

# From Beds to Bytes: Assessing Telecardiology's Role in Reducing Hospitalization for Cardiovascular Care in Liguria

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Cardiovascular diseases remain a primary cause of hospitalization in Europe, with significant economic and clinical impacts. In high chronicity contexts such as Liguria, telecardiology represents a strategic turning point to transform the healthcare system. This study simulates the potential impact of telecardiology on average length of stay (LOS) and bed occupancy, using administrative data from the Italian Ministry of Health. Impact estimates at the territorial level are based on different scenarios of LOS reduction, stratified by patient type (acute and chronic) and by facility types (Integrated Hospital – IRCCS, Local Public Hospital – LHA). These scenarios, grounded in scientific evidence and weighted with data from an international clinical database, were applied to estimate the potential impact at the regional level. The results show higher complexity

and longer LOS in IRCCS hospitals (ICM = 1.12; LOS = 7.73 days) compared to LHA hospitals (ICM = 0.94; LOS = 6.25 days). The adoption of telecardiology could reduce LOS by up to 0.97 days per patient, releasing hospital beds on a regional scale.

**Keywords:** cardiovascular disease, case mix index, health policies, hospital resource utilization, length of stay, telecardiology.

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## 1. Introduction

Cardiovascular diseases (CVDs) represent one of the major causes of morbidity, rehospitalization, mortality, and disability in many countries (Luengo-Fernandez *et al.*, 2023). In 2016, they were responsible for an estimated 17.9 million deaths (31% of global mortality), and this number increased to approximately 19.8 million in 2022, equivalent to 32% of all global deaths. Of these, 85% were caused by heart attacks and strokes (Mohammadzadeh *et al.*, 2022; World Health Organization, 2021).

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These diseases also significantly impact the workforce through disability, early retirement, and absenteeism, reducing productivity and economic output. The economic costs of cardiovascular diseases in the EU increased from €169 billion in 2003 to €210 billion in 2017 (Luengo-Fernandez *et al.*, 2023).

At the national level, cardiovascular diseases remain the leading cause of death in Italy. According to the *Global Burden of Disease 2023* estimates (IHME, 2024), approximately 209,948 deaths were attributed to CVDs in 2023. The age-standardized mortality rate reached 356.5 per 100,000 inhabitants (95% uncertainty interval [UI]: 289-394), while the overall prevalence was estimated at 9.12 million cases (15,483 per 100,000 inhabitants). These figures confirm the substantial epidemiological and societal impact of cardiovascular diseases within the Italian population.

Historical data show that, between 2000 and 2022, Italy experienced a progressive decline in cardiovascular mortality, with rates decreasing from approximately 380 to 370 deaths per 100,000 inhabitants (-2.6%). This decline was particularly marked in the decade 2000-2010, reflecting advances in prevention and acute care, but was followed by a period of stabilization or slight increase between 2020 and 2022, likely related to the indirect effects of the COVID-19 pandemic on chronic disease management.

The disease burden, expressed in *Disability-Adjusted Life Years* (DALYs), also decreased from 6,380 to 5,509 per 100,000 inhabitants (-13.6%), indicating an overall improvement in survival and quality of care.

In contrast, the prevalence of cardiovascular conditions has progressively increased, from 7.25 million cases in 2000 to over 9.1 million in 2022 (+25.6%), with the prevalence rate growing from 12,787 to 15,418 per 100,000 inhabitants. This upward trend reflects population aging and advances in clinical management, which have enhanced survival while simultaneously contributing to the growing chronicity of cardiovascular disease in Italy (IHME, 2024). The overall pattern mirrors the European trend of declining mortality but growing chronicity, underscoring the need for innovative care models that can ensure sustainability and continuity of care for a progressively older and more complex patient population.

The growing chronicity and sustained healthcare demand associated with cardiovascular diseases highlight the need for innovative care delivery approaches.

In today's context, characterized by an increasing digitalization of services, telemedicine is emerging as one of the most promising innovations in the healthcare sector (Halm-Pozniak *et al.*, 2023), also contributing to improvements in the quality of cardiovascular care. According to the World Health Organization (2019), telemedicine refers to the provision of healthcare services at a distance, where communication occurs either between healthcare providers accessing clinical guidance and support, or between remote healthcare users and healthcare professionals. Rather than functioning as a separate specialty, it includes a range of healthcare services delivered through smartphones, video calls, email, wearable devices, and other communication technologies (Mohammadzadeh *et al.*,

2022). It includes various modalities such as televisit, teleconsultation, telemonitoring, and home telecare. As part of integrated digital health interventions, telemedicine also supports clinicians by facilitating access to decision-support tools and peer-to-peer consultations (WHO, 2019). While the benefits of telemedicine in terms of accessibility, continuity of care, cost-efficiency, and patient-centeredness are well documented (De Wever *et al.*, 2025), several challenges persist. These include infrastructural and technical limitations, data privacy and security concerns, and the need for adequate training and organizational support. From the patient's perspective, digital literacy, usability, and trust remain critical determinants of acceptance and sustained engagement with telemedicine services (Borges do Nascimento *et al.*, 2023). In addition, by minimizing the need for in-person visits, this approach helps avoid the risk of cross-infection while reducing the burden on both hospital infrastructure and patients (Hawrysz *et al.*, 2021).

Technological advances have also enabled real-time transmission of clinical data, facilitating timely interventions by healthcare providers in acute situations, such as myocardial infarction, arrhythmias and heart failure, and paving the way for the integration of artificial intelligence-based technologies (De Wever *et al.*, 2025).

Telemedicine represents the primary operational tool for delivering clinical services within virtual hospitals. In this paper, the term virtual hospital refers to an organizational model that delivers hospital-level care remotely through telemedicine and other digital technologies, supported by multidisciplinary clinical teams.

Among the various applications of telemedicine, telecardiology has shown particular promise in the management of chronic cardiovascular conditions. The study by Mokri *et al.* (2025) demonstrates that remote monitoring for patients with heart failure is a cost-effective intervention, with an incremental cost-effectiveness ratio (ICER) ranging between €11,000 and €13,000 per additional quality-adjusted life year (QALY). Although total lifetime costs increase when evaluated from a societal perspective, mainly due to improved survival, these costs remain within thresholds considered acceptable by European healthcare systems, typically defined according to WHO guidelines based on multiples of gross domestic product (GDP) per capita (World Health Organization, 2003). According to the European Commission's *Market Study on Telemedicine* (2018), greater adoption of telemedicine services is associated with an overall reduction in the patient care pathway, which includes consultation times and the resources used, as well as a decrease in mortality rates, accompanied by an increase in quality-adjusted life years (QALYs).

Despite growing interest and emerging evidence in support of telemedicine, regional differences in healthcare system organization, patient demographics, and resource availability highlight the need for localized studies. The Liguria region, which has both a high prevalence of chronic patients and the oldest population in Italy (Osservasalute, 2019; ISTAT, 2024), is challenged by significant pressures related to hospital admissions, length of stay, and healthcare resource use.

In 2022 and 2023, Liguria reported hospitalization rates for heart failure and acute myocardial infarction broadly consistent with national averages, though with marked subregional variability (Osservasalute, 2023; Agenas, 2024). These data confirm the sustained cardiovascular burden on regional hospitals, reflecting the region's aging population and high multimorbidity.

National data indicate that 16.3% of Italians live alone (ISTAT, 2025). Social and economic disparities, combined with a persistent digital barrier, further shape health inequalities, but at the same time highlight opportunities for telemedicine to act as a tool to bridge gaps in service delivery and promote equity (Yao *et al.*, 2022; Saeed & Masters, 2021).

However, there is a shortage of comparative studies based on clinical databases that evaluate differences in outcomes between traditional and virtual hospitals. Available evidence is mostly limited to case studies, qualitative research, or fragmented initiatives. Moreover, there are currently no publicly available standardized databases for virtual wards (Norman *et al.*, 2023; Vallée & Arutkin, 2024), which complicates objective assessment of the clinical and organizational impacts of these models.

The Ligurian context is shaped not only by organizational and policy-related aspects but, importantly, by logistical ones. The region's longitudinal East-West morphology, constrained between sea and mountains, creates structural barriers to health-care accessibility. From a geographical and social perspective, Liguria also shows a dual character: the coastal zone and the metropolitan area of

Genoa are marked by high population density and complex social dynamics, while rural and mountain areas are often disadvantaged in terms of mobility and access to services. Evidence shows that such geographical barriers already affect patient outcomes in Liguria (Di Novi *et al.*, 2020), and that inequalities in accessibility can amplify health inequities (Succi *et al.*, 2023). Our goal is to support policymakers in designing interventions that maximize impact according to institutional settings, territorial constraints, and patient needs.

## 2. Data and methods

The data used<sup>1</sup> for this analysis were obtained from an administrative dataset provided by the Italian Ministry of Health, referring to the year 2022. This dataset includes aggregated information on hospital admissions across Italian regions, with key variables such as the region, local health authority (LHA) identifiers, hospital facility codes and names, medical discipline and their corresponding specialties (e.g., Cardiology), number of patients discharged, total inpatient days, available inpatient days (capacity), number of beds by type (day hospital, day surgery, ordinary inpatient), number of available beds in use. Additional indicators include average length of stay (LOS), the case mix index (ICM), and the bed occupancy rate.

A second dataset from the Ministry of Health<sup>2</sup> (2023) was used to validate and classify each hospital facility, allowing accurate association with the appro-

<sup>1</sup> Data available from: <https://www.dati.salute.gov.it/dataset/dati-di-struttura-e-di-attivita-dei-reparti-presenti-ciascuna-struttura-di-ricovero>.

<sup>2</sup> Data available from: <https://www.salute.gov.it/new/it/banche-dati/elenco-aziende-sanitarie-locali-e-strutture-di-ricovero>.



priate facility type and ensuring structural consistency across records. The validation process was carried out by cross-checking the regional dataset on hospital activity with the official Ministry registry of healthcare facilities.

This registry contains key administrative identifiers such as 'facility code' (*codice struttura*), 'facility name' (*denominazione struttura*), 'facility type code' (*codice tipo struttura*), 'facility type description' (*descrizione tipo struttura*), and 'region name' (*Regione*).

These variables enabled accurate facility matching and classification across datasets, ensuring that each hospital in the regional file corresponded to a formally recognized facility in the Ministry registry.

The dataset was subsequently filtered to include only ordinary inpatient admissions in the cardiology discipline, selecting records with more than zero discharges, ensuring that only active units were considered, and to those with an average LOS exceeding two days. This LOS threshold excluded short-stay cases, such as day surgery and day hospital, which are generally classified as observation rather than inpatient care and are therefore not relevant for our purposes. The adopted threshold of more than two days is consistent with existing research and administrative standards, where hospitalizations of  $\leq 2$  days are typically considered short-stay or observation admissions (Janke *et al.*, 2025; Sheehy *et al.*, 2013).

This integrated dataset provides sufficient granularity to model scenarios of reduction in LOS and associated impacts on bed occupancy, based on adoption of telemedicine interventions. Reduction rates were derived

from a systematic literature review and applied as minimum, central, and maximum scenario estimates in order to simulate the potential effect of implementing virtual hospital models based on telemonitoring. Data processing and analysis were conducted with R software (version 4.3.2), by using dedicated packages for data analysis and graphical visualization.

The classification of hospital facilities was carried out using the 'facility type code' (*codice tipo struttura*) provided in the aforementioned dataset of the Italian Ministry of Health, which identifies the institutional nature and management structure of each facility. Hospitals were grouped into three main categories, in accordance with their organizational setting and role within the regional healthcare system. Table 1 summarizes the classification, including the corresponding facility type codes and descriptions for each category.

The analysis focused on the Liguria region, selecting only hospitals located within the regional territory and belonging to the categories considered<sup>3</sup>.

For each identified category, key average indicators were calculated: the average ICM, which reflects the clinical complexity and severity of patients treated, and the average LOS, representing the mean number of hospitalization days per patient.

Additionally, we used the unique 'facility code' (*codice struttura*) to identify and count distinct hospital

<sup>3</sup> In the Liguria region, the first dataset considered reports 9 cardiology hospital facilities: 7 Local Public Hospitals – LHA (6 LHA – managed hospitals and 1 Classified or Equivalent Hospital under Article 1 of Law No. 132/1968, represented by E.O. Ospedali Galliera) and 2 Integrated Hospitals – IRCCS (San Martino and Gaslini).

**Table 1** – Classification of hospital facilities by facility type code (codice tipo struttura) as defined by the Italian Ministry of Health dataset

| Category                             | Facility Type Code | Description                                                                                                                                                                                                                                                                                                                                        |
|--------------------------------------|--------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Hospitals                            | 0                  | General Hospitals identified as <i>Aziende Ospedaliere</i>                                                                                                                                                                                                                                                                                         |
| Local Public Hospital managed by LHA | 1                  | LHA-Managed Hospitals<br>( <i>Ospedale a Gestione Diretta Presidio A.S.L.</i> )                                                                                                                                                                                                                                                                    |
|                                      | 4                  | Classified or Equivalent Hospital under Article 1 of Law No. 132/1968<br>( <i>Ospedale Classificato o Assimilato ai sensi dell'articolo 1 della legge n. 132/1968</i> )                                                                                                                                                                            |
|                                      | 8                  | Qualified Institution within the LHA<br>( <i>Istituto Qualificato Presidio della A.S.L.</i> )                                                                                                                                                                                                                                                      |
| Integrated Hospital and IRCCS        | 2                  | University Hospital integrated with the National Health Service ( <i>Azienda Ospedaliera Universitaria integrata con il Servizio Sanitario Nazionale</i> );<br>Hospital companies integrated with the University and private University Polyclinics ( <i>Aziende Ospedaliere integrate con l'Università e i Policlinici Universitari privati</i> ) |
|                                      | 3                  | Public, private, and in the form of a foundation IRCCS facilities ( <i>IRCCS pubblico, IRCCS privato, IRCCS Fondazione</i> )                                                                                                                                                                                                                       |
|                                      | 9                  | Research Institutions ( <i>Enti di Ricerca</i> )                                                                                                                                                                                                                                                                                                   |
| Excluded Facilities <sup>1</sup>     | –                  | Private care homes ( <i>Casa di Cura</i> );<br>Community health centers ( <i>Casa della Salute</i> )                                                                                                                                                                                                                                               |

<sup>1</sup> In fact, they do not represent Hospital institutions with clinical and healthcare activities comparable to those of the included categories.

facilities within each category, thus presenting the actual sample size that effectively contributed to the analysis. Based on a systematic review of the literature, two scenarios were defined to estimate the potential impact of telecardiology in reducing the average LOS<sup>4</sup> (Table 2). The first, more conservative scenario assumes a limited impact, with a reduction ranging from 0% to 5%. This range reflects the expected effect among acutely unstable patients, for whom the literature generally reports small or non-significant reductions (Siddique *et al.*, 2021; Cleland *et al.*, 2005).

<sup>4</sup> We assumed that reported reductions in LOS reflect clinically appropriate discharges, consistent with international guidelines (McDonagh *et al.*, 2021), and not the result of inappropriate or non-standard discharge practices.

The second scenario estimates a greater reduction, between 10% and 15%. In such cases, structured telemonitoring programs have demonstrated substantial benefits through improved care coordination, early detection of clinical deterioration, and improved patient self-management. In some cases, literature reports reductions exceeding 20% (Huntley *et al.*, 2016; Siddique *et al.*, 2021; Scholte *et al.*, 2023; Scalvini *et al.*, 2005; Cleland *et al.*, 2005; Inglis *et al.*, 2015).

For each scenario and hospital category, the per patient reduction in hospital stay was calculated by multiplying the average LOS by the respective minimum and maximum reduction rates. In addition, a central estimate<sup>5</sup>

<sup>5</sup> Corresponding to the mean value of each range.

**Table 2** – Estimated reduction in average LOS following the adoption of telemedicine

| Patient Group | Estimated LOS Reduction | Sources                                                                                                                                                                             |
|---------------|-------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Acute         | 0%-5%, if manageable    | Siddique <i>et al.</i> , 2021; Cleland <i>et al.</i> , 2005;                                                                                                                        |
| Chronic       | 10%-15%, up to 20%      | Huntley <i>et al.</i> , 2016; Siddique <i>et al.</i> , 2021; Scholte <i>et al.</i> , 2023; Scalvini <i>et al.</i> , 2005; Cleland <i>et al.</i> , 2005; Inglis <i>et al.</i> , 2015 |

was also calculated: 2.5% for scenario 1 and 12.5% for scenario 2. These percentages were applied to the average LOS observed for each hospital type (Integrated Hospital – IRCCS, Local Public Hospital – LHA) to estimate the potential number of hospital days saved per patient.

To assess the expected impact of telecardiology on bed occupancy and resource optimization, a two-stage simulation model was developed, integrating the Italian Ministry of Health administrative database with clinical data. In the first stage, an international clinical dataset on traditional cardiology admissions was analyzed, covering the period from January 1, 2022, to July 1, 2024 (Cardiology Unit Admission, Kaggle platform)<sup>6</sup>. The dataset includes variables such as type and source of admission (e.g., Emergency Room or another hospital department), insurance coverage, patient identifier, sex, primary diagnosis, admission and discharge dates, discharge status, referring physician, and length of stay (in days). Based on the primary diagnosis, two major patient groups were identified: individuals with chronic cardiovascular conditions (e.g., chronic heart failure, hypertension, persistent arrhythmias) and those with acute, high-complexity conditions (e.g., acute myocardial

infarction, cardiogenic shock, STEMI, pericarditis). Only patients discharged after a hospital stay longer than two days were included in the analysis. The proportion of chronic and acute patients was then calculated relative to the total eligible sample. According to the hypothesis showed in the previous section, a LOS reduction 2.5% for acute patients (scenario 1), and 12.5% for chronic patients (scenario 2). These proportions were used as weights to estimate a single weighted average reduction in LOS. In the second stage, the administrative dataset from the Italian Ministry of Health was re-aggregated at the level of each Local Health Authority<sup>7</sup> in the Liguria region. The weighted average LOS reduction was then applied to the average LOS observed in each LHA. The total number of inpatient days potentially saved was subsequently used to estimate, for each LHA, the annual number of hospital beds that could be freed through the implementation of structured telecardiology programs.

Appendix A presents the formulas used to calculate the main indicators, ensuring methodological transparency and facilitating reproducibility of the analysis.

<sup>6</sup> Data available from: <https://www.kaggle.com/datasets/mansoorahmad4477/cardiology-unit-admission>.

<sup>7</sup> Hospital facilities classified as "Integrated Hospital-IRCCS" were grouped within the LHA of Genoa, to reflect the region's integrated hospital and territorial care pathway.

### 3. Results

Integrated Hospital – IRCCS showed higher clinical complexity (average ICM = 1.12) and a longer average length of stay (LOS = 7.73 days) compared to Local Public Hospital – LHA, which recorded an ICM of 0.94 and an average LOS of 6.25 days. These rates observed in Liguria slightly exceed national values, where the average ICM and LOS are 1.07 and 5.60 days for Integrated Hospital – IRCCS, and 0.89 and 6.60 days for Local Public Hospital – LHA, respectively. Table 3 reports cardiology hospitalization in Liguria, including the number of facilities analyzed by category.

Applying LOS reduction rates derived by literature on telemedicine interventions, we estimated the expected decrease in average length of stay per patient across different hospital categories. As reported in Table 4, for Integrated Hospitals – IRCCS, the

per-patient reduction ranges from 0.19 days in the worst scenario (0 – 0.39 days) to 0.97 days in the best scenario (0.77 – 1.16 days). For Local Public Hospitals – LHA, the estimated reduction is more limited, reflecting their shorter average LOS: 0.16 days (0 – 0.31) and 0.78 days (0.63 – 0.94), respectively.

By combining the length of stay reduction rates reported in the literature with the estimated patient case-mix<sup>8</sup>, a weighted average LOS reduction of approximately 5.5% was calculated. This percentage was then applied to the average LOS of each Local Health Authorities (LHAs) in the Liguria region to estimate the potential number of inpatient days saved. As shown in Figure 1, the Genoa LHA shows the greatest potential for bed savings, with about 3.76 beds freed on average per day over the year, followed by the

<sup>8</sup> 70% acute and 30% chronic.

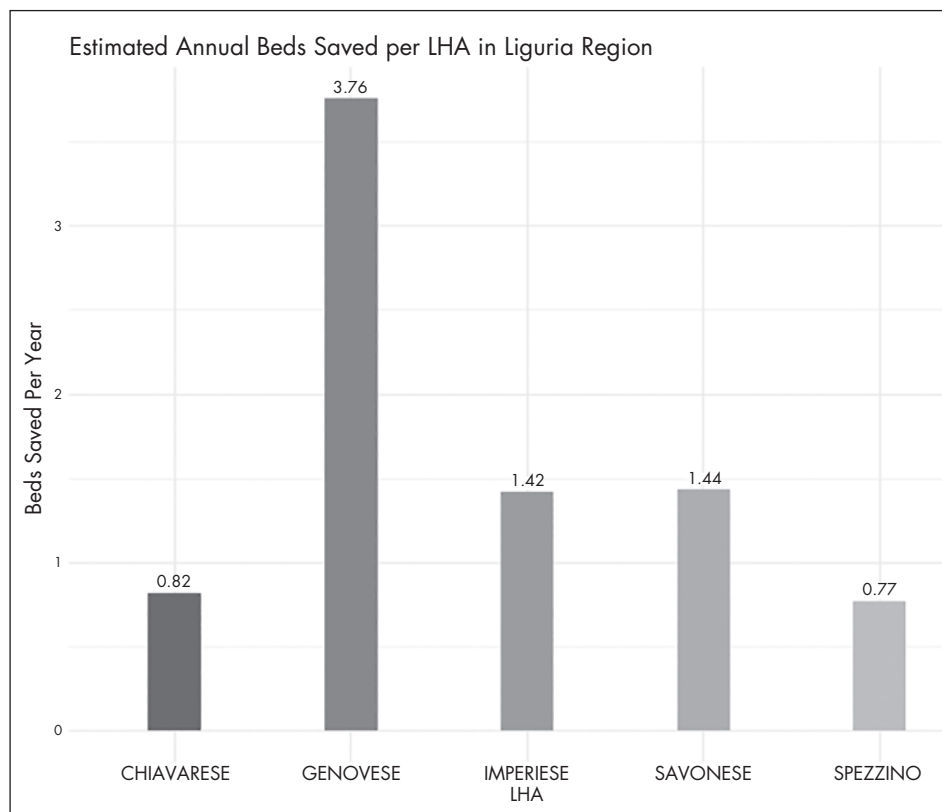
**Table 3** – Summary of hospitalization indicators by hospital category before the telemedicine intervention

| Hospital Type Code          | Average ICM | Average LOS (days) | Number of Facilities |
|-----------------------------|-------------|--------------------|----------------------|
| Integrated Hospital – IRCCS | 1.12        | 7.73               | 2                    |
| Local Public Hospital – LHA | 0.94        | 6.25               | 7                    |

**Table 4** – Estimated LOS reduction per patient (days) by hospital category and scenario after telemedicine intervention

| Hospital Type               | Scenario                      | LOS Reduction per patient (days) |
|-----------------------------|-------------------------------|----------------------------------|
| Integrated Hospital – IRCCS | Worst-case (central)<br>Range | 0.19<br>[0-0.39]                 |
|                             | Best-case (central)<br>Range  | 0.97<br>[0.77-1.16]              |
| Local Public Hospital – LHA | Worst-case (central)<br>Range | 0.16<br>[0-0.31]                 |
|                             | Best-case (central)<br>Range  | 0.78<br>[0.63-0.94]              |





**Fig. 1**  
Annual estimated bed saving  
across Liguria's LHAs

Imperia and Savona LHAs with 1.42 and 1.44 beds respectively. Lower values were observed in the Chiavari (0.82) and La Spezia (0.77) LHAs<sup>9</sup>.

#### 4. Discussion

The analysis emphasizes the differential impact that telemedicine interventions can have across hospital settings in Liguria. Both IRCCS institutions and local public hospitals managed by LHAs may benefit from reductions in LOS, but the magnitude of the reduction depends on the institutional characteristics. In particular, Integrated Hospital – IRCCS facilities display

higher clinical complexity (average ICM = 1.12) and longer lengths of stay (LOS = 7.73 days) compared to Local Public Hospitals managed by LHAs (ICM = 0.94; LOS = 6.25 days). These differences suggest that case complexity, organizational structure, and patient volume are key determinants of telemedicine effectiveness and its impact on hospital bed utilization. Since LHAs represent the majority of inpatient facilities and manage a larger patient population, they emerge as the most strategic setting for resource optimization through innovative technologies. Despite the limited per patient reductions observed in these hospitals, their higher volume and operational heterogeneity contribute to a larger overall impact.

<sup>9</sup> In percentage terms, the estimated annual beds saved by each LHA are distributed as follows: Genoa 45.8%, Savona 17.5%, Imperia 17.3%, Chiavari 10%, and La Spezia 9.4%.

These differences are also reflected in the patient mix: LHAs typically manage a higher proportion of chronic patients with lower clinical complexity, while IRCCS facilities treat a greater share of complex acute cases. Applying a weighted average LOS reduction of approximately 5.5%, based on an estimated distribution of 70% acute and 30% chronic patients, highlights the importance of stratifying telemedicine's impact by patient type. Although this distribution may not perfectly reflect the Ligurian context, it represents a conservative assumption, likely underestimating the actual potential benefits. It is important to note that the results obtained by applying the 70/30 patient mix (where IRCCS facilities were considered within their respective LHA) are consistent with those derived from an alternative calculation that, instead of stratifying by patient type, analysed LHAs and IRCCS separately (Appendix B, Table B1). In both cases, the magnitude of estimated bed savings and the relative differences between care settings remain comparable. This confirms the robustness of the estimates across different organizational models and regional contexts, and provides a solid basis for adapting telemedicine strategies to specific territorial and institutional characteristics.

The analysis also reveals significant territorial variability in potential bed savings, with the Genoa LHA recording the highest impact, while smaller LHAs show limited benefits. This also highlights logistical constraints such as population distribution and accessibility.

These differences reflect heterogeneity in service demand, demographics,

and organizational capacity, underscoring the need for context specific strategies when implementing telemedicine. From a planning perspective, the projected reductions in LOS and bed occupancy offer concrete opportunities to improve hospital efficiency and alleviate pressure on traditional services. These findings can guide targeted investments in telecardiology and digital health initiatives, contributing to the long-term sustainability of the regional healthcare system.

A key reason for prolonged LOS in traditional care pathways is the lack of structured transfer mechanisms to ensure a smooth transition between hospital and community care, particularly for patients with chronic conditions (Qi *et al.*, 2023). Telemedicine addresses this gap by supporting earlier discharge through remote monitoring, virtual consultations, and coordination between hospital and territorial providers (Suárez-Gil *et al.*, 2022). However, effective implementation also requires adequate training of local healthcare clinicians and community-based assistants. Successful adoption of telemedicine depends not only on infrastructure, but also on the ability of human resources to integrate digital tools into daily care practices (Ibrahim *et al.*, 2025; Ye *et al.*, 2023). This aligns with Italy's Ministerial Decree 77/2022, which, within the framework of Mission 6 of the National Recovery and Resilience Plan (PNRR), promotes integrated care and digital tools (e.g., Territorial Operational Centers (COTs)) as key mechanisms to facilitate care transitions and support continuity, making them core elements of a sustainable health system (European Observatory

on Health Systems and Policies, 2022; Ministero della Salute e Ministero dell'Economia e delle Finanze, 2022). Beyond these quantitative findings, several contextual factors influence the scalability of telecardiology. Among the main strengths are the formal recognition of telemedicine within the national policy framework (DM 77/2022), the availability of PNRR funds supporting digital transformation, and the established collaboration between IRCCS and LHAs, which promotes integration of hospital and community care. However, persistent weaknesses include limited digital interoperability across hospital information systems, heterogeneous workforce skills, and organizational fragmentation between hospital and territorial providers, as well as the current absence of dedicated reimbursement models for telemedicine outcomes. At the same time, the ongoing reforms introduced by Mission 6 of the PNRR offer significant opportunities for system strengthening. These include the standardization of digital platforms and the development of integrated care pathways, particularly for chronic and multimorbid patients, a population especially prevalent in Liguria. Conversely, digital inequalities among elderly populations, geographical barriers, and uncertainties regarding long-term funding represent continuing threats to large-scale implementation and equitable access to telemedicine services. These factors mirror the broader heterogeneity in service demand, demographics, and organizational capacity across the region, highlighting the need for context-specific strategies when implementing telemedicine.

Some limitations referring to our study should be considered. The reduction estimates are based on international literature and assumptions that may not fully capture local specificities. These models require validation through empirical studies, pilot interventions, and real-world data collection.

Future research should therefore explore these contextual dimensions more systematically, considering not only discharge criteria, waiting times, and the organization of territorial services, but also logistical factors such as population distribution, accessibility, and geographical barriers, which are particularly relevant in the Ligurian setting. From a policy perspective, integrating telecardiology within overall system reforms will be crucial to ensure alignment with the reorganization of territorial care and investments in human resources. A strategy that combines technological innovation, staff training, and equity considerations can help maximize the long-term sustainability and impact of telecardiology, both in Liguria and as a model for other regions.

## 5. Conclusions

This study confirms the potential of telecardiology to optimize resource use in Liguria, particularly in LHAs with lower patient complexity and higher volumes.

This aligns with national health policies, including the 2019-2021 Health Pact, which promotes the reorganization of territorial services through integrated chronic disease management models that emphasize proactive care and continuity between hospitals and the community (AGENAS, 2021).

Considering the heterogeneous performance across LHAs, telemedicine implementation should follow a gradual and focused approach, supported by investments in technology and staff development, rather than as a standalone initiative disconnected from system reforms. To maximize the clinical and organizational impact of telecardiology, it is essential that health Authorities adopt a differentiated strategy. This involves implementing large-scale programs for chronic patients within LHAs, where proactive care can contribute to significant reductions in length of stay and achieve the greatest efficiencies across the system. Meanwhile, more specialized and personalized interventions should be dedicated to IRCCS institutions, which are better suited to deliver reactive care for complex and acute cases to improve care quality and patient outcomes.

In summary, this analysis underscores the role of both healthcare delivery and system organization in shaping the effectiveness of telecardiology, and supports the development of personalized, evidence-based implementation strategies adapted to the Ligurian healthcare context. The implementation of telecardiology in Liguria should be guided by principles of adaptability, with a focus on areas where the anticipated impact is highest and in alignment with the reform priorities of the National Health System. From a policy perspective, a careful implementation of telecardiology could contribute not only to improving system efficiency and generating significant cost savings but also to reinforcing the territorial capacity to meet the growing demands of chronic cardiovascular conditions.

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## APPENDIX A. Formulas used

- Average ICM<sub>group</sub> =  $\frac{1}{N} \sum_{i=1}^N ICM_i$  where N = number of facilities in the group
- Average LOS<sub>group</sub> =  $\frac{1}{N} \sum_{i=1}^N LOS_i$
- LOS Reduction (days) = Average LOS × Reduction rate (applied separately for IRCCS and LHA facilities)
- Weighted LOS Reduction (%) = (%chronic × Reduction<sub>chronic</sub>) + (%acute × Reduction<sub>acute</sub>)
- LOS Reduction (days) = Average LOS<sub>LHA</sub> × Weighted Reduction
- Annual inpatient days saved = LOS Reduction × Annual number of admissions (per LHA)
- Beds freed =  $\frac{\text{Annual inpatient days saved}}{365}$





## APPENDIX B. Analysis of Hospital Bed Savings by Facility Type Without Patient Stratification in the Liguria Region

**Table B1** – Estimated annual hospital bed savings for two facility types in the Liguria Region (integrated Hospital – IRCCS and Local Public Hospitals managed by Local Health Authorities (LHAs)) under two impact scenarios (minimum and maximum) based on international evidence. The results were calculated without stratifying patients by clinical condition (acute vs chronic), thus providing a benchmark for comparison with stratified models

| Hospital Type               | Scenario         | Beds Saved per Year |
|-----------------------------|------------------|---------------------|
| Integrated Hospital – IRCCS | Range worst-case | [0-1.97]            |
|                             | Range best-case  | [3.94-5.91]         |
| Local Public Hospital – LHA | Range worst-case | [0-5.53]            |
|                             | Range best-case  | [11.07-16.60]       |