermatological lesions at community level with appropriate digital support. General practitioners were properly trained for this purpose. The program was initially implemented in three health areas, covering a population of 96,000 residents. The 2013 results already indicated a significant reduction in diagnosis time (from 6 months to 2.59 days), early diagnosis of malignant tumors and 40% reduction in attended consultations. Further evolutions of the tele-dermatology program have been scaled throughout the territory as mainstream service.

The Urgent Care Program aimed to re-engineer healthcare resources for emergency care of individuals aged >18 years fostering the transition from a highly centralized model at the Emergency Department of HCB to a network care model distributed in the territory. Main actions were: i) Implementation of a standardized triage system (77) across the territory, and

ii) des-centralization of the low complexity emergency care (78) with implementation of defined agreements on referrals among providers. A significant reduction in overall consultations (-19%) at AISBE level was observed from 2008 to 2012. The reduction was more pronounced at HCB (-28.7%), particularly in less complex emergencies (79).

Hospital at Home program (HaH) was implemented in 2006 as a mainstream service across specialties covering two modalities of HaH: hospital avoidance (HaH-HA) and early discharge (HaH-ED) (80–82). The service provides acute, home-based, short-term care aiming at either entirely replacing conventional hospitalization (hospital avoidance) or accelerating discharge (early discharge). The hospital assumes clinical, logistical, and legal responsibility for the patient's care. Each episode of HaH is documented through admission and discharge records (83). This model was progressively implemented across the entire healthcare system in our region between 2011 and 2015, with preliminary positive results (80,84) prompting to scale up HaH across the entire region, as well as to set a specific reimbursement model between 2016 and 2020 (83).

HaH serves as a genuine alternative to conventional hospitalization because it is secure, sustainable, and satisfactory for the patient, as long as it fulfills its intended purpose and does not overlap with other home healthcare services. It can become inefficient and redundant if confused with other types of domiciliary care.

In this context, HaH represents a territorially-based specialized care option that offers complex and intensive hospital treatments in the patient's own home when hospital admission is required. It provides support to all hospitals in AISBE, including PHC and residential centers. HaH assumes the responsibility of managing the patient's complexity at home until the time of discharge (83).

Evidence shows that home hospitalization ensures the transition after discharge (85). In the local setting, the HaH proves to be an integrated care service based on care arrangements shared between the different levels of the system, with the support of information technologies, which effectively prevents hospitalizations due to exacerbations (86,87).

Transitions, which occur between hospital and community care teams, affect all patients, as they often require movements within the healthcare system or significant changes in their treatment. While transitions are unavoidable, it is essential to minimize unnecessary risks to

patient safety. Suboptimal transitions have negative impacts on patients, leading to delays in their treatment process, increased risks of adverse events, extended hospital stays, unplanned visits to emergency services, and higher overall costs (88). Unplanned reentry into the healthcare system is an indicator of inadequate coordination and intervention, highlighting the need for improved transitions. Additionally, a two-way collaboration is established: on one hand, home discharge professionals support community healthcare teams through the leadership of the Assistance and Integration of Care Program (APIC) to ensure smooth transitions; on the other hand, community healthcare teams, following home discharge criteria, identify patients who are early candidates for home discharge and coordinate with home discharge teams upon admission (83).

Since the initial report by Left et al. demonstrating the feasibility and cost-effectiveness of HaH, the evaluation of programs has historically faced notable complexities due to the heterogeneity of the study groups (85,89).

Besides the specific initiatives highlighted in the current section, AISBE is generating a myriad of integrated care interventions showing different levels of maturity that range from pilots to close to mainstream services being assessed in real-world settings (99–101) *However, the most relevant achievement is that over the period, the cultural change has permeabilized across both the institutional and the professional levels such that adoption of a care continuum approach has been incorporated in the mindset of the professionals. Most importantly, the change has been done within the concept of dual hospital which favors the desirable convergence between integrated care and precision medicine.*

The work of hospital-based specialists in the primary care centers of AISBE, on a weekly consultancy basis, is an essential component contributing to pave the way towards mature vertical integration progressively entailing rich bidirectional interactions. It is of note that the COVID epidemic have represented a major disruption of the entire process. But it also offers the opportunity of re-engineering the collaborations across healthcare tiers based on the lessons learnt during the three-year period (2020-2022).

IDENTIFIED CHALLENGES

The current section briefly reports on the key steps and challenges for adoption of innovative integrated care services. The sequential steps needed to ensure sustainable adoption of the services are:

1. *Evidence-based efficacy of the intervention* through appropriate randomized controlled trial (RCT) designs confirming the benefits of the novel intervention under the controlled scenario of the experimental conditions. This is the initial step, as well as the traditional way to generate medical knowledge and to establish causal relationships between intervention and measured outcomes. Despite the evidence of efficacy is the initial necessary step, it does not guarantee that similar positive results will be obtained in real-world scenarios.
2. *Evidence-based effectiveness of the intervention* proving its beneficial effects in real-world settings is required. The dissociation between these two initial steps is known as efficacy-effectiveness gap (EEG) which is a frequent trait of novel complex interventions.
3. The subsequent step is demonstration of *healthcare value generation of the intervention* which is the ratio between effectiveness and costs. However, effectiveness is not measured only through traditional health outcomes (cost-effectiveness analysis). In the assessment healthcare value generation, a broader perspective is adopted in terms of outcomes measured. Together with classical health outcomes, other variables like patient reported outcomes (PROMs) and patient reported experiences (PREMs) are also considered if the assessment of the service follows a Triple Aim approach (90), or a Quadruple Aim approach (91) when the professionals' engagement is additionally considered in the equation.
4. Next steps consist of to assess the factors (barriers/facilitators) modulating the process of deployment. This is usually done using implementation science tools, like the CFIR, which provides useful information to optimize the deployment process, and to inform on the potential for transferability to other sites indicating the need for adjustments to site specific traits.

5. The steps indicated above provide information on KPI required for elaboration of user-profile dashboards aiming at facilitating quality assurance of the service and, ultimately, ensure healthcare value generation in real-world settings which, at the end of the day, determines sustainable adoption of the innovative service.

The above section reports on key steps required for adoption of integrated care services. Despite those steps are conceptually clear, they generate challenges in three main areas:

1. *Practicalities of capturing PROMs and PREMs, particularly in patients with multimorbid conditions are not solved.*
2. *The assessment of healthcare value generation using academic approaches has also limitations for its application in real-world settings. In this regard, the Monitoring and Assessment Framework for the European Innovation Partnership on Active and Healthy Ageing (MAFEIP)* (102)*, supported by the EU Commission, is hardly accepted in the academic arena, whereas approaches like the Multiple Criteria Decision Analysis (MCDA)* (103) *are appealing, but hardly applicable in routine settings.*
3. *There are a myriad of reports attempting to properly measure integrated health services delivery* (104–109)*. But practicalities of the Chronic Care Model (CCM) require further developments*,(30,110,111)*. Importantly, an applicable assessment framework that better*

THE USE CASE: PREVENTION OF UNPLANNED HOSPITALIZATIONS

The adoption of integrated care in Catalonia, and in AISBE, has undoubtably generated a care continuum scenario with well-demonstrated value-based, innovative mainstream services. The setting has received the recognition as a Good Practice at European level. However, the analysis of the progress done so far clearly indicates that the setting will still be evolving as part of a lengthy process of profound worldwide changes in health systems occurring during this XXI Century.

The debates held during the pre-implementation period of JADECARE clearly indicated that, besides the transfer of specific core features to the NA assigned to the oGP, was crucial to identify the strategic directions to be followed by the Catalan oGP in the process of digital health transformation of health systems alluded to above. Accordingly, the action plans focused

in the three blocks indicated above: i) Risk Stratification (B1), ii) Implementation of integrated care services (B2), and iii) Mature digital transformation (B3).

The PhD thesis specifically addresses Block 2 (Implementation), taking as a use case the elaboration and adoption of innovative interventions aiming at preventing hospitalizations in selected CCP. However, the research undertaken paid particular attention to innovative aspects of digital support (Block 3) that are considered highly relevant for successful adoption of complex integrated care interventions. Moreover, selected outcomes from recent studies carried out by the research group in Block 1 (Stratification) played significant roles feeding the qualitative research reported in the thesis.

In summary, unplanned hospital admissions impose a significant financial and organizational burden on healthcare systems around the world. They also have negative effects on the quality of life of patients and contribute to the development of intrahospital complications. Additionally, multiple hospital admissions have been linked to poor survival outcomes in patients with chronic diseases. Consequently, there is a strong rationale for investigating interventions that aim to prevent avoidable hospitalizations using an integrated and patient-centered approach.

People with chronic illnesses, multiple health problems, and frailty are particularly prone to unplanned hospitalizations. These hospitalizations may occur for worsening chronic conditions or during vulnerable periods, such as transitions after hospital discharge.

Existing literature on interventions to prevent hospitalizations in chronic community patients experiencing exacerbation episodes and on transitional care programs aimed at reducing readmissions after discharge are inconclusive. This lack of conclusive results can be attributed to several factors, including differences in the interventions implemented, inadequate description of study protocols, limited comparability between different settings, and others.

Evidence-based efficacy of a clinical intervention demonstrated in a highly controlled setting RCT very often cannot be generalized to the real-world scenario (effectiveness) within the same site. Such efficacy-effectiveness gap (EEG) has been the case for historical research protocols testing the impact of an integrated care intervention aiming at preventing unplanned hospitalizations in complex patients with COPD as primary disease, showing several co-morbid

conditions (87,92). This EEG constitutes a significant barrier for demonstration of generation of health value and achieving long-term acceptance of integrated care services. It can be attributed to three interconnected factors: inefficiency systems that allow to evaluate the quality of the service, inadequate management changes and insufficient digital support.

The current PhD thesis relies on the hypothesis that adoption of interventions properly addressing the three factors alluded to above, that is, personalization, change management and digital support, can generate value-based reductions of unplanned hospital admissions in selected chronic patients.

The research reported in the thesis was undertaken in the context of the original Catalan Good Practice of the Joint Action JADECARE (https://www.jadecare.eu/), an initiative launched to address core aspects of health system transformation in the European Union. The current research includes four original studies addressing three main objectives, as described in the next section.

The extensive experience with HaH at the HCB (80,82,92) *establishes a privileged setting for investigating the benefits and costs associated with the novel service to be tested, that is, prevention of unplanned hospital admissions in selected patients. But, also, to explore its application to enhance transitional care programs after hospital discharge.*

HYPOTHESIS

Mature digital support with appropriate management change and redesign of service workflows, with a patient-centered approach, could facilitate adoption of value-based prevention of avoidable hospitalizations addressed to selected chronic patients, with potential for generalization to other integrated health and social care services.

MAIN OBJECTIVE

The general objective of this PhD thesis is to investigate the role of adaptive case management strategies (ACM) integrated into care interventions to mitigate unplanned hospital admissions among high-risk chronic patients.

SPECIFIC OBJECTIVES

OBJECTIVE 1 – TO EVALUATE HEALTHCARE VALUE GENERATION OF HOME HOSPITALIZATION, INCLUDING TRANSITIONAL CARE AFTER DISCHARGE, AT HOSPITAL CLÍNIC OF BARCELONA (HCB).

Rationale: The objective aims to characterize the appropriateness of home hospitalization as a use case for assessment of deployment strategies within the framework of integrated care for early management of exacerbations and prevention of readmissions in selected patients. It includes two complementary studies: multiple criteria decision analysis (MCDA) and cost-consequence analysis (CCA) of admission avoidance over a one-year period.

Manuscript 1

Herranz, C., González-Colom, R., Baltaxe, E. et al. Prospective cohort study for assessment of integrated care with a triple aim approach: hospital at home as use case. *BMC Health Serv Res*. 2022; 22(1):1133. doi: 10.2196/47672

Manuscript 2

Carme Hernandez, Carme Herranz, Erik Baltaxe et al. The Value of Admission Avoidance: Cost-Consequence Analysis of One-Year Activity in a Consolidated Service. *BMC Cost Effectiveness and Resource Allocation (under review)*

OBJECTIVE 2 – TO PILOT AN ADAPTIVE AND COLLABORATIVE CASE MANAGEMENT DIGITAL PLATFORM; HEALTH CIRCUIT™, TO FOSTER VERTICAL AND HORIZONTAL INTEGRATIONS, AS WELL AS EMPOWERERING PATIENTS FOR SELF-MANAGEMENT

Rationale: Rigidity of service workflows supported by available digital platforms, limitations of current interoperability strategies, as well as lack of independence between data models and service workflows can be overcome with the adaptive case management approach proposed by Health Circuit.

Manuscript 3

Carmen Herranz; Laura Martín-Moreno Banegas; Fernando Dana Muzzi Antoni Siso-Almirall; Josep Roca; Isaac Cano. A Practice-Proven Adaptive Case Management Approach for Innovative Health Care Services (Health Circuit): Cluster Randomized Clinical Pilot and Descriptive Observational Study. *J Med Internet Res.* 2023;25:e47672. doi: 10.2196/47672

OBJECTIVE 3 – TO UNDERTAKE A CO-CREATION PROCESS FOR ELABORATION, DEPLOYMENT AND EVALUATION OF INTERVENTIONS AIMING AT REDUCING UNPLANNED HOSPITALIZATIONS.

Rationale: Lessons learnt from fifteen years deployment and adoption of integrated care in the region of Catalonia (ES), 7,7 M citizens, as well as the analysis of home hospitalization in Catalonia during the period 2015-219 provided the basis for the co-creation process undertaken between October 2021 and December 2022 aiming at elaborating a pragmatic study protocol to be tested during the period 2023-2026, as a basis for future mainstream services aiming at successfully preventing unplanned avoidable hospitalizations in selected chronic patients.

Manuscript 4

Herranz C, Gómez A, Hernández C, González-Colom R, Contel JC, Cano I, Piera-Jiménez, Siso-Almirall, Roca J. A Co-Creation Process Toward Sustainable Adoption of Integrated Care for Prevention of Unplanned Hospitalizations. Int Journal Integrated Care (under review)

MATERIAL, METHODS, AND RESULTS

MANUSCRIPT 1

Herranz C, González-Colom R, Baltaxe E, Seijas N, Asenjo M, Hoedemakers M, Nicolas D, Coloma E, Fernandez J, Vela E, Cano I, Mölken MR, Roca J, Hernandez C. Prospective cohort study for assessment of integrated care with a triple aim approach: hospital at home as use case. BMC Health Serv Res. 2022 Sep 7;22(1):1133. doi: 10.1186/s12913-022-08496-z.

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Abstract

Background: Applicability of comprehensive assessment of integrated care services in real world settings is an unmet need. To this end, a Triple Aim evaluation of Hospital at Home (HaH), as use case, was done. As ancillary aim, we explored use of the approach for monitoring the impact of adoption of integrated care at health system level in Catalonia (Spain).

Methods: Prospective cohort study over one year period, 2017–2018, comparing hospital avoidance (HaH-HA) with conventional hospitalization (UC) using propensity score matching. Participants were after the first episode directly admitted to HaH-HA or the corresponding control group. Triple Aim assessment using multiple criteria decision analysis (MCDA) was done. Moreover, applicability of a Triple Aim approach at health system level was explored using registry data.

Results: HaH-HA depicted lower: i) Emergency Room Department (ER) visits ($p < .001$), ii) Unplanned re-admissions ($p = .012$); and iii) costs ($p < .001$) than UC. The weighted aggregation of the standardized values of each of the eight outcomes, weighted by the opinions of the stakeholder groups considered in the MCDA: i) enjoyment of life; ii) resilience; iii) physical functioning; iv) continuity of care; v) psychological wellbeing; (vi) social relationships & participation; (vii) person-centeredness; and (viii) costs, indicated better performance of HaH-HA than UC ($p < .05$). Actionable factors for Triple Aim assessment of the health system with a population-health approach were identified.

Conclusions: We confirmed health value generation of HaH-HA. The study identified actionable factors to enhance applicability of Triple Aim assessment at health system level for monitoring the impact of adoption of integrated care.

BMC Health Services Research

RESEARCH

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Prospective cohort study for assessment of integrated care with a triple aim approach: hospital at home as use case

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Registration: ClinicalTrials.gov (26/04/2017; NCT03130283).

Keywords: Chronic care, Health Delivery Assessment, Health Services Research, Hospital at Home, Implementation Science, Multiple Criteria Decision Analysis, Triple Aim

Background

Over the last decade, implementation science [1, 2] has experienced significant progresses resulting in well-accepted conceptual frameworks for assessment of healthcare services [3–6]; that should cover the following three areas: i) deployment strategies aiming at identifying barriers/facilitators for service adoption; ii)

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comprehensive approaches to assess outcomes; and iii) identification of key performance indicators (KPI) feeding customized dashboards for continuous long-term quality monitoring of complex interventions [7–10]. Applicability of such recommendations for evaluation of integrated care services (ICS) [3, 11–13] in real-world settings is still an issue limiting service adoption, as well as comparability and transferability across sites [14, 15].

With respect to the comprehensive assessment of outcomes, the Triple and Quadruple Aim approaches [16, 17] are consolidated conceptual strategies for evaluation of value generation [18] of ICS. The Triple Aim takes into consideration the following three outcome categories: i) health and well-being; ii) patients' experience and perception of care; and iii) costs; whereas the Quadruple Aim approach incorporates healthcare professionals' engagement as an additional key determinant to assess healthcare delivery.

The current research should be envisaged as part of the strategy for exploring applicability of a comprehensive framework for evaluation of ICS, covering both vertical and horizontal integration, in the region of Catalonia (Spain) [19]. To this end, we analyzed feasibility of the Triple Aim approach at health system level aiming at monitoring the impact of the process of large-scale adoption of integrated care in Catalonia during the period 2011–2017. Accordingly, a retrospective population-health study was done using registry data [20, 21].

However, the main objective of the current study was to prospectively assess value-based healthcare of Hospital at Home (HaH) over one-year period (2017–2018), as an example of ICS. To this end, information obtained from a Triple Aim assessment of HaH was elaborated using a Multiple Criteria Decision Analysis (MCDA) [22–24], as an academically sound methodology for evaluation of health value generation, aiming to provide the basis for innovative reimbursement incentives and financial sustainability of health-services.

Material and methods

The context

HaH [25–27] refers to home-based delivery of acute hospital services to patients for a condition that otherwise would require acute hospital inpatient care. Such a modality of care encompasses home-based, short-term, services aiming at fully or partially substituting conventional hospitalization; that is, Hospital Avoidance (HaH-HA) and Early Discharge (HaH-ED), respectively.

In 2006, Hospital Clínic de Barcelona, a tertiary reference centre covering a population of 520 k citizens pioneered the deployment of HaH as a mainstream transversal service [28–30]. A recent Cost-Consequence Analysis (CCA) of HaH-HA (Carme H, Carme H, Erik B, Nuria S, Ruben G, Asenjo M, David N, Enric C, Fernandez J, Isaac C, Roca J. Assessment of Hospital Avoidance in a Real-World Setting: a Prospective Cohort Study, Submitted), carried out during the same period, clearly showed higher performance and reduction of both hospital and community-based direct costs, compared to conventional hospitalization.

The Catalan healthcare system (7,7 million citizens), with one-single public payer and high heterogeneity of providers, is organized in three layers being the seven health regions at the top level. Each region includes several geographical areas called health districts covering specialized, intermediate, and primary care needs of the population. It is of note that intermediate care plays a key role facilitating vertical integration [31–34]. The third level, community-based teams, corresponds to clusters of primary care centres within each healthcare district. Catalonia has a total of 369 primary care units covering approximately 20,000 citizens, on average, each of them.

Regional deployment of the Chronic Care model [35] and integration of health and social services has been promoted under the umbrella of the five-yearly regional health plans. Key goals in terms of deployment of the integrated care were established during the 2011–2015 Plan and consolidation of the program was done during the 2016–2020 period [36, 37].

Study groups and design for HaH-HA assessment

The current prospective cohort study performs a real-world data analysis with a Triple Aim approach of the first episode of a subset of non-surgical patients consecutively admitted to HaH-HA, directly from the Emergency Room Department (ER) over one year, from 31st October 2017 to 1st November 2018. Patients undergoing HaH-ED were not considered in the current study to have a more homogeneous intervention group. Inclusion/exclusion criteria, as well as characteristics of the intervention (HaH-HA) have been extensively reported in [28].

A control group (Usual Care, UC), under conventional hospitalization for their first acute episode during the study period, was generated with patients admitted through the ER directly to a general ward, excluding surgical wards and intensive care units, attempting to mimic patients' clinical profiles between HaH-HA and UC. Comparability between HaH-HA and UC groups was improved with a 1-to-1 Propensity Score Matching (PSM) [38, 39] and Genetic Matching [40] taking simultaneously into account two sets of matching variables to ensure patients' comparability before admission and during the acute episode.

The first set of matching variables were: i) age; ii) gender; iii) number of admissions during the previous year; iv) patient's healthcare costs across the health system

in the previous year; and v) patient's population-based risk in terms of Adjusted Morbidity Groups (GMA) [41] scoring. Two additional matching variables, characterizing the acute episode, were included to enhance comparability of the two groups; that is: i) main diagnosis at discharge using the ICD10-CM categories, and ii) case mix index (CMI)[42]. In this regard, GMA is an aggregative index which indicate the burden of an individual's morbid conditions through a disease-specific weighting deduced from statistical analysis based on mortality and the utilisation of health services; whereas CMI reflects both severity/complexity of main diagnosis, as well as the complications occurring during the admission.

The matching parameters were tuned according to overall performance on covariate balancing, assessed by the Mahalanobis distance [43], Rubin's B (the absolute standardized difference of the means of the linear index of the propensity score in the HaH-HA and UC groups) and Rubin's R (the ratio of HaH-HA to UC variances of the propensity score index) metrics [44]. Quality of comparability between HaH-HA and UC after PSM was considered acceptable if Rubin's B was less than 0.25 and Rubin's R was between 0.5 and 2**.**

Triple aim assessment and MCDA of HaH-HA

As indicated above, HaH-HA was assessed with a Triple Aim approach and the outcomes were elaborated using MCDA. Briefly, we aimed to evaluate outcomes that go beyond traditional health variables and include patient reported outcomes and their broader sense of wellbeing, experience with care, and costs from a hospital perspective. For the MCDA, we used the following eight outcomes: i) enjoyment of life [45]; ii) resilience [46]; iii) physical functioning [47]; iv) continuity of care [48]; v) psychological wellbeing [49];(vi) social relationships & participation [50]; (vii) person-centeredness [51]; and, (viii) costs. The questionnaires for all items were administered by a nurse, at 30 days after discharge, in the patients' home. Moreover, two of these questionnaires, explicitly: i) continuity of care; and ii) person-centeredness were administered again at 90 days after discharge.

Additionally, Discrete Choice Experiments (DCE) [52] were used to obtain weights for the following set of outcomes. They were elicited in an online weight elicitation study among five stakeholder groups: i) patients; ii) informal caregivers; iii) professional care providers; iv) payers; and v) policy makers (we pooled responses for payers and policy makers).

Statistical analysis

For every key outcome, MCDA inputs for the performance scores were calculated using the following linear mixed regression models applied to the matched patient groups, missing data was not considered to build the performance regression models:

Where only T0 (30 days after discharge) available,

$$Y = constant + \beta 1^{*} intervention$$

where variable time is available,

$$Y = constant + \beta 1^{*} time + \beta 2^{*} intervention + \beta 3^{*} time^{*} intervention$$

The resulting performance regression models were used to calculate corresponding predicted values. In each group, HaH-HA and UC, the mean score of the predicted values was standardized relatively to the mean score of the predicted values in both groups. The corresponding formulas are:

$$S_{ho} = \frac{x_{ho}}{\left(x_{ho}^2 + x_{uo}^2\right)^{1/2}}, S_{uo} = \frac{x_{uo}}{\left(x_{ho}^2 + x_{uo}^2\right)^{1/2}}$$

x = performance score in terms of mean predicted values

h = Hospital at Home group

u = Usual Care group

o = performance outcome

For each stakeholder group, the mean predicted outcome values were weighted and subsequently summed to obtain a single overall value score for the HaH-HA group and a single overall value score for the UC group.

Finally, a Monte Carlo simulation addressed parameter uncertainty in both performance outcomes and weights. The required number of bootstrap replications (1,000 iterations) was determined checking stability of the results (95% uncertainty interval around the mean overall value scores).

Population-health assessment using a Triple Aim approach

The population-health impact of the regional deployment of integrated care over the period 2011–2017 was assessed using registry data [20, 21]. The Catalan Health Surveillance System (CHSS) [20] was the main data source for analysis of the evolution of traditional health outcomes and costs on a yearly basis for the period 2011–2017; whereas the potential for a Triple Aim evaluation with a population-health approach; that

is, including patient reported outcomes (PROMs) and patient reported experience (PREMs) was explored using the ESCA survey *(Enquesta de Salut de Catalunya)* [21]. This survey periodically assesses health status, behavioural changes in use of healthcare resources and perception of the healthcare system in Catalonia. The survey is done, on a yearly basis, on a randomly selected sample (n = six thousand citizens) of the Catalan population taking as a basis the seven healthcare regions.

The CHSS includes updated registries of the region of Catalonia from primary care, hospital-related events (hospitalizations, emergency room consultations and specialized outpatient visits), pharmacy, mental health, socio-sanitary services and other items (home-based respiratory therapies, dialysis, outpatient rehabilitation and non-urgent healthcare transportation) since 2011 [20]. It allows analyses on use of healthcare resources, pharmacy consumption, prevalence of key disorders and population-based health risk assessment. Data analysis can be done considering different levels of aggregation: Primary Care Units, Primary Care Areas, Health Districts, Health Regions or the entire Catalonia.

In the current study, the CHSS analysis of health outcomes was constrained to the temporal evolution of three selected KPI of quality of management of chronic patients: i) unplanned hospitalizations in emergency rooms of acute hospitals; ii) potentially avoidable hospitalizations; and iii) hospitalizations due to chronic conditions in acute hospitals. The analysis assumes that lower values for the 3 KPI reflect better health outcomes. In the study, we compared three different geographical areas: i) the health district of Barcelona-Esquerra (AISBE, 520 thousand citizens) wherein HCB is the reference hospital and pioneered in the deployment of integrated care services; ii) the entire city of Barcelona (1,7 million citizens) and iii) the entire Catalonia (7,7 million citizens). Rates of the 3 KPIs were adjusted by the corresponding KPI rate for Catalonia in each year, and a 95% confidence interval was fixed based on the Byar's approximation of the exact Poisson distribution which is extremely accurate even with small numbers [53].

Statistics

Categorical variables were summarized as absolute values and frequencies, whereas continuous variables were represented by the mean and the standard deviation or the median and interquartile range, as appropriate. Unpaired Student T tests, Mann–Whitney and Chi-squared test comparing HaH-HA with UC were used to assess changes in the outcomes. Data analyses were conducted using R [54], version 3.6.1 The threshold for significance was set at 0.05.

Results

Triple Aim assessment and MCDA of HaH-HA

Figure 1 displays the distribution of hospital admissions to conventional hospitalization and to the HaH program: HaH-ED and HaH-HA during the study period. A total of 200 consecutive HaH-HA patients, and their corresponding controls, were studied as candidates for Triple Aim assessment. Application of PSM techniques described above reduced the study groups to 137 HaH-Ha cases, and the corresponding controls.

Table 1 displays the baseline characteristics of the two groups before admission and the clinical outcomes during the acute episode until 30 days after discharge. The comparability analysis between HaH-HA and UC shows a highly acceptable matching. It is of note that the two groups showed no differences in mortality. However, patients under HaH-HA presented significantly lower rates of emergency room visits ($p = <0.001$) and hospital admissions, unplanned ($p = 0.012$) and planned ($p = 0.031$), during the 30-day period after discharge than the UC group.

The raw data of the eight outcomes before the MCDA (Table 2) indicate that HaH-HA group showed slightly better physical functioning ($p = 0.019$), and higher scores for both patient-reported experience measures: continuity of care ($p < 0.001$) and person-centeredness ($p < 0.001$) than the UC group.

Two outcomes reflecting patients' experience with care: i) continuity of care; and ii) person-centeredness (Table 2, 30 days after discharge) were also assessed at 90 days after discharge without showing significant changes: mean change (95%CI), 0.022 (-0.25–0.29) and -0.3 (-1.16–0.51), respectively.

The direct HaH-HA costs per patient during the episode was, on average 1,127€; whereas the direct UC costs per patient was slightly more than double, mean 2,346€. It is of note that the average cost savings per patient in HaH-HA (1,220€) were mostly generated (95%) by a reduction in staff (54%), testing (17%), catering (12%) and infrastructure (12%) costs (Table 3S). Likewise, healthcare expenses across the health system during the 30-days transitional care period after discharge; that is, including use of healthcare resources at community level, were 62% lower in HaH-HA than in UC ($p < 0.001$).

The main results of the MCDA of HaH-HA are depicted in Table 3. The table indicates standardized values of each of the outcomes indicating (PROMs) and patient experience with care (PREMs), as well as health care costs, weighted by the opinions of the stakeholder groups, i.e.: patients, carers, health professionals and policy makers/payers. It is of note that from all stakeholder perspectives, HaH-HA consistently showed higher overall value scores than UC (Table 4S). In addition, the

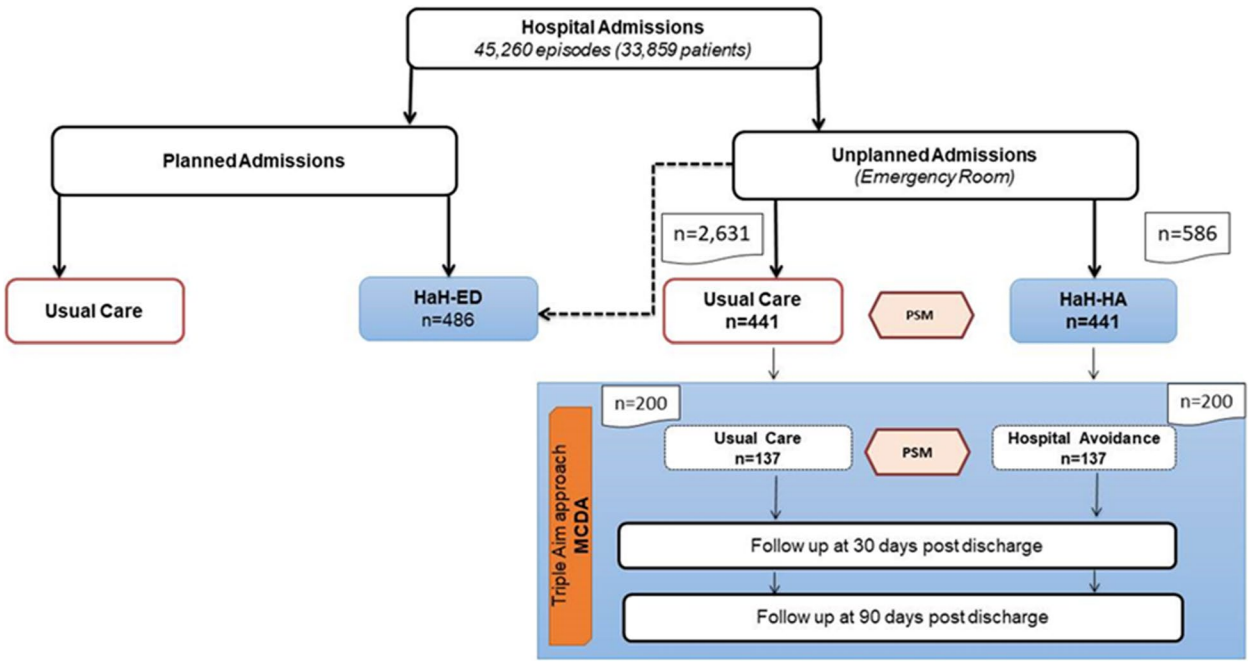

Fig. 1 Distribution of hospital admissions during the study period. Five-hundred eighty-six first episodes of HaH admissions, directly from the Emergency Room (HaH-HA), were registered during the study period. A sample of 2.631 conventional hospitalizations was used to generate a usual care (UC) group, as described in the text. The entire intervention group, after propensity score matching (PSM), consisted of 441 HaH-HA patients that were compared with the corresponding matched controls (UC), as reported in (Carme H, Carme H, Erik B, Nuria S, Ruben G, Asenjo M, David N, Enric C, Fernandez J, Isaac C, Roca J. Assessment of Hospital Avoidance in a Real-World Setting: a Prospective Cohort Study, Submitted) During the study period, two-hundred consecutive HaH-HA patients were assessed with a Triple Aim approach to perform Multiple Criteria Decision Analysis (MCDA) that was finally done in 137 HaH-HA patients after PSM with a UC group. Comparisons between the entire HaH-HA population ($n=586$), the CCA study ($n=441$) and the current study ($n=137$) are reported in Tables 1S-3S

results of the Monte Carlo simulation disclosed that the weighted aggregation of the performance scores is significantly greater in HaH-HA group, showing no overlap of the corresponding 95%CI. This finding is also observable assessing the intervention using the weighting preferences from every stakeholder, showing no overlap of the corresponding 95%CI (Fig. 2).

Population-health assessment using a Triple Aim approach

Figure 3 displays the yearly evolution, from 2011–2017, of the three selected KPI reflecting quality of chronic care in the study areas: i) health district of Barcelona-Esquerra; ii) city of Barcelona; and iii) Catalonia. From top to bottom, the panels depict adjusted rates per 10 thousand citizens for: i) unplanned ER visits in acute hospitals, ii) potentially avoidable hospitalizations, and iii) hospitalizations due to chronic conditions in acute hospitals. Over the period 2011–2014, both avoidable hospitalizations and hospitalizations of chronic patients showed a reduction in both the city of Barcelona and the entire Catalonia; whereas AISBE clearly presented a plateau with lower adjusted rates for all KPI than Barcelona and Catalonia. Interestingly, all KPIs in the three geographical areas presented a sustained increase (worsening) after 2013, reaching convergence at the end of the study period. The CHSS allowed such analysis, with different levels of data aggregation, for a large amount of health outcomes and for costs.

The feasibility analysis of the ESCA survey to assess PROMs and PREMs by geographical areas identified some limitations. The ESCA outcomes could partly be mapped to the MCDA variables displayed in Tables 2 and 3. Briefly, four domains: i) psychological well-being; ii) social relationships and participation; iii) resilience; and iv) enjoyment of life were assessed with well-identified measurement tools and showed equivalences with specific MCDA outcomes. Other three domains did not have a standardized measurement tool but showed some equivalences with specific MCDA outcomes, namely: i) physical functioning; ii) activation and engagement; and iii) person centeredness. Only one domain, continuity of care, could not be mapped into the ESCA survey. Moreover, the analysis of the yearly evolution, by geographical areas, of the ESCA outcomes could not be done because of two main technical issues. Firstly, changes

Table 1 Characteristics of the study groups after propensity score matching before admission and clinical outcomes after discharge

	HaH-HA_MCDA (*n* = 137)	UC_MCDA (*n* = 137)	*P- value*
BASELINE CHARACTERISTICS			
Socio-demographics			
Age (years), mean (SD)*	72.42 (13.92)	72.79 (15.37)	.836
Gender (male), n (%)*	80 (58.39)	79 (57.66)	.902
Gender (female), n (%)*	57 (41.61)	58 (42.34)	.902
Use of healthcare resources			
Hospital resources in previous 12 months			
Rate of all-cause emergency room visit, mean (SD)	1.85 (1.19)	1.76 (1.23)	.231
Rate of all-cause Hospital admissions, mean (SD)*	1.45 (0.9)	2.02 (1.54)	.171
Rate of planned admissions, mean (SD)	1.32 (0.67)	1.67 (0.91)	.152
Last visit (days) to outpatient clinic before admission, mean (SD)	78.36 (86.09)	78.07 (81.86)	.981
Last hospitalisation (days) before admission, mean (SD)	202.12 (108.21)	222.25 (110.74)	.413
Length of stay in days (total days per year), mean (total)	11.45 (458)	14.75 (590)	.408
Intensive care unit stays, n (%)	7 (12.10)	4 (5.70)	.405
Outpatient visits, mean (SD)	6.14 (7.19)	5.64 (5.55)	.604
Hospital resources in previous 7 days			
Outpatient visits, mean (SD)	1.20 (0.63)	1.25 (0.62)	.405
Healthcare costs across tiers in previous year			
€ per year, mean (SD)*	7,023.81 (9,478.93)	8,138.43 (8,083.83)	.854
Multimorbidity and severity			
GMA scoring, mean (SD)*	27.93 (14.72)	28.8 (18.74)	.872
CLINICAL OUTCOMES AT DISCHARGE			
Total length of stay (days), mean (SD)	8.20 (4.70)	7.74 (5.96)	.479
Case Mix Index	0.72	0.75	.792
Mortality during episode, n (%)	0 (0)	0 (0)	1
Use of resources during Hospital Avoidance			
All-cause Emergency Room visits, n (%)	2 (1.46)	N/A	NA
All-cause In-Hospital re-admissions, n (%)	4 (2.92)	N/A	NA
Outcomes at 30 days after discharge			
All-cause Emergency Room visits, n (%)	5 (3.65)	20 (14.6)	< .001
Unplanned Hospital admissions, n (%)	5 (3.65)	15 (10.95)	.012
Planned admissions, n (%)	2 (1.46)	9 (6.57)	.031
Mortality, n(%)	1 (0.73)	1 (0.73)	1
MATCHING ASSESSMENT METRICS			
Rubin's B	**0.050**		
Rubin's R	**0.598**		

Legend. HaH-HA, Hospital al Home-Hospital Avoidance; UC, Usual Care; GMA, Adjusted Morbidity Groups scoring; N/A, not applicable

introduced in ESCA during 2016–2017 did not allow comparability during the entire study period. A second limitation was that the characteristics of the sampling: size and distribution of data did not allow appropriate comparisons among the geographical areas considered in the current research. Up to 4000 surveys were done in the city of Barcelona with unknown distribution by health districts and approximately 400 surveys corresponded to each of the other six health regions.

Discussion

Hospital avoidance: main findings and context of the analysis

The current report provides a value-based assessment of Hospital at Home-hospital avoidance taking into consideration health and well-being, experience with care and healthcare costs, considering the acute episode and the 30-day period post-discharge. The MCDA clearly showed that HaH-HA was superior to UC, for those candidates meeting the inclusion/exclusion criteria. The research,

Table 2 Raw data of the eight outcomes before the MCDA

Criteria/Outcomes	Questionnaire	Range	Score: Mean (SD)		*P*-value
			HaH-HA	UC	
			n = 137	*n* = 137	
Enjoyment of life	ICECAP-O	1–4	2.50 (0.89)	2.48 (0.87)	.496
Resilience	BRS	6–30	20.52 (5.48)	19.72 (5.99)	.278
Physical functioning	SF-36	0–100	55.27 (35.43)	45.45 (31.87)	.019
Continuity of care	NCQ	0–5	3.82 (1.20)	3.30 (1.15)	< .001
Psychological well-being	MHI-5	0–100	69.32 (23.52)	68.07 (22.11)	.623
Social participation	IPA	0–24	7.13 (3.95)	7.00 (3.77)	.768
Person-centeredness	P3CEQ	0–18	15.94 (2.95)	14.62 (3.80)	.001
Health care costs	€		1,126.76 (226.17)	2,346.33 (519.14)	< .001

Results expressed as mean (standard deviation). Questionnaires used for the MCDA (Multiple Criteria Decision Analysis) and CCA (Cost Consequence Analysis) are indicated in the Methods section. HaH-HA, (Hospital at Home-Hospital Avoidance); UC, Usual Care

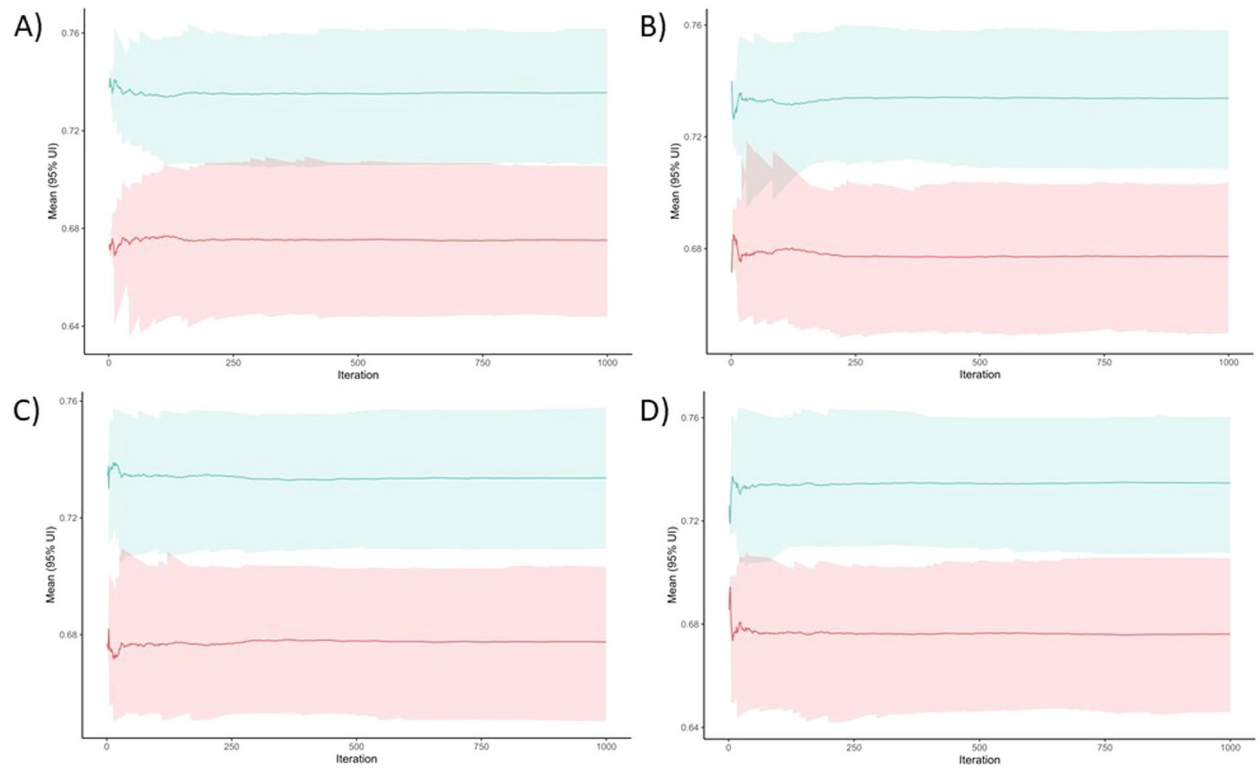

Fig. 2 Sensitivity analysis of MCDA with DCE weights based on a Bootstrap analysis (1,000 iterations) of the MCDA overall score between hospital avoidance (HaH-HA) (green) and usual care (UC) (red) groups. In each iteration, the values of the eight outcomes considered in the MCDA were weighted according to the DCE results and subsequently summed to obtain a single overall value score. The panels show the mean overall value score across all bootstrap iterations (set to 1000) and their 95% Uncertainty Intervals (UI) for HaH-HA and UC and for each stakeholder group: **A**) Patients; **B**) Carers; **C**) Professionals; **D**) Payers + Policy Makers. The four panels show no overlap between intervention and control groups along the bootstrap replications

taking HaH-HA as use case, clearly shows feasibility and applicability of the Triple Aim approach for comprehensive assessment of specific integrated care services, as proposed in [19]. The results are along with those seen in the retrospective CCA carried out with the entire population of patients included in HaH-HA during the study

Table 3 Overall scores of the multiple criteria decision analysis (MCDA)

Criteria/Outcomes	Relative Weights	Case Mix MCDA Sub-Group ($n = 137$)			
		Standardized performance		Weighted aggregation	
		HaH-HA	UC	HaH-HA	UC
Enjoyment of life	0.22	0.71	0.71	0.15	0.15
Resilience	0.13	0.72	0.69	0.09	0.09
Physical functioning	0.12	0.77	0.64	0.09	0.07
Continuity of care	0.15	0.75	0.66	0.11	0.10
Psychological well-being	0.14	0.71	0.70	0.10	0.10
Social participation	0.11	0.72	0.70	0.08	0.08
Person-centeredness	0.09	0.74	0.67	0.07	0.06
Health care costs	0.05	0.87	0.49	0.04	0.02
Overall value score				**0.73**	**0.67**
(95% CI)				**(0.71–0.76)**	**(0.65–0.70)**
Percentage HaH-HA > UC				**98.4**	

Criteria/Outcomes: 8 outcomes categories assessed in the MCDA at 30 days after discharge; Relative weights: pooled weights of all five stakeholder groups; Standardized performance: Overall scoring for each outcome, HaH-HA: Hospital at Home-Hospital Avoidance, UC: Usual Care; Weighted aggregation: Standardized performance times corresponding relative weight. HaH-HA, Hospital at Home-Hospital Avoidance; UC, Usual Care; Overall value score: mean overall scores for HaH-HA and UC; 95% Uncertainty Interval; Percentage HaH-HA > UC, percentage of iterations in the Monte Carlo simulation showing higher overall value scores in HaH-HA than UC.

period (Carme H, Carme H, Erik B, Nuria S, Ruben G, Asenjo M, David N, Enric C, Fernandez J, Isaac C, Roca J. Assessment of Hospital Avoidance in a Real-World Setting: a Prospective Cohort Study, Submitted), which strengthens the messages of the current research and reinforces the interest for a comprehensive health delivery assessment (Tables 1S, 2S and 3S). It is of note that cost-savings associated to HaH-HA are mostly attributable to organizational changes and digital support of the service rather than to specificities of the patients' traits. Accordingly, our results can be reasonably generalized for this type of intervention provided that the general characteristics of the HaH-HA service are maintained [55].

Triple aim assessment of specific integrated care services

The use of MCDA allowed measured outcomes to be balanced by the opinions of relevant stakeholders which shows high potential to facilitate decision making at policy level. We believe that the HaH-HA study provides a methodological approach that can be easily generalizable for assessment of other ICS involving complex interventions.

It is of note that our research aimed to explore applicability of the Triple Aim approach for assessment of ICS in real world settings. One key limiting finding was that the administration of the questionnaires assessing the seven qualitative variables included in the MCDA required approximately 45 min per patient which precludes use in routine testing. Pilot testing carried out before the initiation of the study protocol indicated that administration of questionnaires earlier during admission might not provide robust results because of limitations for data capture due to patients' clinical conditions. Moreover, the lack of significant changes between 30-days and 90-days after discharge might indicate the need for improving discriminative power of administered questionnaires.

One lesson learnt is that capturing relevant information from patients in real-world scenarios requires refinement of the measurement tools including questionnaires and characteristics of the digital support. We could hypothesize that comprehensive outcomes' assessment using properly validated visual-analogic scales and/or artificial intelligence-powered brief questionnaires [56] could be alternative approaches to be explored for a desirable adoption of Triple Aim assessment in routine healthcare delivery assessment. The use of user-friendly digital tools conceived to support collaborative work and adaptive case management, as described in [57], should greatly facilitate capturing patients' information. Such digital tools should also allow a fluent capture of professional inputs allowing Quadruple Aim [16] assessment of healthcare services.

Lessons learnt from population-health study

It is widely accepted that generation of evidence on value-based integrated care at health system level is still an unmet need. The current study indicates that the

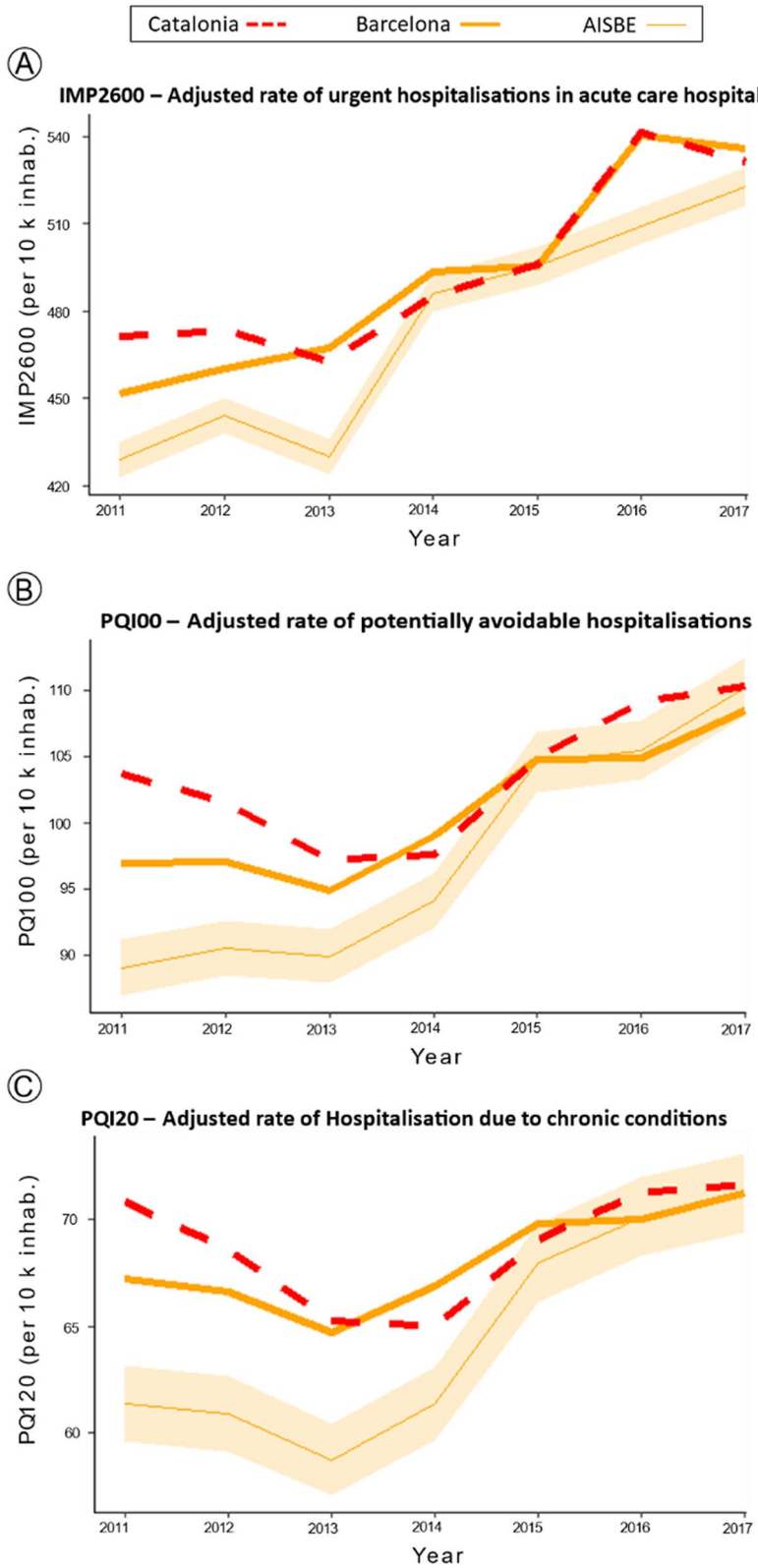

Fig. 3 Quality of chronic care in the study areas

characteristics of the CHSS fulfill the requirements of health policy makers at regional level and constitute an appropriate tool for assessment of traditional health outcomes, as well as analysis of associated direct costs. In contrast, the ESCA survey shows clear limitations for a Triple Aim assessment that could be easily by overcome by refining the digital support by capturing citizens' answers with visual-analogic scales and modifying the sampling characteristics aiming at enhancing robustness of the analysis of specific geographical areas.

The results displayed in Fig. 3 reflect highly complex phenomena and may require deeper analysis for a proper understanding of the information. A possible interpretation of the evolution of the selected KPIs indicating quality of chronic care could be as follows. Convergence of selected KPIs between AISBE (early adopter of integrated care services since 2006), the city of Barcelona and the region of Catalonia might be explained by preparation and active deployment of the 2011–2015 Catalan Health Plan heavily promoting integrated care and digitalization of healthcare. However, worse health outcomes in the three areas after 2013 might likely reflect the negative effects of a marked (-10%) reduction of financial healthcare resources during the period 2011–2018, due to the 2008 economic crisis.

Future perspectives

In our setting, the 2011–2015 Health Plan for Catalonia (Spain) stimulated a substantial expansion of HaH with various approaches and overall positive results. It is of note that the successful regional deployment of HaH during the period 2015–2019 is currently being analysed as an original Good Practice (oGP) within the Joint Action on implementation of digitally enabled integrated person-centred care (JADECARE, 2020–2023). We believe that proposals generated by the current research should trigger improvements in the assessment integrated care services facilitating comparability and transferability of Good Practices across sites.

Conclusions

The current study performed a comprehensive assessment of HaH-HA in a real-life setting using the novel methodological approach of MCDA and produced evidence on health value generation of the intervention. The research identifies key actionable factors for Triple Aim assessment of the impact of integrated care interventions at health system level.

Abbreviations

HaH: Hospital at home; HaH-HA: Hospital avoidance; UC: Conventional hospitalization; MCDA: Multiple criteria decision analysis; ER: Emergency room department; KPI: Key performance indicators; ICS: Integrated care services; HaH-ED: Early discharge; CCA: Cost-consequence analysis; PSM: Propensity score matching; DCE: Discrete choice experiments; CHSS: Catalan health surveillance system; PROM: Patient reported outcome; PREM: Patient reported experience; ESCA: Catalan health survey; AISBE: The health district of Barcelona-Esquerra; GMA: Adjusted Morbidity Groups scoring; oGP: Original Good Practice.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12913-022-08496-z.

Additional file 1.

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Authors' contributions

Conception and design: Herranz C, González, R, Hernández C, Roca J. Analysis and interpretation of the data: Herranz C, González-Colom C, Baltaxe E, Seijas N, Asenjo M, Hoedemakers M, Nicolas D, Coloma E, Fernandez J, Vela E, Cano I, Rutten-van Mölken M, Roca J and Hernandez C. Drafting of the article: Herranz C, González R, Hernandez C, Roca J. Critical revision of the article for important intellectual content: Herranz C, González-Colom C, Baltaxe E, Seijas N, Asenjo M, Hoedemakers M, Nicolas D, Coloma E, Fernandez J, Vela E, Cano I, Rutten-van Mölken M, Roca J and Hernandez C. Final approval of the article: Herranz C, González-Colom C, Baltaxe E, Seijas N, Asenjo M, Hoedemakers M, Nicolas D, Coloma E, Fernandez J, Vela E, Cano I, Rutten-van Mölken M, Roca J and Hernandez C. Statistical expertise: Gonzalez R, Cano I, Vela E, Asenjo M. Collection and assembly of data: Hernández C, Seijas N, Herranz C, Baltaxe E, Vela E, Asenjo M.The author(s) read and approved the final manuscript.

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Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available due to administrative reasons but are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Ethics study was approved by the Credited Research Ethics Committee of the Hospital Clinic of Barcelona (Ref. 2017–0451 and 2017–0452). The current data analysis was developed under the umbrella of the EU project SELFIE [58]. All methods were performed in accordance with the relevant guidelines and regulations (i.e., Declaration of Helsinki). All participants in the HaH-MCDA protocol signed an informed consent ahead of any procedure. The population-based study was carried out using deidentified and aggregated data from health registries (CHSS and ESCA), not requiring written informed consent.

Registration of the study protocol at ClinicalTrials.gov was done (26/04/2017, NCT03130283), as part of the analysis of the service.thics approval and consent to participate.

Consent for publication
Not applicable.

Competing interest
All authors have disclosed no conflicts of interest.

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ABSTRACT

Background: Many advantages of hospital at home (HaH), as a modality of acute care, have been highlighted, but controversies exist regarding the cost-benefit trade-offs. The objective is to assess health outcomes and analytical costs of hospital avoidance (HaH-HA) in a consolidated service with over ten years of delivery of HaH in Barcelona (Spain).

Methods: A retrospective cost-consequence analysis of all first episodes of HaH-HA, directly admitted from the emergency room (ER) in 2017–2018, was carried out. HaH-HA was compared with a propensity-score-matched group of contemporary patients admitted to conventional hospitalization (Controls). Mortality, re-admissions, ER visits, and direct healthcare costs were evaluated.

Results: HaH-HA and Controls (n=441 each) were similar in age (73 [SD16] *vs* 74 [16]), gender (male, 57% *vs* 59%), multimorbidity, healthcare expenditure during the previous year, case mix index of the acute episode, and main diagnosis at discharge. HaH-HA presented lower mortality during the episode (0 vs. 19 (4.3%); $p < 0.001$). At 30 days post-discharge, HaH-HA and Controls showed similar re-admission rates; however, ER visits were lower in HaH-HA than in Controls (28 (6.3%) vs 34 (8.1%); p = 0.044). Average costs per patient during the episode were lower in the HaH-HA group (€ 1,078) than in Controls (€ 2,171). Likewise, healthcare costs within the 30 days post-discharge were also lower in HaH-Ha than in Controls ($p < 0.001$).

Conclusions: The study showed higher performance and cost reductions of HaH-HA in a real-world setting. The identification of sources of savings facilitates scaling of hospital avoidance.

Registration: ClinicalTrials.gov (26/04/2017; NCT03130283).

Keywords: Hospital at home; Early readmissions; Health Services Research; Implementation science; Transitional Care

The Value of Admission Avoidance: Cost-Consequence Analysis of One-Year Activity in a Consolidated Service

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KEY POINTS

- Hospital at home, modality hospital avoidance, shows high potential for value generation in real-world settings by improving health outcomes and generating cost-savings.

- Positive outcomes of hospital avoidance seem associated to adequate management change and digital support.

STATEMENTS AND DECLARATIONS

Competing Interests: All authors have disclosed no conflicts of interest.

INTRODUCTION

Over the last twenty years, hospital at home (HaH) has reached maturity in various health systems worldwide, although some heterogeneities have been reported across sites [1–3]. This service is currently considered a consolidated alternative to inpatient care for selected patients requiring hospital admission [4]. Furthermore, HaH has shown high potential to promote continuity of care by preventing hospitalizations and reinforcing transitional care after discharge [5,6], thus enabling vertical integration between hospital and community-based care [7,8].

Despite the promising results and potential benefits associated with HaH, some controversies have been raised regarding the extent of the value generation in healthcare [9–11]. These discrepancies are partly explained by differences in the complexity of target patients and service delivery context, with important implications regarding the characterization of its different modalities, reimbursement regimes, and adoption strategies [12–14]. This heterogeneous scenario stresses the need for investigating real-world experiences in implementing and deploying HaH services.

In our center, a tertiary university hospital providing specialized care to a catchment population of 520,000 citizens, HaH was implemented in 2006 as a mainstream service across specialties covering two modalities of HaH: hospital avoidance (HaH-HA) and early discharge (HaH-ED) [7,15,16]. The service provides acute, home-based, short-term care aiming at either entirely replacing conventional hospitalization (hospital avoidance) or accelerating discharge (early discharge). This model was progressively implemented across the entire healthcare system in our region between 2011 and 2015, with preliminary positive results [7,17,18]. These positive results prompted the Catalan Health Service, the only public health payer providing universal healthcare to the 7.7 million population, to scale up the HaH service across the region and set a specific reimbursement model between 2016 and 2020 [19].

The long-lasting experience with HaH service and analytical accounting used in our center sets a privileged scenario to investigate the benefits and costs associated with this service. Therefore, we conducted a cost-

consequence analysis (CCA) [14] of all first episodes of HaH-HA registered within a one-year course after more than one decade of implementation and consolidation of the HaH service in our center.

METHODS

Study groups and design

This was a retrospective CCA of all first-time HaH-HA admissions issued from the emergency room department in the Hospital Clínic of Barcelona among non-surgical patients between October 31, 2017, and November 1, 2018. The costs and outcomes of HaH-HA patients were compared with a 1:1 matched comparator group of conventional hospitalizations in our center. Patients under the modality HaH-ED were excluded from the analysis.

Candidates to HaH-HA were screened in the emergency room by trained professionals of the HaH team. Individuals were eligible for HaH-HA if: they were aged 18 years or older, lived in their house within the catchment area, had a formal or informal caretaker (including relatives) available 24 hours per day, had a phone at home and signed the informed consent to be hospitalized at home. We considered all medical conditions.

The comparator group (Controls) was built from non-surgical patients admitted for conventional hospitalization from the emergency room within the same period. We paired HaH-HA patients with control patients 1:1 using a propensity score matching (PSM) [20,21] and genetic-matching technique [22]. For matching purposes, we took into account two sets of matching variables to ensure patients' comparability regarding both baseline characteristics (i.e., before admission) and hospitalization characteristics.

The first set of matching variables included age, gender, number of admissions in the previous year, patient's healthcare costs across the health system in the previous year, and health risk based on the adjusted morbidity groups (AMG) index [23]. The AMG is a summary measure of morbidity that considers a weighted sum of all chronic and relevant acute conditions from all diagnostic group codes of the International

Classification of Diseases, clinical modification (ICD-10-CM). The AMG can be used as a numerical index or as population-based risk groups, defined according to percentile thresholds for the distribution of the AMG index across the entire population of Catalonia. Both the index and the risk groups have shown a good correlation with relevant health outcomes and the use of healthcare resources [24,25].

The second set of variables for paring HaH-HA and control patients included relevant characteristics of the hospitalization episode, such as the main diagnosis at discharge based on the ICD-10-CM categories and the case mix index (CMI). The CMI summarizes the severity and complexity of the main diagnosis and health events occurring during the hospital stay.

Characteristics of home and conventional hospitalizations

The HaH-HA group followed the standard of care for HaH at Hospital Clínic de Barcelona, which has been extensively reported elsewhere [7]. Briefly, a patient admitted to HaH-HA is assessed in person daily by the HaH team, which consists of either a nurse or a nurse and physician (at physician's discretion) with remote access to the patient's electronic record. Interventions available at home include regular tests (e.g., blood and microbiology tests, clinical ultrasound, electrocardiogram), most of the intravenous and nebulized treatments, and oxygen therapy. A pathway for elective transfer back to the hospital (e.g., for additional tests not available at home) and emergency transfer in case of clinical deterioration are also available.

The control group followed the usual care for in-house hospitalizations; patients were assigned to a hospital bed within the corresponding service according to the primary diagnosis and followed up by the medical and nurse staff of the corresponding ward or service.

Upon discharge, patients in the two groups were transferred to the corresponding primary care teams, with access to electronic health records. However, the HaH team shares responsibilities with the primary care team during the transitional care period until 30 days after discharge.

Outcomes and costs

The CCA included health outcomes and direct costs [26]. Health outcomes included length of hospital stay, 30-day mortality, and all-cause hospital admissions and visits to the ER within the 30 days following discharge. In patients admitted to HaH-HA, we also collected the patient experience by administering a 9-item satisfaction questionnaire [7] on discharge.

Costs were estimated using an analytical accounting approach [27]. Direct costs included honoraria of staff professionals, pharmacological and non-pharmacological therapy, consumables, testing and procedures, transportation, catering, and structural costs (i.e., information systems, electricity, etc). We also considered healthcare expenditure associated with any resource use of the healthcare system during the 30 days following discharge.

The two data sources used for the study were: the SAP Health Information System at HCB and the Catalan Health Surveillance System (CHSS) for analysis of the acute episode and calculations after discharge, respectively.

Data analysis

Health outcomes and costs were described by the number and percentage over available data for categorical variables and mean and standard deviation (SD), or median and interquartile range (IQR, defined by the 25^{th} and 75^{th} percentiles), as appropriate. The matching parameters were tuned to enhance the covariate balancing, as follows: caliper: 0.2, function: logit, replace: FALSE, ratio: 1:1, matching method: Genetic Matching. Genetic Matching uses an optimization algorithm based on "GENetic Optimization Using Derivatives (GENOUD)" [28] to check and improve covariate balance iteratively, and it is a generalization of propensity score and Mahalanobis distance [29]. The matching was assessed by the Mahalanobis distance, Rubin's B (the absolute standardized difference of the means of the linear index of the propensity score in the HaH-HA and Controls) and Rubin's R [30] (the ratio of HaH-HA to Controls variances of the propensity score index) metrics. Quality of comparability between HaH-HA and Controls after PSM was considered acceptable if Rubin's B was less than 0.25 and Rubin's R was between 0.5 and 2. Unpaired Student T tests,

Mann-Whitney, and Chi-squared tests comparing HaH-HA with Controls were used to assess changes in the costs and clinical outcomes. Data analyses were conducted using R [31], version 3.6.1 (R Foundation for Statistical Computing, Vienna, Austria). The threshold for significance was set at a two-sided alpha value of 0.05.

Ethical conduct of the study

The Ethical Committee for Human Research at Hospital approved the study protocol (refs. 2017-0451 and 2017-0452), which waived the collection of informed consent for the secondary use of routine care data. All methods were conducted in accordance with the relevant guidelines and regulations, including the General Data Protection Regulation 2016/679 on data protection and privacy for all individuals within the European Union and the local regulatory framework regarding data protection.

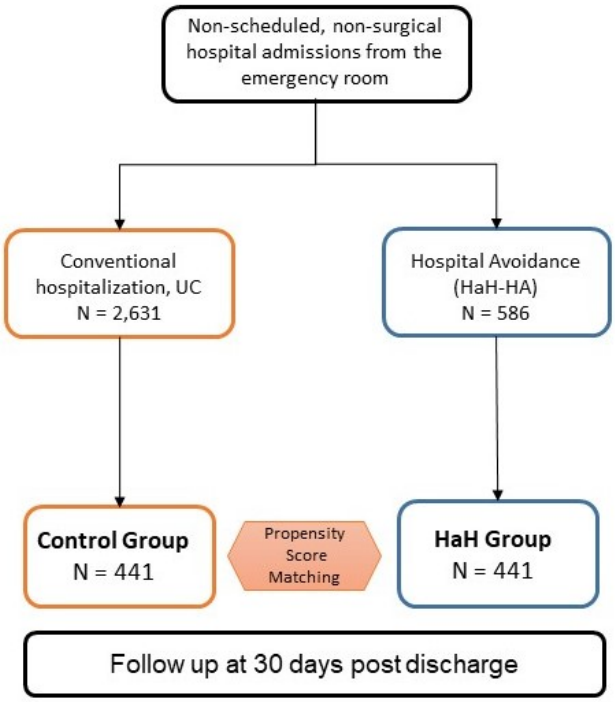
RESULTS

Study participants

During the study period, the ER department dictated 586 unplanned non-surgical HaH-HA admissions in patients without previous episodes of HaH. The comparator group was built using a dataset of 2,631 conventional non-surgical admissions carried out during the study period. After propensity score matching, the two groups: HaH-HA and Controls, consisted of 441 cases each (**Figure 1**).

We found no significant differences between the characteristics of the HaH-HA selected for the propensity-score matching (n=441) and those of the entire series of patients admitted to HaH-HA within the investigated period (n=586) (**Table S1**).

Figure 1. Number and distribution of patients



Legend *– Five-hundred eighty-six first episodes of HaH admissions, directly from the Emergency Room (HaH-HA), were registered during the study period. After propensity score matching, the HaH-HA group fell to 441 patients (Comparisons among the two study groups and the study population of 586 patients are reported in* ***Tables 1S, 3S*** *and* ***4S****, see text for details).*

Table 1 summarizes the baseline characteristics (i.e., before admission) of individuals included in the HaH-HA and the comparator group. The two groups were well balanced regarding their demographic characteristics and previous use of hospital resources and healthcare expenditure. The health risk on admission, measured using the AMG index, was also similar between groups. However, the stratification of patients across the population-based categories of health risk showed that the HaH-HA had a higher percentage of individuals in the intermediate-risk group and a lower percentage of individuals in the high-risk group than the control group.

Table 1. Characteristics of the study groups after propensity score matching before admission.

	HaH-HA	Controls	*P* value
SOCIO-DEMOGRAPHICS			
Age (years), mean (SD)*	72.71 (16.30)	73.94 (16.01)	0.259
Gender (male), n (%)*	250 (56.69)	262 (59.41)	0.412
USE OF HEALTH CARE RESOURCES			
Hospital resources in previous 12 months			
Rate of all-cause emergency room visit, mean (SD)	1.63 (1.04)	1.75 (1.26)	0.829
Rate of all-cause Hospital admissions, mean (SD)*	1.66 (1.22)	1.62 (1.30)	0.786
Rate of planned admissions, mean (SD)	1.37 (0.72)	1.40 (0.87)	0.832
Last visit (days) to outpatient clinic before admission, mean (SD)	85.98 (91.96)	91.39 (94.39)	0.522
Last hospitalisation (days) before admission, mean (SD)	192.16 (108.75)	175.22 (126.70)	0.262
Length of stay in days (total days per year), mean (total)	11.48 (1,538)	11.49 (1,333)	0.786
Intensive care unit stays, n (%)	19 (8.50)	18 (9.60)	0.547
Outpatient visits, mean (SD)	5.99 (7.19)	5.45 (5.69)	0.357
Hospital resources in previous 7 days			
Outpatient visits, mean (SD)	1.11 (0.42)	1.14 (0.42)	0.765
Healthcare costs across tiers in previous year			
€ per year, mean (SD)*	5,627 (8,119)	6,543 (6,869)	0.070
MULTIMORBIDITY & SEVERITY			
GMA scoring , mean (SD)*	24.94 (15.17)	25.09 (14.51)	0.884
GMA category, n (%)			
Tier 1 < P_{50}	6 (1.4)	8 (1.8)	0.798
Tier 2 [P_{50} - P_{80})	31 (7.0)	30 (6.8)	0.988
Tier 3 [P_{80}-P_{95})	97 (22.0)	69 (15.7)	**0.019**
Tier 4 [P_{95}-P_{99})	83 (18.8)	117 (26.5)	**0.005**
Tier 5 ≥ P_{99}	224 (50.8)	217 (49.2)	0.689
Statistics to assess matching			
Rubin's B			0.2
Rubin's R			1.2

Legend. *PSM, propensity score matching; HaH-HA, Hospital al Home-Hospital Avoidance; Controls, Conventional hospitalizations; GMA, Adjusted Morbidity Groups scoring; *Matching variables.*

Hospitalization characteristics and outcomes

The main diagnosis at discharge in the two groups, HaH-HA and Controls, showed the same distribution of percentages across the ICD-10-CM disease groups: 25% were urinary tract infections, 15% chronic respiratory diseases, 13% pneumonia, 11% acute lower respiratory tract infections, 9% heart failure, 8% skin infections, 6% flu, 3% symptoms, injury, and poisoning, 3% hypertensive disease and other heart diseases, 3% pneumonitis caused by bronchial aspiration, 4% other conditions requiring admission. Detailed information is provided in **Table 2S**.

Table 2. Characteristics of the acute episode and main outcomes.

	HaH-HA (n=441)	Controls (n=441)	P value
Total length of stay (days), mean (SD)	7.89 (4.37)	7.37 (6.17)	0.142
Case Mix Index	0.69	0.73	0.633
Use of resources during Hospital Avoidance			
All-cause Emergency Room visits, n (%)	6 (1.36)	N/A	N/A
All-cause In-Hospital re-admissions, n (%)	18 (4.08)	N/A	N/A
Mortality during episode, n (%)	0 (0)	19 (4.31)	**N/A**
Outcomes at 30 days after discharge			
All-cause Emergency Room visits, n (%)	28 (6.35)	34 (8.06)	**0.044**
All-cause Hospital admissions			
Unplanned Hospital admissions, n (%)	24 (5.44)	23 (5.45)	0.777
Planned admissions, n (%)	13 (2.95)	10 (2.37)	0.598
Mortality, n (%)	7 (1.59)	7 (1.66)	0.933

Legend. *HaH-HA, Hospital at Home-Hospital Avoidance; Controls, Conventional hospitalizations; N/A, not applicable*

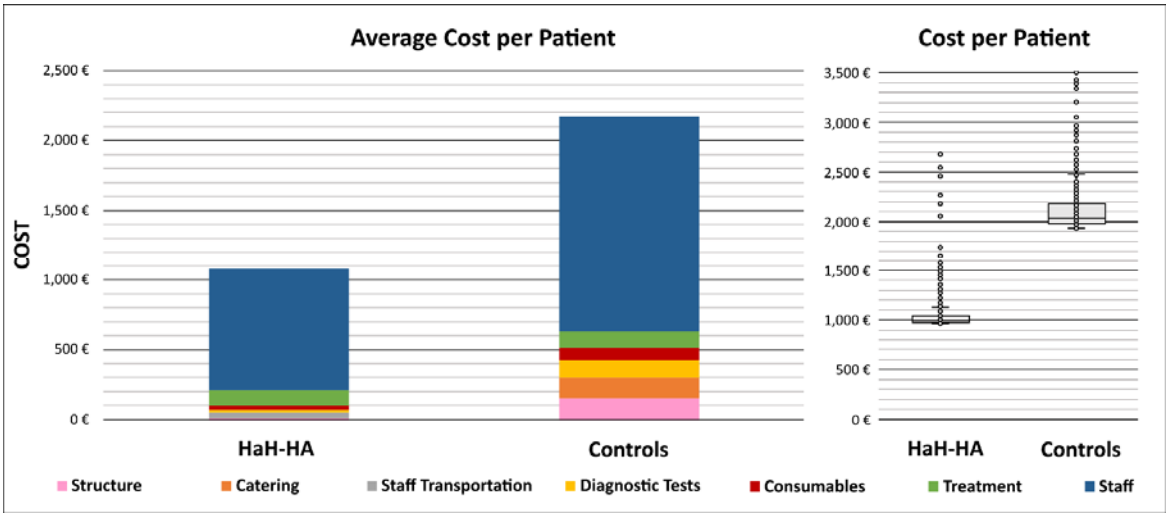
The characteristics of the acute hospitalization episode are summarized in **Table 2**. The two groups had similar CMI and length of stay. However, mortality and visits to the emergency room for any cause within the 30 days following discharge were significantly higher among patients with conventional hospitalization). In the HaH-HA group, 6 (1.4%) patients worsened their clinical condition during the episode, requiring a visit to the ER department and returning home. Likewise, 18 (4.1%) patients discontinued HaH-HA for similar reasons and were admitted to conventional hospitalization. The administration of the satisfaction questionnaire to patients admitted to HaH-HA revealed that 97% were highly satisfied with the service (**Figure S1**). Comprehensive information on the acute episode is provided in **Table 3S**.

Mortality and hospital admissions for any cause within the 30 days following discharge were similar in the two groups (**Table 2**). However, the conventional hospitalization group reported a significantly higher percentage of all-cause visits to the emergency room within the 30-day post-discharge period.

Healthcare costs

The total direct costs associated with the hospitalization episodes were € 475k and € 957k for the HaH-HA and comparator groups, respectively. **Figure 2** displays the cost per patient (average according to concepts and cost distribution across each group). In the two groups, costs associated with staff salaries accounted for the greatest proportion of all items. The average cost per episode was € 1,078 and € 2,171 ($p < 0.001$) for HaH-HA and conventional hospitalization episodes, respectively. Cost savings per episode in HaH-HA compared to conventional hospitalization were mostly attributable to staff (€ 867 *vs.* € 1,539; $p < 0.001$), followed by catering (€ 0 *vs.* € 149), infrastructure (€ 13 *vs.* € 151; P<.001), testing (€ 21 *vs.* € 124; $p < 0.001$), and consumables (€ 31 *vs.* € 89; $p < 0.001$). HaH-HA had no statistically significant impact on costs associated with the treatment (€ 110 *vs* € 119; $p = 0.662$). Contrarily, compared to usual care, HaH-HA showed significantly increased costs on staff transportation (€ 36 *vs.* € 0). In the HaH-HA group, none of the patients or their relatives required additional external support during the hospitalization episode. Transportation to the hospital, when needed, was afforded by the public healthcare payer.

Figure 2. Average cost per pacient



Legend *– In the left panel, the two columns indicate the average cost per patient for HaH-HA (Hospital at Home-Hospital Avoidance) and matched Controls (conventional hospitalizations), respectively. The colors indicate the weight of the different cost components (see text for details). The right panel depicts the box plots of the cost analysis.*

The general healthcare expenditure within the 30 days following discharge was significantly lower in individuals admitted to HaH-HA than those with conventional hospitalization (€ 764 vs. € 1,022; P<0.001). For the two groups, all post-discharge healthcare costs were afforded by the public healthcare payer; no indirect costs afforded by patients or their relatives were considered in the analysis. **Table S4** provides a detailed list of costs associated with healthcare resource consumption within the 30 days following discharge.

DISCUSSION

In this control-matched comparison of HaH-HA and conventional hospitalization, we found that HaH-HA was associated with significantly lower mortality during hospitalization and lower visits to the emergency room within the 30 days following discharge, despite the similar characteristics of the two groups, including the patients' CMI on admission and the length of stay. The overall cost per episode was nearly half in the HaH-HA

compared with conventional hospitalization. This cost reduction was primarily attributed to staff, catering, infrastructure, and testing. Likewise, patients admitted for a HaH-HA showed significantly lower healthcare expenditure within the 30 days following discharge.

Our findings are in the upper range of care quality of HaH studies in Europe [32,33] US [34–36], and Australia [37–40], taking into account the heterogeneity of services in the type of care, reimbursement regimes, and adoption strategies. Furthermore, the maturity of both integrated care and digital support may strongly influence the success of implementation and adoption strategies [16]. This factor, which increases the complexity of assessing HaH, may have also influenced the cost assessment. Thus, the innovation and change management with digital support of the service, which was gradually implemented in the early phases of HaH [7,41] but accelerated during the study period, may have contributed to cost reduction and improved health outcomes observed in our analysis.

Using a control-matched population strengthens our analysis admitted for conventional hospitalization within the same period in a real-world setting. This approach required ruling out 145 patients of the 586 hospitalized at home within the investigated period. However, our analysis of the baseline characteristics showed no differences with the final analysis dataset; therefore, we do not expect this exclusion to limit the representativeness of our cohort. Other strengths of our analysis include the possibility of collecting integrated data regarding healthcare resource utilization (including primary care) before and after the hospitalization episode, as well as using of analytical accounting for the cost analysis. This approach provided a detailed picture of costs, which is impossible with case-mix payment tools, such as the diagnostic risk groups used in several reports.

On the other hand, the current study was limited to the assessment of the direct costs of the healthcare provider, losing sight of indirect costs (e.g., home careers, etc…). More importantly, we could not gather societal costs or economic burdens for caretakers or patients' relatives. Therefore, our cost-consequence analysis from the healthcare provider and healthcare system perspective shall be expanded in the future by including all these indirect and societal costs.

Aside from highlighting the need for a more comprehensive analysis of costs, our study paves the way to identifying key performance indicators that consider both site-specific and general features and allow for continuous monitoring of HaH performance. Another aspect of HaH to be explored is the implications of this type of care for improving the continuity of care by fostering vertical integration (i.e., between specialized and community-based care) and horizontal integration (i.e., between healthcare and social care). Although the role of HaH in these integrations was out of the scope of our analysis, health professionals working in a HaH are a natural bridge between specialized and community-based care during the transitional period during and after discharge [42]. Hence, HaH should be promoted as a facilitator of integrated care pathways, and future studies should investigate the contribution of HaH to maintaining the continuity of care in these transitions.

CONCLUSIONS

Our analysis indicates that HaH-HA adds overall value for healthcare providers and the healthcare system. Taken together, our study and the current literature on the field highlight the need for adopting comprehensive and applicable assessment frameworks for HaH to facilitate the comparability and transferability of the service.

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MANUSCRIPT 3

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ABSTRACT

Background: Digital health tools may facilitate the continuity of care. Enhancement of digital aid is imperative to prevent information gaps or redundancies, as well as to facilitate support of flexible care plans.

Objective: The study presents Health Circuit, an adaptive case management approach that empowers health care professionals and patients to implement personalized evidence-based interventions, thanks to dynamic communication channels and patient-centered service workflows; analyze the health care impact; and determine its usability and acceptability among health care professionals and patients.

Methods: From September 2019 to March 2020, the health impact, usability (measured with the system usability scale; SUS), and acceptability (measured with the net promoter score; NPS) of an initial prototype of Health Circuit were tested in a cluster randomized clinical pilot (n=100) in patients with high risk for hospitalization (study 1). From July 2020 to July 2021, a premarket pilot study of usability (with the SUS) and acceptability (with the NPS) was conducted among 104 high-risk patients undergoing prehabilitation before major surgery (study 2).

Results: In study 1, Health Circuit resulted in a reduction of emergency room visits (4/7, 13% vs 7/16, 44%), enhanced patients' empowerment (*P*<.001) and showed good acceptability and usability scores (NPS: 31; SUS: 54/100). In study 2, the NPS was 40 and the SUS was 85/100. The acceptance rate was also high (mean score of 8.4/10).

Conclusions: Health Circuit showed potential for health care value generation and good acceptability and usability despite being a prototype system, prompting the need for testing a completed system in real-world scenarios.

KEYWORDS

continuum of care management; innovative healthcare services; collaborative tools; digital health transformation; usability; acceptability; health care service; Health Circuit; health management; management; support; digital aid; aid; care; prototype; surgery; testing.

Original Paper

A Practice-Proven Adaptive Case Management Approach for Innovative Health Care Services (Health Circuit): Cluster Randomized Clinical Pilot and Descriptive Observational Study

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Abstract

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Introduction

Worldwide, conventional disease-oriented approaches are being replaced by innovative, preventive, patient-centered health care services with digital health tools that support vertical (between the hospital and the community) and horizontal (between health and social services) integration. However, despite the broad consensus there are still significant challenges in ensuring care continuum across health organizations [1].

In many cases, cooperation among health care tiers and providers needs digital support for secure bidirectional and instantaneous communication to avoid information gaps or duplications and assist the care team in making shared decisions. Moreover, the nondeterministic nature of health care services requires a shift in focus from a set of prescriptive tasks to context-dependent, flexible, often-evolving care plans aimed at achieving optimal outcomes for each patient.

In 2001, adaptive case management (ACM) was introduced in the workflow management literature to support knowledge workers (eg, physicians, architects, and lawyers) [2] and unpredictable business processes that require flexibility. Because knowledge-based work is data-intensive, the ACM approach can foster more informed decisions and customize business processes as necessary [3,4]. The application of these ACM principles is essential for efficient digital health transformation. Improved end-user engagement, personalization to the evolving patient's health status, and better communication and coordination between health care professionals are just some examples of the benefits of ACM when applied to innovative health services [5].

The current study presents the precommercial experience of co-design and prototyping of a digital health tool (Health Circuit) with an ACM approach during the period from 2019 to 2021. The process had 2 consecutive steps. In an initial phase, from 2019 to 2020, the feasibility of a secure bidirectional communication channel was tested for improving the management of complex chronic patients with high risk of hospitalization. In a second phase (2020-2021), ACM principles were incorporated to enable virtual sharing of care plans among all team members of an innovative prehabilitation service [6-8] that provided both home and community-based care to candidates for major abdominal surgeries.

While the first pilot study aimed to analyze the service's potential with respect to management of unplanned events and patient self-management, both studies shared the common objective of assessing the Health Circuit approach with respect to its usability and acceptability as perceived by end users.

Methods

Context

It is of note that the precommercial experience reported in this study benefited from the combined input of all the stakeholders, including end users, from a health district integrated care area in the city of Barcelona (Área Integral de Salud Barcelona Esquerra; AISBE), which includes 520,000 citizens. All stakeholders have long experience in piloting digital support for enhanced management of chronic patients [9,10]. The project was part of the activities of the Catalan Open Innovation Hub on Digitally Enabled Integrated Care Services, which is 1 of the 4 original European Union Good Practices in the European Joint Action on Implementation of Digitally Enabled Integrated Person-Centered Care (JADECARE) [11].

Within this regional digital health transformation context, the first reported study for prevention of hospitalizations in complex chronic patients (2019-2020) focused on assessment of a prototype-level (technology readiness level [TRL] 5) [12] secure bidirectional communication channel with a twofold purpose: (1) facilitating management of unplanned events through direct access to a single case manager who could eventually trigger a shared decision-making process with other health professionals (primary care, specialists, or both) and (2) empowering patients' self-management with the aim of increasing self-efficacy through shared videos and educational material.

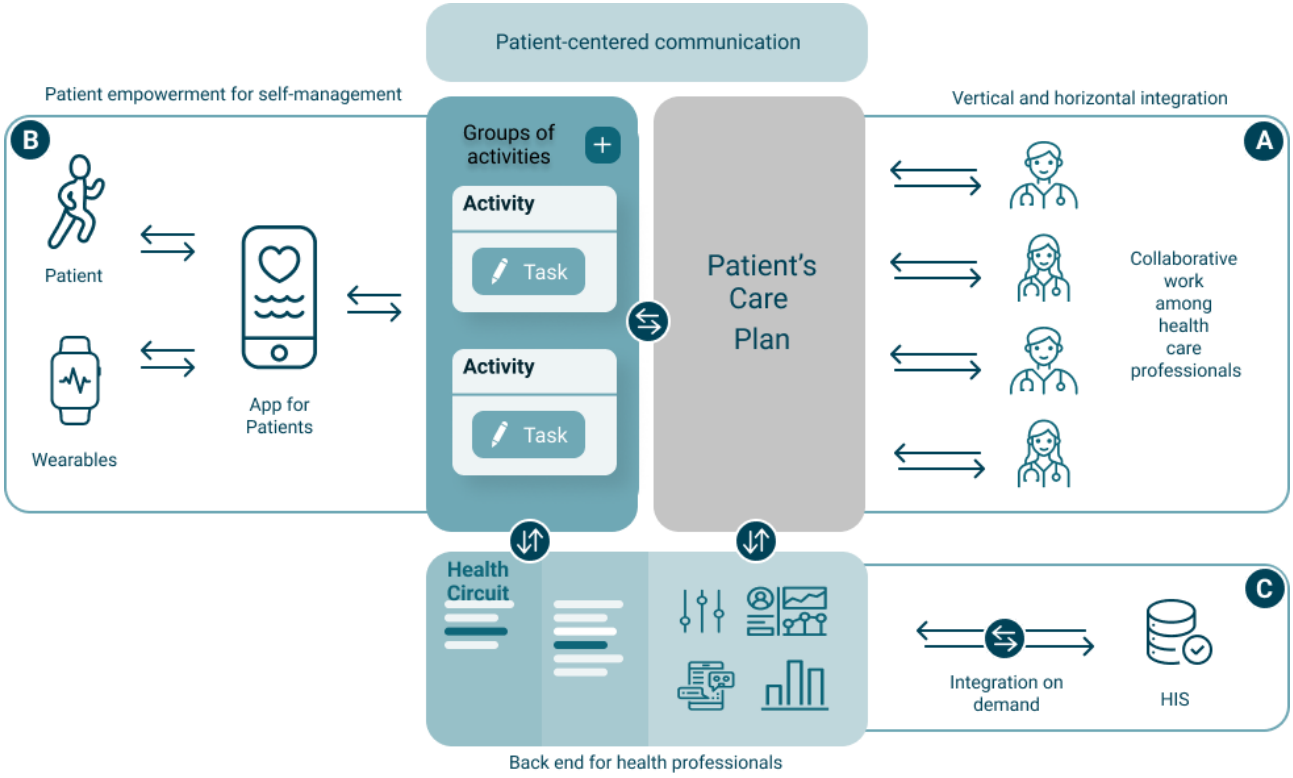
The second reported study (2020-2021) focused on assessing the acceptability and usability of a pilot version of Health Circuit (TRL 7) for enhancing patient adherence to the prehabilitation program at the Hospital Clinic of Barcelona (HCB) [13,14]. In recent years, prehabilitation has emerged as a health-value intervention to reduce postoperative morbidity and mortality in a variety of surgical populations [6]. In related work, we have previously demonstrated the efficacy [7] and potential effectiveness [8,15] of prehabilitation. It is of note that the impact of prehabilitation in real-world settings seems strongly associated with actionable areas, such as enhancing patients' adherence and transferability to community settings, which requires digital support with an ACM approach [14] to enable virtual sharing of care plans among professionals across health tiers and prescription of nonpharmacological interventions to promote patient empowerment for self-management.

Health Circuit Approach

The ACM approach of Health Circuit aims to empower professionals to define dynamic service workflows as patient-centered, evidence-based interventions with special input on combining pharmacological and nonpharmacological interventions. It can be viewed as a semiautomated and event-driven task manager for professionals and patients that enables them to perform certain activities in the context of the patients' treatment.

It is collaborative in the sense that health care professionals must share their knowledge and decisions with their peers (Figure 1).

Figure 1. Schematic depiction of Health Circuit. (A) Health care professionals easily adapt and customize shared care plans over time, facilitating a connected experience for both the patient and the health care professional. (B) Patients participate in effective health coaching and self-management strategies, on any device, for a goal-oriented and personalized health plan to manage both expected and unexpected events. (C) Without requiring tight system integration, Health Circuit allows health care providers to progressively replace conventional disease-oriented approaches with a predictive, preventive, personalized, and participatory integrated care approach. HIS: health information system.



Main Features of Health Circuit

Case-Centered

The collaboration is bounded by the case, meaning that a group of professionals interact with each other and the patient in the context of the case.

Multichannel Communication

The communication channel is a tool for helping in decision-making. A secure chat between a number of peers starts with a particular issue in mind and, when resolved, leaves a summary of the decision and motivations for it, which then is translated into some action. It is also used to help patients solve doubts and issues with their treatment. This is the front-line support to collaborative work.

Multidisciplinary Shared Care Plan

The activities to be performed are related to different specialties and disciplines from various levels of care but are shared in a common care plan. A care plan represents the workflow of how a treatment is planned to be addressed. It has a layered structure with 3 levels of elements, comprising, from bottom to top, tasks, activities, and groups of activities. Tasks are what is ultimately actionable. They represent things like "the third session of physiotherapy at the hospital gym," "filling in some questionnaires for the second time," and "the fifth day of receiving nutritional tips." Activities generate identical tasks over a period with a given recurrence. They can be started or ended automatically by linking them to events related to other activities. Groups of activities help enabling or disabling activities at a higher level (eg, baseline assessments; weekly follow-ups).

The structural dependencies between the above elements, in the sense of the care plan or service workflow that represents the treatment, translate into 2 main concepts: semiautomated processes, comprising activities that are dependent on or related to the outcome or completion of other activities; and overridability, that is, using structures that do not impose strict rules on professionals, so they can override any decision with proper motivation; this is registered into the system for accountability.

Event-Driven Architecture

Health Circuit is designed with an event-driven architecture in mind. This means that the internal structure of the care plan is based in events and actions (ie, a publish-subscribe software architecture pattern) that can be linked together. Events are anything that happens, from "the activity A started" or "the group of activities X ended" to "the weekly total step count passed the 80% threshold." Actions are a limited set of operations that can be performed, like "start or end an activity or activity group" or "send a push, SMS, or email notification to a patient or professional." More advanced scenarios will introduce actions that represent integration with third party systems, like "upload a report to the health information system."

Such an event-driven architecture is scalable and open and allows introducing a visual workflow editor, so that health care professionals without technical skills can define and customize their own care plan templates.

Tailored Integration With Existing Corporate-Specific Health Information Systems

Delivery as a low-barrier corporate communication channel without requiring tight system integration will maximize adoption across the global health care information technology (IT) market. When required, Health Circuit can be easily integrated with site-specific health information systems by means of standards-based (eg, Health Level Seven Fast Health Interoperability Resources; HL7-FHIR) interoperability middleware, provider-specific web services, or application programming interfaces. This can be the case for the calendar of appointments, the agenda of health care professionals, admission and discharge reports, and authentication with corporate-specific centralized user management systems.

Compared to digital health solutions developed through a traditional consultancy process, Health Circuit allows multidisciplinary health care teams and patients to start collaborating right away via the multimedia communication channel, preparing the stakeholders to formalize the need for coordination over time based on a shared care plan representing a workflow template of how a treatment is agreed to be addressed. This means that health care professionals can face new cases reusing structured, evidence-based experience with previous cases without needing any special skills. Over time, health care professionals should be able to adapt the system to their own evidence-based care plans without needing the help of any IT specialist.

Community-Based Management of Complex Chronic Patients With High Risk for Hospitalization

The protocol was designed as a cluster randomized controlled trial conducted in 3 primary care teams pertaining to the Consorci d'Atenció Primària de Salut Barcelona Esquerra (CAPSBE) primary care area of Barcelona, with an intervention to control ratio of 2:1 and a follow-up period of 3 months. Eligible patients (n=100) were selected from among 441 participants of the study [16] who had a referral primary care team in CAPSBE. Due to the nature of the intervention, neither the participants nor the investigators in direct contact with them were blinded. The doctors included were the reference doctors of each of the study patients and were not selected by the researchers. They all agreed to participate in the study, consent was given, and randomization was conducted.

The inclusion criterion was an adjusted morbidity group (AMG) score ≥3 [17,18]; this is a proxy of moderate to high risk based on multimorbidity criteria. AMG is an aggregative index that estimates the individual's burden of disease from a disease-specific weighting obtained from a population-based statistical analysis based on mortality and the use of health services. Moreover, patients or caregivers in the intervention group were required to have a smartphone or tablet compatible with the Health Circuit prototype mobile app with an Internet connection. The exclusion criteria were physical or psychological problems preventing the use of Health Circuit and being unemployed.

The study run between September 2019 and March 2020. For both the intervention and the control group, sociodemographic data and digital literacy characteristics were collected at baseline, the Fantastic Questionnaire [19] and Elders Health Empowerment Scale (EHES) [20] were collected at baseline and at 3 months, and the patients' and professionals' satisfaction with and assessments of the usability of the Health Circuit prototype and the continuity of care were measured with the self-administered net promoter score (NPS) [21], the System Usability Scale (SUS) [22], and the Nijmegen Continuity Questionnaire [23], respectively. All data were collected face to face at the beginning and at the end of the study and was stored on the RedCap platform. Multimedia Appendix 1 provides details.

For the intervention group, a motivational interview was conducted at baseline with one case manager who aimed to co-design a personalized and comprehensive care plan and empower the patient for self-management of their conditions (Table 1). The nurse case manager carried out follow-up visits at 15 days, 1 month, and 2 months after the start of the study and were always available during the 3 months of the intervention when the patients reported any query or health problem through the app. Patients and professionals affiliated with the intervention primary care centers were instructed on the functionalities of the Health Circuit prototype (Multimedia Appendix 2).

In the control group, both patients and professionals followed standard of care procedures for regular and emergency visits, both by telephone and in person, depending on the center's availability.

Results are presented as means (SD) or percentages, as indicated. Comparisons were made using the chi-square or Fisher exact test for categorical variables and the Student test (according to the distribution of the variables) for numerical variables.

Table 1. Sociodemographic baseline characteristics of 47 patients with high risk for hospitalization.

	Intervention (n=31)	Control (n=16)	*P* value[a]
Age (years), mean (SD)	72.7 (13.7)	78.1 (8.8)	.11
Male, n (%)	20 (64)	12 (75)	.52
Higher educational level, n (%)	19 (61)	6 (38)	.25
Widowed, n (%)	14 (45)	1 (6)	.004
Living with family, n (%)	22 (71)	14 (88)	.25
Retired, n (%)	20 (64)	15 (94)	.11
AMG[a] score, n (%)			.46
Moderate risk (80th to 95th percentiles)	15 (48)	7 (44)	
High risk (95th to 99th percentiles)	16 (52)	9 (56)	

[a]AMG: adjusted morbidity group, an index indicating multimorbidity and the complexity of the patient, expressed in percentiles [17,24].

Prehabilitation of High-Risk Candidates for Major Surgical Procedures

A descriptive observational study was carried out including patients (n=104) who completed the prehabilitation program at HCB 8 between July 2020 and July 2021 and agreed to participate in the study. The study was offered to all patients included in the prehabilitation program on the dates described (n=213).

The inclusion criterion was having a smartphone or tablet compatible with the prototype mobile app (Prehab) with an Internet connection. The exclusion criteria were (1) physical or psychological problems precluding the use of the mobile app and (2) not having a carer.

The prototype version of Health Circuit tailored to the prehabilitation process (Prehab; TRL 7) allowed care team members to prescribe and monitor nonpharmacological interventions for patient self-management through a mobile app, which included (1) physical activity goals, (2) nutritional tips, (3) mindfulness exercises, and (4) patient-reported outcomes. Moreover, patients had access to a one-to-one chat with the case manager [25] for enhanced management of multimorbidity. Multimedia Appendix 3 provides details.

At the end of the prehabilitation program (4-6 weeks on average), the patients' satisfaction with and assessments of the usability of the mobile app were collected with the self-administered NPS and SUS, respectively. Moreover, the patients' use of the mobile app was evaluated according to (1) the number of chat interactions, (2) adherence to reporting of daily physical activity, (3) completion of follow-up questionnaires, and (4) access to the tailored education material on mindfulness, nutrition, and physical activity. Results are presented as means or percentages, as indicated.

In this study the back end for health care professionals was not assessed because the recruitment and follow-up of study participants was done with only one health care professional, a case manager physiotherapist.

Ethics Approval

Study approval was obtained for the cluster randomized clinical pilot from the Ethics Committee for Clinical Research of the HCB (HCB/2018/0805), and the trial was registered at ClinicalTrials.gov (NCT04056663) on August 14, 2019. Patients read, understood, and filled out the informed consent form, which was signed before enrollment in the study. The Ethics Committee for Medical Research of HCB approved the premarket pilot study (HCB/2016/0883). Informed consent forms were understood, accepted, and signed by all the included subjects.

Results

Community-Based Management of Complex Chronic Patients With High Risk for Hospitalization

Two primary care units were randomly assigned as intervention units and 1 as a control unit. From an initial sample of 100 eligible patients, 41 did not meet the participation criteria. The Consolidated Standards of Reporting Trials (CONSORT) study flowchart is shown in Multimedia Appendix 4. The remaining 59 patients were assigned to one of the study arms according to the reference center. A total of 47 patients, 31 in the intervention arm and 16 controls, completed follow-up. The initial demographic characteristics are shown in Table 1.

Detailed information on the availability of smartphones (32/36, 88% in the intervention group and 13/18, 72% in the control group), digital baseline characteristics, baseline use of technology, and health information sources at the beginning of the study can be found in Multimedia Appendix 5.

During the study period, a total of 28 consultations, 12 clinical and 16 administrative, were done by 26 of 31 patients in the intervention group. In all cases, the events were solved in a timely manner. Offline chat was used in 78% (22/28) of the consultations and phone calls in the remaining 22% (6/28).

The intervention had positive clinical impacts in terms of less use of health care resources, increased patient empowerment ($P<.001$), and improved perception of continuity of care ($P<.001$). As depicted in Table 2, the intervention group had fewer hospital (0 vs 1) and primary care (4 vs 7) emergency

room visits, a lower hospitalization rate (0 vs 2), less mortality (0 vs 2), and half the number of visits to primary care (27 vs 52) compared to the control group. However, these results were not statistically significant. The difference in Δ empowerment (pre-post) in the intervention group and the control group was 9 points (4.5 vs –4.56).

Table 2. Clinical and patient-reported outcomes during the study period.

Outcome variables	Intervention (n=31)	Control (n=16)	*P* value
Hospital emergency room visits, n	0	1	N/A[a]
Primary care emergency room visits, n (%)	4 (13)	7 (44)	N/A
Primary care visits, n (mean per patient)	27 (1.59)	52 (3.25)	N/A
Hospitalizations, n (%)	0 (0)	2 (13)	N/A
Mortality, n (%)	0 (0)	2 (13)	N/A
Baseline lifestyle [19], mean score (SD)	41.18 (3.53)	36.06 (4.36)	N/A
Δ Lifestyle (pre-post) [19], mean score (SD)	2.62 (4.49)	0.43 (4.15)	N/A
Baseline empowerment [20], mean score (SD)	36.46 (5.38)	28.44 (6.24)	<.001
Δ Empowerment (pre-post) [20], mean score (SD)	4.5 (5.23)	-4.56 (5.38)	<.001
Continuity of care [23], mean score (SD)	4.84 (2.40)	2.75 (1.26)	<.001

[a]N/A: not applicable.

Usability and Acceptability

The patients reported good satisfaction and usability for the mobile app (NPS score 31 and SUS 68/100, respectively), as well as a high acceptance rate (mean score 7.8/10). However, the backend for health professionals had a neutral score in terms of satisfaction and usability (NPS score –80 and SUS 54/100, respectively) with an acceptance score averaging 5/10. Despite these results for the acceptability and usability of the backend, 75% (12/16) of the professionals participating in the study indicated that the remote consultations had good overall quality, 87% (14/16) reported that they would continue to use remote consultations as a support tool, and 69% (11/16) of the professionals considered that telemedicine can improve the state of patients' health.

Prehabilitation of High-Risk Candidates for Major Surgical Procedures

A total of 104 patients of 213 (mean age 69, SD 11 years, 67% men) that agreed to download the Prehab mobile app (TRL 7) [26,27] during the study period were included in the study.

The mobile app obtained good usability scores (NPS score 40 and SUS 85/100), as well as a high acceptance rate (mean score 8.4/10).

The patient's primary use of the mobile app was to follow the prescription for daily physical activity, in 96% (n=100) of the cases. The weekly nutrition follow-up questionnaires were completed by 40% (n=42) of the patients; 37% (n=38) of study participants used the chat at least once to communicate with the prehabilitation team members (ie, physiotherapists and nutritionists). Only 21% (n=22) of the participants completed the daily mindfulness exercises. Educational tips on nutrition and physical activity were used by 33% (n=34) and 26% (n=27) of the study participants, respectively.

Discussion

Principal Results

We have presented the Health Circuit ACM approach to help health care professionals create patient-centered workflows combining both pharmacological and nonpharmacological interventions. It functions as a semiautomated task manager for professionals and patients, allowing them to perform certain activities as part of the patient's action plan. This approach encourages collaboration and sharing of knowledge among health care professionals. We assessed the feasibility of the approach for two innovative health care services: (1) enhanced management of complex chronic patients with high risk of hospitalization through a secure bidirectional communication channel and (2) scalability of a prehabilitation service that was previously demonstrated to be efficient [7] and cost-effective [8,15], incorporating the virtual sharing of health plans that include nonpharmacological activities toward patient empowerment for self-management.

The pilot study on community-based management of complex chronic patients with high risk for hospitalization (with a TRL of 5) showed the potential of the approach to enhance management of unplanned health events, leading to less use of health care resources as well as improved patient empowerment for self-management and perception of continuity of care. The results are encouraging, especially when considering that both patients and health care professionals reported reasonably good usability and acceptability, despite the high mean age of the study participants (72.7 years) and the series of limitations that prototype-level digital health tools with a low TRL tend to have. Similarly, Health Circuit, which has a TRL of 7, was reported to have good usability and acceptability in the pilot study on prehabilitation of high-risk candidates for major surgical procedures, improving patient adherence to nonpharmacological treatment, especially in the case of daily physical activity.

Strengths and Weaknesses

Despite the precommercial nature of the digital health tools supporting each of the 2 feasibility studies, reasonably good usability and acceptability results were obtained in real-world clinical settings. The positive results reinforce the need to pursue the development of a commercial product with potential for cost-effectiveness and profitability in real-world settings.

However, we must acknowledge several limiting factors of the studies, such as small sample sizes, the local health care settings, and the descriptive observational study design of study 2, which may preclude the generalization of the findings to other populations or health care settings.

Finally, although one of the limiting factors for adoption of value-based care services is still acceptability and usability among stakeholders, especially older people, the reported studies contribute to the growing body of evidence that indicates the positive effects of eHealth services on patient health outcomes [28-31] (eg, enhanced patient empowerment and adherence to care plans) at a lower cost.

Adaptive Case Management

Change management is critical for ensuring effective digital health transformation, as it helps stakeholders to adapt to new processes and technologies, build support for change, and achieve the goals of the transformation. By taking an ACM approach, health care organizations can minimize disruption, ensure stakeholder buy-in, and improve the quality of care. Briefly, front-line support for flexible case-centered collaboration requires secure multichannel communication, whereas shared care plans can be introduced to multidisciplinary care teams in a stepwise manner, leading to a more standardized care protocol as the result of the effective adoption of organizational interoperability.

Perspectives and Future Developments

The aim of Health Circuit is to facilitate large-scale adoption of value-based care services, such as the 2 innovative health care services considered in this study. Therefore, future actions should focus on easing the implementation of digitally enabled, integrated, person-centered care by means of a flexible approach to shared care processes and a holistic approach to health risk assessment.

In this vision, ACM processes dictate information needs, which is a great opportunity to decouple data from applications, enabling data to follow patient-centric care processes and helping to scale up innovations for value-based health care. Storing data with open standards, such as OpenEHR, allows data analysts to develop the secondary use of understanding cost-effectiveness within the context of a certain care plan. With this infostructure, AI experts can train automated decision support for health risk assessment. This can potentially also be done for health risk assessment to indicate the best care plan for a given type of patient. This minimizes certain risks, like mortality or unplanned hospital admissions.

Conclusions

The Health Circuit approach to ACM demonstrated potential for value generation, as well as reasonably good usability and acceptability results among end users. The 2 pilot studies validated the feasibility of the approach to enable collaboration and knowledge-sharing among health care professionals from different levels of care and with patients.

Therefore, Health Circuit can play a crucial role for the adoption of patient-centered, integrated care by enabling health care professionals from different disciplines and organizations to make better-informed decisions about patient care, which can lead to personalized medicine based on health risk assessment that considers the needs and circumstances of each patient.

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Conflicts of Interest

IC and JR hold shares of Health Circuit SL, a spin-off company of the Hospital Clinic of Barcelona. IC is also the CEO of Health Circuit SL. All other authors declare no conflicts of interest.

Multimedia Appendix 1

Net promoter score and System Usability Scale measures.
[DOCX File , 12 KB-Multimedia Appendix 1]

Multimedia Appendix 2

User manual: Community-based management of complex chronic patients with high risk for hospitalization.
[DOCX File , 767 KB-Multimedia Appendix 2]

Multimedia Appendix 3

User manual: Prehabilitation of high-risk candidates for major surgical procedures.
[DOCX File , 551 KB-Multimedia Appendix 3]

Multimedia Appendix 4

Flow diagram of Health Circuit.
[DOCX File , 42 KB-Multimedia Appendix 4]

Multimedia Appendix 5

Digital baseline characteristics in the intervention group and baseline use of technologies and health information sources.
[DOCX File , 35 KB-Multimedia Appendix 5]

Multimedia Appendix 6

CONSORT-eHEALTH checklist (V 1.6.1).
[PDF File (Adobe PDF File), 9628 KB-Multimedia Appendix 6]

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Abbreviations

ACM: adaptive case management
AISBE: Área Integral de Salud Barcelona Esquerra
AMG: adjusted morbidity group
CAPSBE: Consorci d'Atenció Primària de Salut Barcelona Esquerra
EHES: Elders Health Empowerment Scale
HCB: Hospital Clinic of Barcelona
HIS: Health information system
HL7-FHIR: Health Level Seven Fast Health Interoperability Resources
IT: information technology
NPS: net promoter score
SUS: system usability scale

TRL: technology readiness level

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ABSTRACT

Introduction: Multimorbid, frail, patients are frequent candidates for unplanned hospitalizations generating a high burden on healthcare systems. But efficiencies of interventions aiming at preventing potentially avoidable admissions have not been yet shown. The current case practice describes the elaboration of a pragmatic study protocol, generated within the JADECARE initiative (2020-2023), aiming at preventing avoidable admissions in real-world settings.

Methods: We used the implementation science approach reported in *BMC Health Serv Res 19, 370 (2019)* combining co-design techniques, quantitative analyses, and quality improvement methodologies. Interviews to 5 patients and 15 professional leaders, followed by two design-thinking sessions, were done (Oct 2021 to Feb 2022) to examine regional adoption of integrated care in Catalonia. Moreover, analysis of 50 K hospitalizations followed by two co-design sessions were conducted between Jul and Dec 2022.

Discussion: The co-creation process identified lack of personalization of the interventions, poor management change and immature digital support as main explanatory factors of the efficacy-effectiveness gap seen in previous reports. A pragmatic study protocol for prevention of avoidable hospitalizations, to be tested during the period 2023-2026, is proposed.

Conclusions: An adaptive case management approach for digital support and management changes are recommended for value-based, patient-centred, prevention of unplanned hospitalizations.

Key words: Adaptive Case Management, Digital Support, Prevention of Hospitalizations, Integrated Care.

A Co-Creation Process Toward Sustainable Adoption of Integrated Care for Prevention of Unplanned Hospitalizations

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ABSTRACT

Introduction: Complex chronic patients (CCP) are prone to unplanned hospitalizations leading to a high burden on healthcare systems. To date, interventions to prevent unplanned admissions show inconclusive results. We report a co-creation process performed into the EU initiative JADECARE (2020-2023) to elaborate an integrated care program aiming at preventing unplanned hospitalizations.

Methods: A two-phase process of structured interviews and design thinking (DT) sessions was conducted. Firstly, we assessed the management of CCP in Catalonia (ES) through twenty interviews (five patients and fifteen professionals), including the results of a cluster analysis of 761 hospitalizations, followed by two DT sessions (Oct 2021 to Feb 2022). Then, we examined the 30- and 90-day post-discharge periods of 49,604 hospitalizations as input for two DT sessions with seven professionals.

Discussion: The co-creation process identified poor personalization of the interventions, the need for organizational changes, immature digitalization, and suboptimal services evaluation as main explanatory factors of the observed efficacy-effectiveness gap. Additionally, a program for prevention of unplanned hospitalizations, to be evaluated during 2023-2025, was generated.

Conclusions: A digitally enabled adaptive case management approach to foster collaborative work, as well as organizational re-engineering, are endorsed for value-based prevention of unplanned hospitalizations.

Key words: Adaptive Case Management, Co-creation, Design Thinking, Digitalization, Prevention of Unplanned Hospital Admissions

INTRODUCTION

Complex chronic patients (CCP) (1) frequently face unplanned hospitalizations, either due to episodes of exacerbation, or during periods associated with increased vulnerability, like the transition from hospital to the community after hospital discharge (2). It is widely accepted that unplanned hospital admissions generate significant dysfunctions, and a high financial burden, on healthcare systems worldwide (3).

The reports from reputed international organizations (4,5) indicate that a relevant percentage of unplanned hospitalizations are avoidable. However, the existing literature examining interventions to reduce admissions in selected CCP with episodes of severe exacerbations (6)and in transitional care programs (7) aiming at decreasing early readmissions after hospital discharge provide inconclusive messages. This can be attributed to the heterogeneity of the interventions and/or suboptimal description of the protocols leading to poor comparability, among other factors. Overall, there is a clear consensus on the need to explore the potential of clinical processes to efficiently prevent unplanned hospitalizations within a care continuum scenario (8).

To this end, a co-creation process was undertaken within the Catalan original Good Practice (oGP) of the European Union (EU) Joint Action JADECARE (9), running in the period 2020-2023. Two factors triggered the initiative of the case practice. Firstly, during the pre-implementation phase of JADECARE, internal discussions within the Catalan oGP highlighted the necessity of reevaluating the preventive management of CCP. The second triggering factor was the unsolved efficacy-effectiveness gap (EEG) observed between the promising results of a two-centre randomized controlled trial (RCT), carried out in 2006 (10) and the lack of effectiveness observed when the same intervention was replicated in a pragmatic RCT conducted during 2015 (11).

The case practice focused on designing and adopting person-centred integrated care interventions for selected CCP to prevent unplanned hospitalizations. This approach covered

two situations: firstly, selected patients showing a high risk of severe exacerbations due to clinical severity, poor self-management and/or environmental factors; and secondly, transitional care strategies after hospital discharge.

Ultimately, the targeted objectives in this case practice are: i) To identify key factors explaining the observed EEG; ii) To produce well-defined interventions, including identification of target candidates, as well as the steps needed to achieve mainstream adoption, and iii) To evaluate the potential for generalization/transferability of such interventions at the EU level.

The report sequentially describes the regional context of the analysis, the main achievements of the two-phase co-creation process based on structured interviews and design thinking (DT) sessions, and the process for the elaboration of the program for the prevention of unplanned hospitalizations to be tested during 2023-2025.

DEVELOPMENT AND IMPLEMENTATION OF THE CASE PRACTICE

Setting the scene

Since 1981, the Catalan Health System (12,13) has been fully responsible for policy formulation, organization management, service delivery, and financial aspects of the health services in Catalonia (ES), with 7.7 million citizens. While key areas such as basic legislation, interregional coordination, pharmaceutical policy, international health policy, and educational requirements remain under the Spanish central government's control, the Catalan Health System holds complete jurisdiction over subsidiary legislation, public health initiatives, the organizational structure of the healthcare system, accreditation, and planning processes, as well as purchasing and service provision activities.

The regional system ensures universal coverage and free access at the point of use. Healthcare expenditure represents approximately 8% of the gross domestic product paid by taxes (14). The single public payer, CatSalut (15), has a well-defined separation from a network of multiple

providers fully accounted for in terms of health objectives, activity, invoicing system, financial aspects, and evaluation system. Basic principles and traits of the regional health system are: i) civil society participation, ii) access equity, and iii) robust tradition of regional health planning. The latter has an essential role in triggering key sustainable changes at the regional level, as recently assessed by the 2020 WHO report on the "*Thirty-year Retrospective of Catalan Health Planning: Driver of Health System Transformation"* (16). It is of note that the level of citizen's satisfaction regarding health services, measured yearly through the Health Survey of Catalonia (ESCA) - "Enquesta de Salut de Catalunya"(17), is on average 8/10.

Integrated Care in Catalonia (ES) – The regional health planning (18,19) has played a backbone role in triggering the health system transformations toward digitally supported integrated health and social care services during 2011-2020.

Since the early 1980s, the primary healthcare centres (PHCs) in Catalonia have been the first point of contact for individuals seeking healthcare services. PHCs are staffed by general practitioners, community nurses, paediatricians, and other healthcare professionals. Citizens are assigned to a specific PHC based on their residence, such that each PHC is responsible for serving a defined population within its catchment area. This structure, designed to be patient-centred, plays a major role in facilitating the care continuum. The second major component in the integrated care scenario is the different modalities of services grouped into the concept of intermediate care and end-of-life services. Such area was conceived in 1986 under the seminal program "Vida als Anys" (Life to Years) (20) and further evolved toward a myriad of interconnected service modalities, displayed in **Table 1**. During 2011-2020, coordination of social support services, dependent on city councils and healthcare, has also been a core objective.

Table 1 – Service modalities supporting care continuum in Catalonia.

SERVICE MODALITIES	CHARACTERISTICS
Primary Care	
Primary Health Centres (PHC)	Are the first point of contact for individuals seeking healthcare services and coordinate patients' cure and/or care.
Home Care	Home-based support services directly provided by the PHC
Intermediate Care (socio-health services) – Outpatient regime	
Specialized support teams	1. UFISS - Professionals (physician, nurse, and social worker) devoted to assessment of complex geriatric cases. Ascribed to intermediate care hospitals. 2. EAIA – Dedicated to detection and management of multimorbid patients with high social risk showing acute clinical episodes. 3. ETODA - Stands for outpatient direct observation therapy teams devoted to a specific program for tuberculosis therapy. The aim is to guarantee the correct performance of the treatment by patients with social problems, through the direct supervision of the administration of the medication**.**
Palliative care (PADES)	Interdisciplinary teams, coordinated with PHC, devoted to end-of-life care with a holistic approach.
Socio-health day hospitals	The objectives of day care services are assessment and comprehensive treatment, rehabilitation and ongoing maintenance care targeting geriatric or multimorbid patients.
Intermediate Care (socio-health services) - Hospitalization	
Long stay units	For rehabilitative treatment, maintenance care and prevention of complications, and as support for elderly people with long-term chronic diseases that have generated functional disabilities.
Convalescence units	Mid-stay unit to restore the functions or activities affected by health problems in geriatric multimorbid patients needing functional recovery after undergoing a surgical, medical, or traumatic process**.**
Sub-acute care units	For people with chronic and advanced disease who, due clinical exacerbation, need the continuation of a treatment under continuous clinical supervision. The aim of this care is to achieve clinical stabilization and comprehensive rehabilitation
Palliative care units	End-of-life hospitalizations
Hospital Care - Hospital at Home (HaH)	
Full (Hospital Avoidance) or partial (Early Discharge) substitution of conventional in-patient admission by home hospitalization (administered by hospital-based professional teams) for patients showing clinical criteria of hospitalization due to an acute health event.	
Social Support	
Interdepartmental Plan of Social and Health Interaction (PIAISS), approved in 2014. Further developed in (21)	

UFISS: Functional Unit for Socio-health care; EAIA: Integrated Care Team for specific target groups; ETODA: Team Directly Supporting Therapy on Outpatient basis.

Two distinct documents influenced the development of the current integrated care case, each contributing to its conceptual framework. One document encompasses the fundamental characteristics of the regional care model for chronic patients (1), providing operational definitions of frailty, CCP, and advanced chronic patients (ACPs) with a life expectancy of less than 18 months. The second report outlines the ongoing digital strategies for 2021-2025 (22), specifically focusing on implementing a knowledge-based digital platform to support cloud-based health services.

Co-creation process within JADECARE

The co-creation process was conducted following a grounded theory approach, combining inputs from recent quantitative analyses (23,24) and DT methodologies (25), as indicated in **Figure 1**, wherein the timeline and the focus of each of the two phases are depicted. The first co-creation phase, named "Discovery", had a twofold purpose: i) to identify actionable factors to enhance regional CCP management; and ii) to generate specific recommendations to be tested during 2023-2025. Whereas the second phase, named "Confirmation", took advantage of a comprehensive analysis of Hospital a Home (HaH) in Catalonia (ES), executed during the last semester of 2022. Such analysis provided the opportunity to assess the post-discharge period in a large dataset of hospital admissions. The aim was to confirm some assumptions and proposals generated in the Discovery phase.

Overall, the recommendations produced during the two co-creation phases were the basis for elaborating the roadmap for deploying and adopting a program for the prevention of unplanned hospitalizations in selected CCP.

For the entire co-creation process, the research team was assisted by a qualitative research and service design specialist recruited as a facilitator for planning and leading the expert panel discussions. A description of the methodological aspects, including the selection criteria of the participants in the structured interviews and the DT sessions and the results of the process, is provided in the online **Supplementary material**.

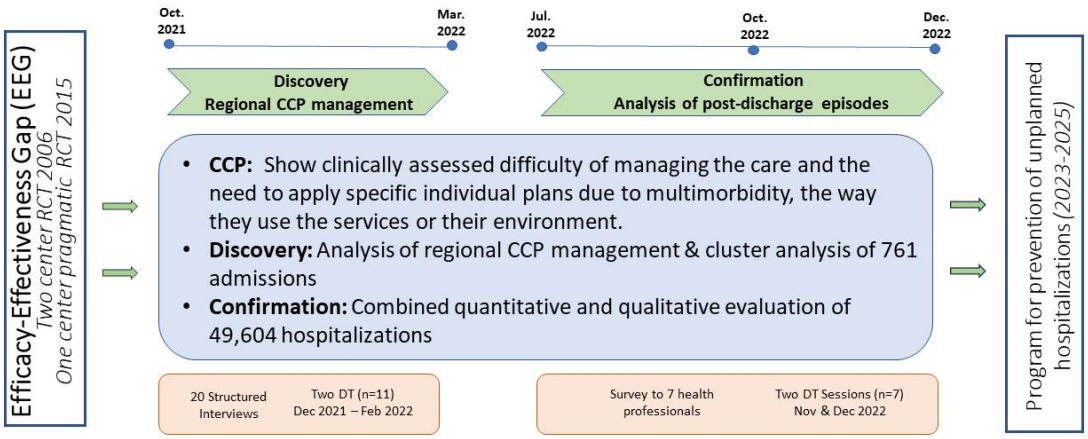

Figure 1 Two-phase co-creation process timeline *-* ***A trigger:*** *The efficacy-effectiveness gap (EEG) seen between two studies carried out in 2006* (10) *and 2015* (11). ***The Discovery phase****: devoted to the analysis of regional Complex Chronic Patients (CCP) management and identifying the main explicable factors for the EEG. CCP represent 4% of the population, allocated above P95 of the population-based risk stratification pyramid.* ***The Confirmation phase,*** *assessing value generation of Hospital at Home, was used to analyse the interactions between the hospital teams and community-based services, reflecting the status of vertical integration* (24). ***The final outcome*** *is the elaboration of a program for preventing unplanned hospitalizations to be tested during 2023-2024. DT: Design Thinking.*

Discovery Phase: The regional complex chronic patients' program. The process was initiated with twenty structured interviews, mean duration 45 min each, to selected representative individuals, followed by two DT sessions of 120 min duration each. The interviews were administered to five representative patients and fifteen leading health professionals (**Table 1S**).

For the patients, the interviews were structured to capture the reported experience on the following aspects: i) initiation of the acute episode, ii) emergency room admission, iii) hospitalization period; iv) follow-up after hospital discharge, v) intermediate care, if needed, vi) home-based support and services, if needed; vii) primary care services; and viii) care continuum.

For the fifteen leading professionals, the interview addressed the following items relative to CCP: i) problems associated to the identification of CCP, ii) roles and interactions among healthcare professionals in the care of CCP, iii) satisfactoriness of the current CCP management, iv) challenges, unmet actionable needs and proposals for CCP management, v) proposals to reduce unplanned hospitalizations in CCP, and v) challenges, unmet actionable needs and proposals to enhanced transitional care after hospital discharge.

Eleven leading health professionals with different profiles (nine of them also participating in the interviews) attended the two DT sessions (**Table 1S**).

The results of the interviews were processed and analysed to nourish the first DT session. The information gathered was used to generate a Context Analysis (**Figure 1S**), whereas the patients' answers were the basis for elaborating an Empathy Map (**Figure 2S**).

The second item used as input data for the first DT session was the asymmetrical results of the studies conducted in 2006 and 2015 (10,11) showing the efficacy-effectiveness gap (EEG) alluded to above.

Finally, the last input was a recent study conducted at Hospital Clinic Barcelona (HCB) (23), combining predictive modelling for mortality and early re-admissions after hospital discharge and a cluster analysis in 761 patients. The study outcomes triggered a lively debate on tailored interventions to improve the personalization of transitional care after hospital discharge. **Figure 2**, reproduced from (23), displays the main traits of the four clusters of patients identified in the study, as well as their mortality rate and use of healthcare resources after discharge. Clusters # 1 and #2 include patients with a mean age in the early seventies. It is of note that patients in cluster #2, with potentially reversible risk factors related to unhealthy lifestyles, clearly showed worse health status and poorer prognosis than those in cluster #1. Whereas individuals in clusters #3 and #4 showed a similar mean age in the mid-eighties, with high medical or social complexity, respectively. The study's results fostered the debate on service selection depending

on the patient profile, for example, home care or intermediate care programs (Clusters #3 and #4) versus community-based prevention of unplanned hospitalizations (Clusters #1 and #2).

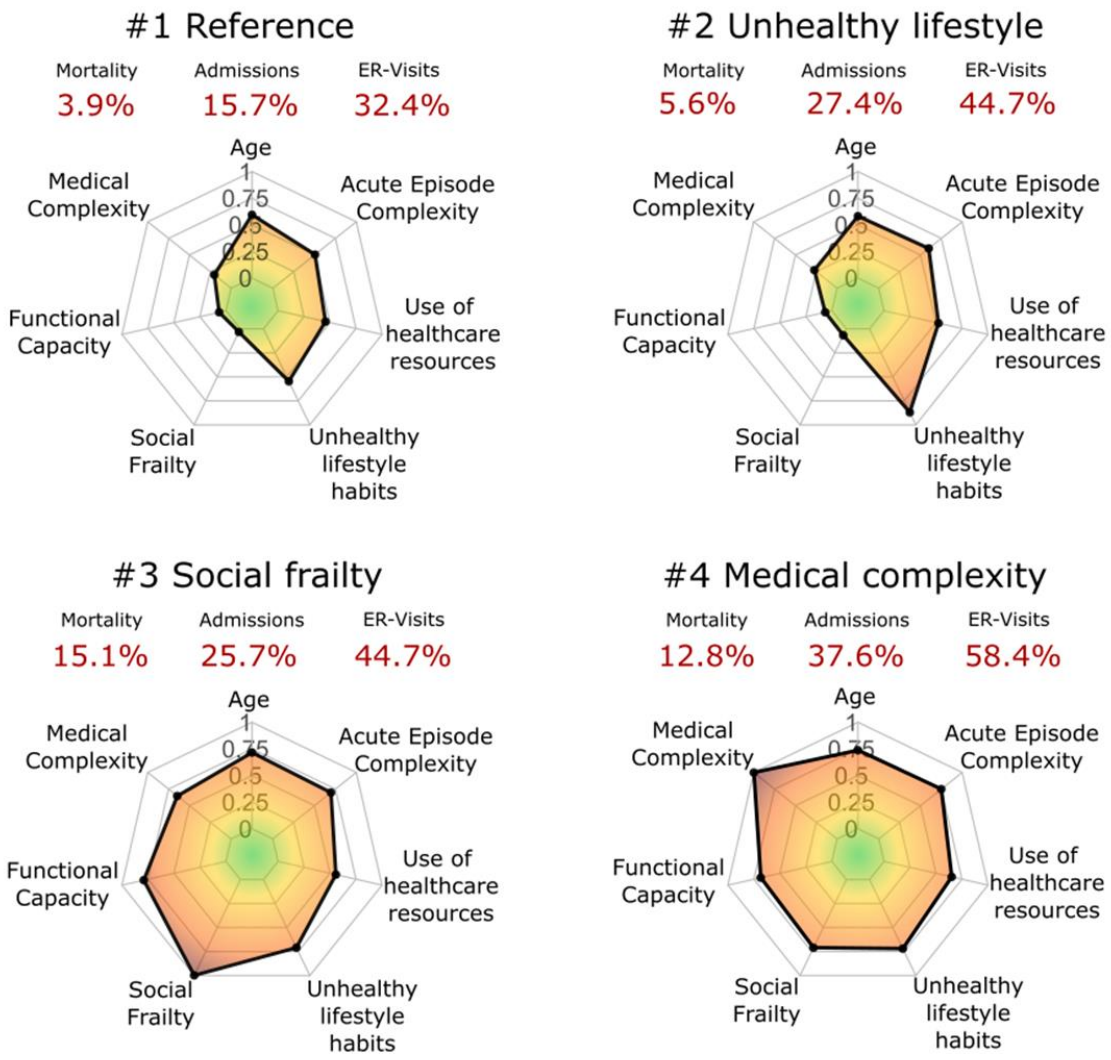

Figure 2 legend– *Radar plots of the main characteristics of the four clusters of patients identified in* (23). *All the features are normalised and grouped into seven categories: i) age; ii) medical complexity; iii) functional capacity; iv) social frailty; v) unhealthy lifestyle habits; vi) use of healthcare resources; and vii) acute episode complexity. The mortality rates, hospital admissions and emergency room visits are displayed in red.*

The first DT session was devoted to analysing the characteristics of the current regional CCP management. At the end of the first session, we performed a SWOT analysis on CCP management, as well as a summary of the results of the first DT session (**Figure 3S**), that were used to feed the second session focused on exploring actions to improve CCP outcomes within a care continuum scenario. An Impact-Feasibility Matrix (**Figure 4S)** was generated from the debate.

The Discovery phase's main results identified four actionable EEG determinants to be analysed further in the Confirmation Phase. The results of the Discovery phase support the hypothesis that an efficient program to prevent unplanned hospitalizations in selected CCP could be elaborated by properly articulating the following areas:

1. *Change management* was identified as the most relevant determinant of the EEG requiring attention for action. However, several different factors/needs were considered under the epigraph, namely: i) a better definition of the boundaries and interplay among different modalities of services depicted in **Table 1**, with emphasis on integration between health and social care services, ii) a definition of professionals' profiles and roles required for enhanced management of selected CCP to be included in a program for prevention of unplanned hospitalizations, iv) unmet specific needs in terms of education and training of those professionals, v) request for a deeper debate defining patients' profiles, including their specifics needs for cure and/or care, and vi) shared care agreements across healthcare tiers and collaborative work are not adequately supported.
2. *Personalization of the interventions –* The cluster analysis results (**Figure 2**) (23) show four different patients' profiles with specific needs for personalization of integrated care strategies. These results reinforced the need for exploring the boundaries and interplay among different modalities of clinical and social care services indicated in **Table 1**, as well as the debate on cure and/or care needs in specific groups of CCP. Moreover, the personalization in terms of the type of concurrent diseases, and disease severity, focuses on the complementarities between disease-focused *vs* patient-oriented management. Also, case management strategies to monitor the progress of the patient's status should be considered. These aspects highlight the importance of carefully selecting services and dynamically personalizing interventions over time. Moreover, such requirements have also impact on the roles of the professionals involved in the preventive program.

3. *Mature Digitalization* – Current digital support was considered not to meet the requirements for the management of CCP. The group identified the following requirements to provide scalable digitalization: i) support collaborative work with an adaptive case management (ACM) approach. By implementing ACM, integrated care processes can be designed, developed, and implemented in a way that empowers patients, clinicians, and other stakeholders, leading to improved health outcomes and better patient experiences., ii) supporting cloud-based digital health tools with an ACM approach, interoperable (ad-hoc) with existing electronic health records from different suppliers across healthcare tiers.
4. *Adoption and assessment* – The transition from evidence-based efficacy of any intervention to the demonstration of effectiveness and healthcare value generation assessed using a Triple or Quadruple Aim approach (26) was considered a must. Nevertheless, the applicability of the current assessment tools in real-world scenarios shows major limitations. As reported in (27) there is an urgent need to develop and validate applicable tools to evaluate PROMs/PREMs, or their surrogates, for mainstream interventions in real-world scenarios. Also, identifying relevant key performance indicators (KPI) and elaborating appropriate dashboards for quality assurance after service adoption were proposed as core requirements. To this end, refinement of the comprehensive evaluation approach described in (28), aiming at enhancing its applicability, was strongly recommended.

Confirmation Phase: Analysis of Post-Discharge Episodes. The assessment of value generation, and transferability, of HaH in Catalonia (ES) during the period 2015-2019 (24), carried out in the context of JADECARE, offered the opportunity to analyse a large dataset of post-discharge episodes. Also, to explore the interactions between the hospital teams and community-based services, reflecting the status of vertical integration.

Comprehensive quantitative, and qualitative, analyses were conducted on all episodes of HaH and their corresponding control group of patients under conventional hospital admissions, generated through propensity score matching techniques. A total of 49,604 episodes from 27 different hospitals were examined. The analysis included patients' characteristics, multimorbidity-complexity, use of healthcare resources and expenditure during four well-defined periods: i) one year before the acute episode, ii) during the acute episode requiring hospital admission, iii) 30-days, and iv) 90-days after hospital discharge. A large portion of the patients fell into the spectrum of CCP, as reported in (24), with no differences in health outcomes between modalities of hospitalization, either HaH or in hospital.

The outcomes of the quantitative analysis of the hospital admission episodes, and the results of a survey previously administered to a panel of seven experts in HaH, fed the debates of the two subsequent DT sessions participated by the same group of 7 experts (**Figure 1, Table 2S**). While both quantitative and qualitative analyses of value generation of HaH were reported in (24), the assessment of the post-discharge period, including the interactions between hospital and community-based professionals during transitional care period after discharge, was essentially confirmatory of the considerations raised in the Discovery phase.

Interestingly, the study showed huge heterogeneities among healthcare suppliers within the same healthcare system. The analysis of the factors behind such heterogeneities fully supported the need to consider the four actionable identified during the Discovery phase. Moreover, the two DT sessions indicated a high potential of the HaH teams to foster productive interactions between specialized professionals and community-based teams leading, to mature vertical integration.

Program for prevention of unplanned hospitalizations

The research team at HCB-IDIBAPS assumed the recommendations generated in the two-phase co-creation process (**Figure 1**) to elaborate the basis for a program aiming at preventing unplanned hospitalizations in selected CCP, described as follows.

The program's main aims of are: i) early detection and management of exacerbations, as well as early identification of undesirable events after hospital discharge, ii) patients' empowerment for self-management, and iii) shared care agreements and collaborative work across levels of care.

The profile of the target candidates for the program should fulfil the following traits: i) multimorbid outpatients with a high risk for hospital admissions because of a previous history of repeated severe exacerbations requiring admissions, ii) patients with a high morbidity burden, measured with the Adjusted Morbidity Groups (AMG) (29,30) scoring, that is, all those cases allocated in the at-risk stratum of the population risk pyramid of Catalonia (i.e. above percentile 80 of the regional AMG scoring distribution) and iii) patients not being allocated to home care or intermediate care programs depicted in **Table 1**.

The AMG score is an aggregative index based on diagnostic codes, which indicates the burden of an individual's morbid conditions through a disease-specific weighting deduced from statistical analysis based on mortality and the utilization of health services. Moreover, all hospital post-discharges with an AMG score above percentile 80 should be evaluated as potential candidates for personalized 30-days transitional care interventions.

The research team proposes three sequential phases to finetune and evaluate the program to prevent unplanned hospitalizations, facilitating its adoption as a mainstream service at the end of a two-year (2023-2025) process, including: i) Preliminary Studies, ii) Assessment of preventive interventions, and iii) Adoption as a mainstream service.

During the two years, the testing will be done in a cohort of 200 multimorbid outpatients showing two main traits: i) multimorbid individual allocated close to the tip of the ($> P_{80}$) of the

Catalan risk stratification pyramid based on the AMG scoring (29,30), and ii) having chronic obstructive pulmonary disorders of moderate to severe intensity as one of the main diagnoses. Such a cohort will be followed up for a longer period, as part of the EU project, “Knowledge for improving indoor air quality and health” (K-Health in Air) (31), aiming to explore the relationships between indoor air quality and health status in chronic patients.

Table 2 indicates the main actions, directly derived from the co-creation process, to be evaluated and subsequently incorporated into the mainstream program to prevent unplanned admissions in selected CCP.

339 **Table 2 – Actions to be included in the program for prevention of unplanned hospitalizations.**

ACTIONS	COMMENTS
1. CHANGE MANAGEMENT	
1.1. Define flexible clinical processes with a holistic approach.	Elaborate the skeleton of the clinical process considering: i) clinical endpoints, actions associated to main diagnosis and co-morbidities, as well as environmental and social factors.
1.2. Define roles and profile of the advanced care nurse	Key roles are: i) patients' empowerment for self-management, ii) care and cure actions following plans defined in 1.1, iii) early detection/management of exacerbations. Double ascription to primary care & Hospital at Home teams. Coordination with intermediate care service modalities
1.3. Integrate primary to quaternary preventions	Evolution from current focus on primary prevention to integration of all prevention levels in the management of the program candidates
1.4. Redefine interactions between nurse and patient	Initial motivational intervention followed by patient's agreements on a personalized care plan (non-pharmacological interventions). Patient's activation and empowerment following the procedures reported in (32,33)
1.5. Training programs for professionals and patients	Education/training of professionals and patients before the program initiation following the innovative approaches reported.
2. PERSONALIZATION OF THE INTERVENTIONS	
2.1 Service selection	Selection of the patient as candidate to the program or allocation into other service modalities indicated in **Table 1**
2.2. Harmonize disease- vs patient-oriented approaches.	The intervention (personalization of the clinical process) must consider the individual diseases (type, severity, and progress), as well as their potential interactions (also regarding pharmacological aspects).
2.3. Consider social and environmental factors	The holistic approach of the intervention requires consideration of the non-clinical aspects (social status, education level, environment, etc…) that may have influence on health status
2.4. Consider evolution of health status overtime	The characteristics of the intervention decided in the initial evaluation requires adaptation to the progress of the patient's condition. The balance between cure and care should be considered.
3. MATURE DIGITAL SUPPORT	
3.1. Adaptive Case Management (ACM)	Combinations of multiple factors influencing patient's health status, and unexpected events (exacerbations), requires flexible management of the clinical process which can be achieved with an ACM approach.
3.2. Communication Channel.	A communication channel based on chat (including intelligent chatbots) with multimedia support is essential to provide proactive interactions among stakeholders.
3.3. Collaborative work	Digital support to collaborative work among professionals and with patients across healthcare tiers in a must for executing share care agreements.
3.4. Capture of patient's self-tracking data	Efficient patients' input data from: i) non-disruptive sensors, ii) chat with the advanced care nurse, and/or iii) short questionnaires (with Likert scales) may play a relevant role in decision making and knowledge generation.
3.5. Ad-hoc integration	Cloud-based technologies with ad-hoc integration with providers' health information systems is the proposed approach for provision of digital support to the service.
4. APPLICABLE ASSESSMENT IN REAL-WORLD SETTINGS	
4.1. Evaluation of the process of implementation	Evolution of classical tools for assessment of the service deployment (i.e. Consolidated Framework for Implementation Research, CFIR (34)) must be adopted to enhance applicability in real-world settings.
4.2. Patient Reported Outcomes Measures (PROMS)/Patient Reported Experience (PREMS)	Role of sensor measurements (i.e., Heart Rate Variability), info from the chat and short questions (Likert scale) are candidates to substitute classical questionnaires (33,35–37).
4.3. User-profiled dashboards	Identification of Key Performance Indicators (KPI) and build-up management dashboards can contribute to service quality assurance over time.

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The initial six months, from October 2023 to March 2024, will be devoted to the evaluation of innovative strategies for patient assessment consisting of three parallel independent study protocols addressing early detection and enhanced management of acute episodes of exacerbations. The three items to be explored are, respectively: i) feasibility and impact of continuously monitoring the heart rate variability, as compared with the periodic administration of standard health questionnaires (diaries) (38), ii) the feasibility of pragmatically capturing Patient Reported Outcomes/Patient Reported Experiences (PROMS/PREMS) using mobile technology (33,35,37,39); and iii) the role of forced oscillation technique (FOT), as compared to forced spirometry (FS) (40).

The subsequent phase will consist of personalized preventive interventions, following the recommendations indicated in **Table 2**. The interventions will be run by a nurse case manager over twelve months, from April 2024 to March 2025. The nurse will have a double assignment to the primary care teams and the HaH team at HCB-IDIBAPS. The digital support to the intervention will be based on a customized version of the cloud-based ACM platform named Health Circuit™ (33). Evaluation of the effectiveness and value generation of the intervention using a Quadruple Aim approach is planned, as well as the assessment of the deployment process with a pragmatic modification of the Consolidated Framework for Implementation Research (CFIR) approach (34). The identification of Key Performance Indicators (KPI), and elaboration of a dashboard, for subsequent continuous quality assurance and management of the intervention, will be made.

The final six months, April to September 2025, will be used to adapt of the profiles of the target candidates and the program's characteristics to the requirements of mainstream service. This period will be also employed to consolidate the final steps of certification of the digital tools supporting the service.

DISCUSSION

The current integrated care case took advantage of the lessons learnt throughout the regional adoption of digitally supported integrated care guided by the two Catalan Health Plans 2011-2015 and 2016-2020 (18,19).

JADECARE (2020-2023) (9) has provided an adequate frame for critically evaluating the achievements and failures over more than one decade of adoption. Also, has prompted several quantitative assessments (23,41) that have contributed to the co-creation process.

The Discovery phase allowed a structured analysis of the unmet needs of the regional management of CCP and facilitated the identification of four actionable areas for improvement, tackling: i) organizational aspects and novel professional roles, ii) personalization of the services, iii) innovations in digital support fostering collaborative work and use of ACM principle, and iv) structured support to the assessment of the transition from a study protocol to a sustainable adoption of the intervention. It is of note that the outcomes of the Confirmation phase were fully aligned with those previously identified in the Discovery phase, confirming the role of HaH as a relevant facilitator of vertical integration.

Beyond the recommendations alluded to above, the case practice has activated the application of specific technological and organizational solutions, generating synergies with early phases of the EU project K-Health in Air (31) as a testing field of the program for the prevention of unplanned hospitalizations during 2023-2025. It is reasonably expected that, at the end of the two-year period, the finetuned interventions will be ready for adoption as a mainstream service in a real-world scenario.

The authors are cognizant of the fact that certain intricacies of the organizational solutions presented in the document may need site-specific adaptations when contemplating their applicability to other European scenarios that exhibit varying health system structures.

To our knowledge, the current study illustrates all the steps of the long journey from the necessary demonstration of evidence-based efficacy with RCT, to a sustainable adoption of the intervention, that is: i) need for assessment of effectiveness, iii) evaluation of the deployment process using implementation science methodologies, iv) assessment of healthcare value generation, and v) identification of KPI (and elaboration of user-profiled dashboards) for continuous quality assurance of the service after adoption. Since those steps are expected for most integrated care interventions, we believe that the recommendations raised by the current study are generalizable to other use cases beyond the program for preventing unplanned hospitalizations.

LESSONS LEARNED

The two-phase co-creation process has generated the following key learnings:

1. A nurse case manager in the community, can play a central role for enhanced management of CCP, also bridging with hospital-based specialists, as well as with other modalities of clinical and social care services for chronic patients.

2. Personalization of the interventions aiming at preventing unplanned hospitalizations according to: i) the evolving patient's health status, ii) the relative weight of the different patient's morbidities, as well as iii) to other determinants of frailty and complexity, constitutes a key requirement.

3. Innovative cloud-based digital support, following ACM principles, and interoperable with different health and social care suppliers, fosters more informed decisions through collaborative work and facilitates end-used engagement.

4. The underwent co-creation process has demonstrated its effectiveness as a systematic and robust pathway for identifying the key elements necessary for the intervention's transition from demonstrating evidence-based efficacy to being adopted as a value-based mainstream service. Those steps, reported in the case practice, are generalizable to other integrated care services.

5. Transferability of recommendations, for the four actionable areas, at European level is possible. But the need for site specific organizational adjustments shall be considered according to the characteristics of each health system.

CONCLUSIONS

The present study outlines the co-creation process employed to identify four crucial factors (change management, intervention personalization, advanced digitalization, and improved real-world service evaluation) influencing the observed EEG in previous studies that aimed to test an intervention for preventing unplanned hospitalizations in CCP. Based on those main determinants, the study provides recommendations for a scalable program for preventing unplanned hospitalizations targeting selected CCP and transitional care strategies after hospital discharge. Moreover, the research proposes the sequential steps to pave the way towards the adoption of the intervention as a mainstream value-based service.

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COMPETING INTERESTS

None declared.

ACRONYMS

ACM: Adaptive Case Management

ACP: Chronic conditions

AMG: Adjusted Morbidity Groups

ATDOM: Home Care

CCP: Complex chronic patients

CFIR: Consolidated Framework for Implementation Research

DT: Design-thinking

EEG: Efficacy-effectiveness gap

ESCA: Enquesta de Salut de Catalunya

EU: European Union

HaH: Hospital Care - Hospital at Home

JADECARE: The Joint Action on implementation of digitally enabled integrated person-centred care.

KPI: Key performance indicators

PADES: Palliative care

PHCs: Primary healthcare centres

PIAISS: Plan of Social and Health Interaction

RCT: Randomized controlled trial

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DISCUSSION

The research conducted to address the three specific objectives of the PhD Thesis: i) analyses of the role of HaH in a care continuum scenario, ii) developments to face the evolving needs of digital support to integrated care services, and iii) co-creation process towards prevention of unplanned hospital admission in selected CCP, was conducted within the frame of the Join Action JADECARE. This setting generated highly productive bidirectional interactions between the Catalan oGP and both the corresponding NA and the entire consortium during the project lifetime. Such interactions have, with no doubts, enriched the analyses carried out during the elaboration of the thesis. Consequently, the potential for generalization of some of the outcomes, well beyond the specificities of the use case addressed, significantly increased.

The Discussion section has been structured in the following four subheadings: i) Main findings ii) Key lessons learnt, iii) Steps toward achievement of mature digital support of integrated care services, and iv) Strategy and practicalities for the implementation of the use case. We believe that the PhD thesis has achieved relevant outcomes that support the initial hypothesis and fulfilled the key points of the three objectives.

MAIN FINDINGS

The first article assessed hospital avoidance (HaH-HA), as an integrated care service, using a Triple Aim approach; that is, taking into consideration health outcomes, patient reported outcomes (PROMs), patient reported experiences (PREMs) and operational costs. The study clearly confirmed healthcare value generation of the modality of care.

A relevant achievement of the study was the successful testing of the MCDA as a health economics instrument aiming at supporting decision making at a policy level. The MCDA combines quantifiable results (Triple Aim assessment) weighted by the opinions of different stakeholders (professionals, patients, carers, policy makers, managers). Despite the interest of the approach, we acknowledge that the instrument is still in the academic research domain.

Moreover, the practicalities of the data collection for the Triple Aim assessment of HaH-HA, in particular PROMs and PREMs clearly showed poor applicability of the questionnaires administered to patients to be used for assessing mainstream services in real-world settings, as discussed in the manuscript, and further analyzed under the subheading Lessons Learnt. It is of note that the study group analyzed in the first article corresponded to a representative

subset of the entire population of HaH-HA patients attended at HCB over one-year period (Oct 2017- Oct 2018).

The second manuscript evaluated all HaH-HA patients attended at HCB during the same period (Oct 2017-Oct 2018). In the study protocol, HaH-HA assessment, health outcomes and direct operational costs, was done using a cost-consequence analysis (CCA). The results were fully aligned with those seen in the first article. The study was highly valuable because identified the sources of savings and demonstrated a significant financial benefit generated for the provider. In summary, HaH-HA generated three types of added values for a high-tech hospital, like HCB: i) Financial savings, ii) Release of beds to be potentially used for tertiary care, and iii) fostered vertical integration.

In summary, the results of the two initial manuscripts indicate that the first objective of the PhD thesis was fully achieved.

The third article of the PhD thesis addressed two highly relevant aspects of digital health transformation, a core component of integrated care services. Firstly, the study describes the uniqueness of the Health Circuit™, a digital platform supporting an ACM approach that facilitates collaborative work across healthcare tiers, as well as patients' empowerment for self-management. Health Circuit™ also promotes a digital support fully embedded into patient-centered clinical care processes. The potential of the novel digital instrument to foster large-scale adoption of integrated care services is extensively discussed below. Besides the description of the technological platform, the article tested pre-commercial prototypes in CCP and in candidates for the prehabilitation program at HCB, respectively.

A second component to be highlighted in the article was the design of the intervention in the pilot on community-based management of CCP. In the study, the potentialities of the digital support for innovative, and productive, interactions between the nurse care manager and the patient were demonstrated. The nurse performed a comprehensive assessment of the patient's environment, and circumstances, that often contributed to enrich the clinical action plan. After a motivational interview with the patient, a refined action plan was agreed, and saved in a video, that was used for periodic follow-up of patient's adherence to the action plan. A communication channel (chat) facilitated periodic interactions between patient and the

nurse case manager. Moreover, the pilot study provided valuable information on usability and acceptability of the digital support.

Finally, the fourth manuscript of the PhD thesis describes a co-creation process aiming at elaborating a program to prevent unplanned hospital admissions in selected CCP. As described, several quantitative and qualitative studies were feeding the design-thinking sessions conducted during the study period.

This co-creation process reported in the fourth study, as well as the results of the three previous manuscripts, contributed to identify the following six intertwined facets of large-scale deployment of integrated care:

1. *HaH as an integrated care service fostering vertical integration.*
2. *Issues in the assessment of health and social care services.*
3. *Novel approaches facilitating patients' data capture.*
4. *Mature digital support in an integrated care scenario.*
5. *Steps toward successful adoption of innovative integrated care services.*
6. *Prevention of unplanned hospitalizations as use case.*

The lessons learnt in each of these six items is briefly described below.

KEY LESSONS LEARNT

HaH as an integrated care service fostering vertical integration – The Triple Aim analysis of HaH done in the first article convincingly showed that the HaH program at HCB outperformed conventional hospitalization in terms of health outcomes, PROMs and PREMs, as well as regarding cost savings. The latter was confirmed in the cost consequence analysis reported in the second article of the thesis.

The mixed-methods analysis of the regional HaH program during the period 2015-2019 (93), involving 27 different hospitals, was also confirmatory. Likewise, the 2023 OECD report on HaH confirmed healthcare value generation of HaH, identified the determinants of transferability of the modality of care and raised a warning in terms of the need for preserving equity by facilitating access to the service to socially depressed candidates and their families.

Moreover, a clear consensus was achieved in terms of health professionals' agreement on the positive impact of the different modalities of HaH favoring vertical integration. This is so

because of several factors associated to specific characteristics of the HaH professional teams, namely: i) Performing holistic evaluations, and interventions, to the patients; ii) Becoming familiar with the characteristics of patients' home and environmental determinants of patients' health, iii) Having shared responsibilities during the transitional care period, usually until 30-days after hospital discharge, and iv) Interacting with the primary care teams. This would clearly improve the care continuum of users when hospital admission is necessary. Moreover, the heterogeneities among the 27 healthcare providers observed in (93)clearly indicated that transitional care should be considered as target area in a future program for preventing unplanned hospitalizations in selected CCP. A reduction in the number of health providers would undoubtedly lead to a reduction in the fragmentation of the health sector, and this would certainly lead to better coordination results.

An ancillary result of the cost consequence analysis carried out in the second article was that HaH expenditure was clearly above the real costs of the service which constitutes a clear example of using reimbursement incentives for fostering service adoption. Since 2016, the reimbursement scheme has been successfully implemented, only for hospital avoidance, at regional level. Seven years after regional adoption of HaH is likely time for adapting reimbursement to performance assessed using user-profiled dashboards build-up based on agreed KPI.

Issues in the assessment of healthcare services. The research carried out during the study period identified several distinct challenges in the assessment of health care services, namely: i) Measurement of outcomes of specific interventions, evaluated following Triple or Quadruple Aim approaches, ii) Assessment of the impact of integrated care at health system level, iii) Evaluation of the implementation process, and, last, but not least iv) Continuous quality assurance of the intervention as mainstream service after sustainable adoption. All these four aspects were somehow considered in our analyses, despite the assessment of healthcare services was not the core area of our research. The main lessons learnt in each of these items are listed below:

i. *Assessment of outcomes of a specific intervention* – Two different unmet needs were identified. Firstly, inadequacy of the existing tools to measure PROMs and PREMs due to: i) Limitations for administering the corresponding questionnaires due to time constraints, as well as need of patients' cooperation in clinically unstable situations, ii) Poor resolution of

some questionnaires for evaluation of patients' changes overtime, and iii) Lack of validated questionnaires for multimorbidity. A second element to be considered is the methodology to be used by policy makers to support, or not, adoption of an intervention as mainstream service. In this regard, the MCDA approach used in the first manuscript seems an elegant method to be adopted by health policy makers, but we believe that some practicalities need to be solved before moving from the current academic research status to become a large-scale applicable tool. However, the debate between MCDA and other methodologies, like MAFEIP, is clearly beyond the scope of the PhD thesis.

ii. *Assessment of the impact of integrated care at health system level* – The first manuscript tested the potential of application of a Triple Aim approach to assess the impact of chronic care management at health system level, from 2011 to 2018. The study seems to indicate that with some relatively minor technical modifications at regional level, a Triple Aim assessment of adoption of integrated care is feasible.

It is of note that the research provided unexpected information on the decline of three indices reflecting quality of chronic care during the study period, partly explainable by the financial crisis. Worthy to mention that large-scale deployment of initiatives on integrated care emerged (Catalan Health Plan 2011-15) in parallel to a process of disinvestment, both structurally and in human resources. The overall health budget from 2010 onwards suffered a very significant decrease that did not recover the same figures until 2020. The government plan of the current legislature approved the creation of the State Agency for integrated social and health care.

A priority measure is to develop and to approve in the Catalan Parliament, the regulations that will enable the creation of the administrative body that will integrate Integrated Social and Health Care. At the same time, priority will be given to the operational deployment of 4 strategic lines: integrated care in geriatric homes, integrated social and health care at home, integrated social and health care in mental health and integration of social and health information systems. These priority objectives include the unavoidable strengthening of human resources dependent on primary care centers, especially primary care and community nurses dependent on primary care.

iii. *Evaluation of the implementation process* – The purpose is to identify barriers and facilitators for adoption such that the deployment process can be optimized and adapted to site specific characteristics. The CFIR (38) constitutes the most extended method to

assess an implementation process, but several problems in terms of applicability have been detected. Ongoing evolutions of the tool are being tested (38,94). However, a better standardized and simplified CFIR release, leading to improved applicability in real-world scenarios, is clearly an unmet need.

iv. *Continuous quality assurance of an intervention after adoption as mainstream service*. An extended erroneous practice is not to take into consideration a frequently observed EEG when implementing innovative healthcare interventions. Continuous quality assurance after adoption is mandatory for ensuring sustainability of healthcare value generation. To this end, identification of relevant KPI and elaboration of user-profiled dashboards for follow-up of the quality of the service is clearly needed and it should be implemented on routine basis.

Novel approaches facilitating patients' data capture. Non-disruptive, highly applicable, ways to capture patients' data during daily life activities are needed for early detection and management of exacerbations aiming at preventing unnecessary hospital admissions. Moreover, such data capture may facilitate interactions between patient and professionals, as well as constitute input information to assess performance of the interventions, as surrogates for PROMS and PREMS. During the current research, recent literature in this area was superficially scanned, providing the following conclusions: i) Non-disruptive monitoring of biological variables like heart rate, physical activity, sleep quality, stress, among others, may serve the purposes alluded to above with superior results than standard questionnaires (95) ii) Heart rate variability appears as an interesting candidate variable to be further explored (96) iii) Large variabilities, and poor reproducibility, seen in questionnaires and diaries used in clinical trials clearly indicate an unmet need in this field, iv) It is reasonable to hypothesize that really short/simple questionnaires with Likert scales may advantageously replace more academic approaches (i.e. standardized questionnaires) to capture patients' health status and experience. The integrated and common electronic health record in all primary care centers in Catalonia has proved to be an indispensable tool for clinical decision-making and continuity of care, focusing decision-making in primary care centers.

Mature digital support in an integrated care scenario. Over the last years digital health transformation has made significant progresses in several dimensions such as: imaging, electronic prescriptions, electronic health records, personal health folders, information

exchange platforms to overcome interoperability limitations, among others. However, digital tools efficiently supporting: i) Shared care arrangements across healthcare tiers, ii) Patients' empowerment for self-management, iii) Response to unplanned events, as well as iv) Personalization of care and coverage of specificities of the different providers clearly are unmet needs to be solved to achieve better engagement of health professionals and patients in a care continuum scenario.

Steps toward successful adoption of innovative integrated care services. As described in the Introduction of the PhD thesis, over the past decade major steps toward generation of evidence on healthcare efficiencies of integrated care have been done. Also, the elaboration of successful strategies for deployment and adoption of integrated care services has experienced important progresses. Issues on assessment of the services have been reported. While conceptual aspects of the assessment seem properly addressed, the major remaining challenge is an applicability issue. That is, to properly solve the transition from academic approaches of the assessment to application in real-world scenarios. We believe that the Joint Action JADECARE, and specifically the current PhD thesis, provide valuable contributions in this area. Major sequential steps for successful adoption of integrated care services are listed below.

RECOMMENDATIONS FOR THE ADOPTION OF INTEGRATED CARE SERVICES

Sustainable adoption of specific integrated care services within a care continuum ecosystem is a lengthy and complex process. However, key sequential steps, indicated below, are needed:

1. *Existing (or generating) evidence of efficacy of the innovative service.*
2. *Assessment of the maturity of the ecosystem wherein deployment is planned.*
3. *Elaboration of a complete implementation plan.*
4. *Generation of evidence of effectiveness, and cost-analysis, in the ecosystem.*
5. *Assessment of the process of implementation and identification of KPI*

Prevention of unplanned hospitalizations as use case. The topic was selected as use case of the thesis because of the following factors: i) the phenomenon generates a high burden on

health systems, ii) efficacy of a preventive intervention had been historically proven (87) and iii) a clear EEG was identified (92) as a challenge to be faced.

The outcomes of the co-creation process reported in the fourth manuscript of the PhD thesis are currently being implemented, in parallel with the deployment of the EU project K-Health in Air, following four well-defined phases (97) The strategy proposed is briefly described below.

The main objectives of K-Health in Air are: i) To explore potential relationships between indoor air quality (IAQ) and health status in highly vulnerable outpatients, ii) To identify IAQ determinants of undesirable health events, and iii) To propose preventive strategies.

MATURE DIGITAL SUPPORT

The uniqueness of the novel digital platform relies on three main characteristics: i) Clinical services structured as flexible care processes following an Adaptive Case Management (ACM) approach, including a mobile application for the patients and a back-end application for health professionals, ii) Multimedia communication channel facilitating accessibility and collaborative work, across healthcare tiers, to health professionals and patients, and iii) Cloud-based services decoupling data logics from applications facilitating flexible, on demand, modalities of interoperability with providers. In this regard, digital support is fully embedded in the care plans (**Figure 4**). Main advantages of the digital platform are:

i) The ACM approach facilitates personalization of the intervention according to multimorbidity features and/or specificities of the patients, introduction of changes in the care plan due to unexpected events or new outcomes, as well as tailoring the care plan to the specificities of the provider. The technological approach implemented in Health Circuit™ allows the introduction of the changes needed in the care plan by the clinical professionals without requiring support of specialized technical people.
ii) The multimedia channel facilitates collaborative work among the different stakeholders. It provides complementarities to the ACM approach facilitating the interactions among professionals that may sometimes have different backgrounds and/mindsets.
iii) The interoperability proposition (**Figure 5**) based on: i) Cloud-based services, and ii) Decoupling data logics and applications, using an Open EHR approach (98), has advantages in several aspects. It allows adaptation of the level of integration according to the needs of a specific setting. Provides flexibility for introduction and testing of artificial intelligence (AI)

solutions for clinical decision support and, last but not least, show high scalability of the services supported by the digital platform with important efficiencies at all levels. At this point an implicit debate opens up about the control and protection of personal data in the Open EHR. This discussion cannot be the subject of this doctoral thesis. However, in our opinion, the depositary and guarantor of control and access to health data should be, in the first place, the patient, and in the second place, his or her reference healthcare team: family doctor and family and community care nurse in primary care. The evaluation of any care process on the basis of all available indicators should be carried out from primary care.

Figure 4. Main characteristics of the novel digital platform (Health Circuit™) tested in the PhD thesis.

Source: Research group original

ADAPTIVE CASE MANAGEMENT (ACM) OF CARE PROCESSES

A care process is a structured, multidisciplinary care plan that defines the steps of patient care for a certain disease in a specific healthcare centre. Modelling care processes can improve the quality of patient care through efficient use of resources and clear responsibilities.

Compared to processes in industry, healthcare processes are more flexible as they vary for each individual patient

Furthermore, treatment processes can vary for the same disease for every provider, although they generally follow a clinical guideline.

- *ACM addresses the need to model **activities** that **depend on evolving circumstances and ad-hoc decisions** by healthcare professionals regarding a particular medical case.*
- *A **medical case** involves the care of a patient in the context of a medical history and current clinical problems.*
- ***ACM** is usually directed by a case manager, with **minimal predefined work to be performed**. As experience grows in resolving similar cases over time, a set of **common practices and care processes can be defined for managing cases** in a more rigorous and repeatable manner.*
- ***Planning at run-time** is a fundamental characteristic of case management, which implies the **selection and scheduling of specific tasks** for a case, and ad-hoc **collaboration with other healthcare professionals** on the tasks.*
- *Decisions may be triggered by **expected and unexpected events or new facts**, such as an emergency room entry or completion of certain tasks/milestones.*

In this sense, clinical guidelines should be proposed by scientific societies. And from them, clinical pathways adapted to the service portfolio of healthcare providers will emanate in each territory.

ACM allows healthcare professionals themselves to create and modify all aspects of a case at any time (including the case model)

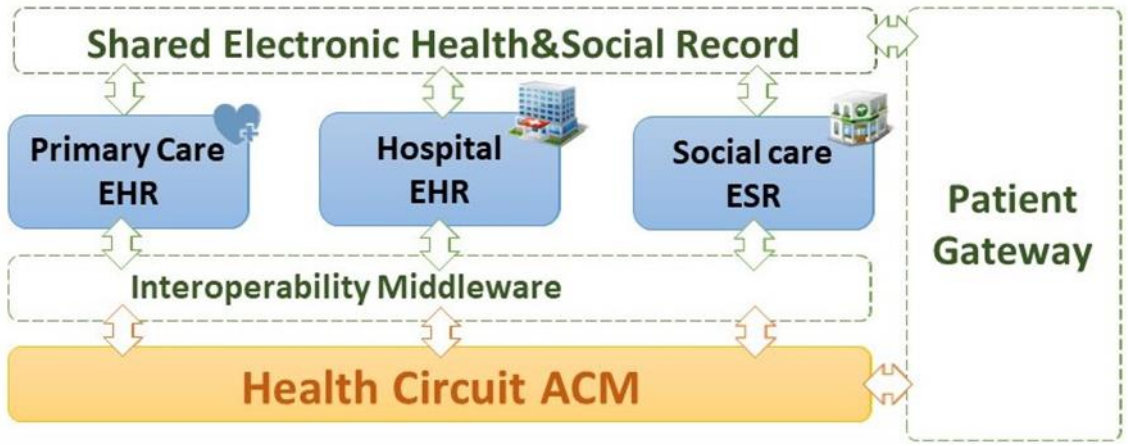

Figure 5. Health Circuit™ interoperability. The Health Circuit™, cloud-based, platform is interoperable with different health and social care providers through an interoperability middleware to be customized on demand. It is also interoperable with the patient gateway, the personal health folder.

Source: Research group original

STRATEGY FOR IMPLEMENTATION OF PREVENTION OF UNPLANNED HOSPITAL ADMISSIONS IN CCP

The final purpose of the study to be carried out in the environment of the K-Health in Air project is to generate the necessary elements to define the specificities of the program for its successful adoption in a real environment. Major issues to be addressed in the study as a result of the lessons learned are:

- Refinement of general characteristics of the preventive intervention
- Comparative analysis of sensor monitoring and questionnaires.
- Evaluation of short questionnaires (Likert scales) supported by the mHealth tool, as compared to standard questionnaires to assess PROMs and PREMs.
- Patient's education and training on early detection of exacerbations and agreement on specificities of the care plan, including the protocol for interactions between patient a nurse using the communication channel.
- Assessment of the potential for prevention of hospitalization
- Definition of the profile of the nurses taking care of the service and functionally and organizationally depend on primary care, including training needs, integration in the team and definition of the protocol to bridge with hospital-based professionals.

- Elaborate on the profile of CCP candidates for the preventive program. The initial hypothesis is that patients allocated in Clusters 1 and 2 (fourth manuscript) are the ideal candidates, whereas patients' profiles close to Clusters 3 and 4 are candidates for home-based programs.
- Definition of the boundaries, and relationship, with the different programs addressed to CCP management in the ecosystem. That is, in Catalonia, those listed in Table 1 in the fourth manuscript.
- Identification and validation of KPI required for long-term continuous quality assurance of the intervention as mainstream service.

Also, user-profiled dashboard, based on KPI identified in the previous phase, will be elaborated, and tested. The mainstream service will be addressed to two target groups: i) clinically stable high risk CCP, and ii) selected CCP after hospital discharge.

SUMMARY OF THE DISCUSSION

The three objectives of the PhD thesis were properly aligned to facilitate the identification of the six actionable areas analysed in the section, aiming at improving chronic care management.

The current research produced specific recommendations for each of those areas that should lead to enhanced adoption of integrated care, contributing to the Next Generation Medicine proposed at EU level.

Specific developments were analysed, and activated, to achieve mature digital support to healthcare services. Moreover, a detailed action plan for the use case on prevention of unplanned hospital admissions for selected complex chronic patients is already in place.

It is our understanding that the generic elements of the adoption strategy proposed, as well as some of its core elements, can be extrapolated to other innovative integrated care services.

CONCLUSIONS

1. Hospital at Home is a modality of care, with proven efficiencies and transferable across sites, that shows high potential for bridging with community-based services, efficiently contributing to foster vertical integration.

2. The core features of the technological platform developed by Health Circuit™, and tested in the current research, represent a major step toward mature digital support to healthcare services facilitating adaptive case management and collaborative work among actors across health and social care tiers.

3. The co-creation process undertaken to elaborate and evaluate an intervention for prevention of unplanned hospital admissions produced a realistic action plan for successful adoption of the intervention as a mainstream service in real-world settings. Core elements of the adoption strategy proposed can be generalized to other innovative integrated care services.

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