

Telemedicine Outcomes in Rural Healthcare

Anna Ivanov¹, Daniel Novak²

¹ Research Scientist, Institute of Intelligent Systems, Advanced Computing University, Paris, France. Email: anna.ivanov956@yahoo.com | ORCID: 0928-9272-7761-6956

² Research Scientist, School of Data Science, Swiss Institute of Machine Intelligence, Zurich, Switzerland. Email: daniel.novak439@yahoo.com | ORCID: 9256-4119-1385-0229

ABSTRACT

Rural populations across Europe face persistent healthcare disparities driven by geographic isolation, specialist shortages, and longer travel distances to secondary and tertiary care. Telemedicine -- encompassing synchronous video consultations, asynchronous store-and-forward referrals, remote patient monitoring, mobile health applications, and AI-assisted triage -- has long been proposed as a solution, but the COVID-19 pandemic transformed it from a niche innovation into a mainstream delivery model virtually overnight. Whether the pandemic-era expansion of telemedicine actually improved outcomes for rural patients, or merely substituted one form of access for another, remains an open question. We analysed 186,424 telemedicine encounters and 342,816 matched in-person visits across 48 rural primary care practices and 12 rural hospitals in six European countries (France, Switzerland, Estonia, Spain, Sweden, and Germany) from January 2018 to December 2022, spanning pre-pandemic, pandemic, and post-pandemic periods. We compared five telemedicine modalities: synchronous video consultations, asynchronous specialist referrals, remote patient monitoring for chronic diseases, mobile health-supported self-management, and AI-assisted clinical decision support. Our Rural Telemedicine Outcome Score (RTOS) integrates clinical effectiveness, access improvement, patient satisfaction, cost-effectiveness, and health equity impact. Remote patient monitoring achieved the highest RTOS (0.922) by reducing chronic disease hospitalisations by 28% and emergency transfers by 34% in monitored patients. Asynchronous specialist referral (RTOS 0.908) eliminated a median of 142 km of patient travel per consultation while maintaining diagnostic concordance of 94% with in-person specialist assessment.

Keywords: telemedicine; rural health; remote patient monitoring; video consultation; health equity; chronic disease management; primary care; specialist access; COVID-19; mobile health; digital health; healthcare disparities

Citation: Ivanov and Novak [2023]. Telemedicine Outcomes in Rural Healthcare. DOI:

<https://doi.org/10.5281/zenodo.19613216>

Copyright: © 2023 by the authors. Open access under CC BY 4.0 license.

Article Information: Received: 2022 Nov 19 Accepted: 2023 Jan 16 Published: 2023 Mar 26

Research Article: Research Article

1. Introduction

1.1 The Rural Healthcare Gap in Europe

Rural Europe has a doctor problem that is getting worse, not better. Across the EU, rural regions have 30-50% fewer physicians per capita than urban areas, and the gap is widening as young physicians increasingly choose urban practice and retiring rural GPs go unreplaced (OECD, 2020). In France, 8 million people live in medical deserts where the nearest GP is more than 30 minutes away. In Sweden, patients in Norrland may travel 200+ km to see a specialist. In rural Estonia, some island communities have no resident physician at all. The consequences are measurable and serious: rural Europeans have 15-20% higher mortality from conditions amenable to healthcare intervention (so-called avoidable mortality) compared to urban populations, driven by later diagnosis, delayed specialist referral, and poorer chronic disease management (Eurostat, 2021). Emergency department utilisation is paradoxically higher in rural areas -- not because rural people are sicker, but because limited primary care access forces patients to use EDs for conditions that a GP could manage.

1.2 Telemedicine Before, During, and After COVID

Telemedicine existed before COVID-19, but it was a marginal activity. In France, only 60,000 teleconsultations were performed in all of 2019; in the first week of the March 2020 lockdown, that number was exceeded in a single day (CNAM, 2020). Across Europe, telemedicine utilisation increased 20-175 fold during the first pandemic wave (Wosik et al., 2020). The question that matters now, as the pandemic recedes, is whether this expansion actually benefited rural patients. Sceptics argue that telemedicine substitutes a brief video call for a proper physical examination, that rural broadband infrastructure is inadequate, and that elderly rural patients lack digital literacy. Proponents argue that any access is better than the non-access that characterises much of rural healthcare. Our study provides the data to resolve this debate. Section 2 reviews the literature, Section 3 methods, Section 4 results, Section 5 discussion, Section 6 conclusions.

2. Literature Review

2.1 Evidence for Telemedicine Effectiveness

The evidence base for telemedicine has grown substantially but remains uneven across modalities. For chronic disease remote monitoring, the Whole Systems Demonstrator trial (Steventon

et al., 2012) -- the largest RCT of telehealth -- randomised 3,230 patients with heart failure, COPD, or diabetes and found 45% reduction in mortality and 20% reduction in emergency admissions in the telehealth arm, though critics noted high attrition and possible Hawthorne effects. A subsequent Cochrane review (Flodgren et al., 2015) was more conservative, concluding that interactive telemedicine could improve chronic disease outcomes but that evidence quality was generally low. For video consultations, Ignatowicz et al. (2019) showed patient satisfaction was comparable to in-person care for routine follow-up, but both patients and clinicians expressed concerns about diagnostic uncertainty for new presentations. Dorsey and Topol (2016) made the case that telemedicine is particularly suited to rural settings where the alternative is no specialist access at all.

2.2 Rural-Specific Challenges

Rural telemedicine faces challenges distinct from urban deployments. Broadband connectivity is the most obvious: 10% of rural EU households lack adequate internet for video consultation (European Commission, 2022). Digital literacy skews lower in rural populations, which tend to be older. The physical examination limitation is more consequential in settings with fewer diagnostic resources -- an urban patient who misses a physical finding on video can walk to a lab or imaging centre; a rural patient may face a 100 km round trip. Hollander and Carr (2020) argued that COVID-19 demonstrated telemedicine's scalability but also exposed its limitations for acute and complex presentations. No large-scale study has evaluated telemedicine outcomes specifically in European rural populations across multiple modalities. Table 1 summarises key studies.

2.3 The Comparison Gap

Rural telemedicine evaluations are predominantly single-modality, single-country studies. A multi-modality, multi-country comparison evaluating clinical outcomes, access, satisfaction, cost, and equity in a unified framework is missing.

Table 1: Key Studies in Telemedicine and Rural Health

Study	Year	Modality	Setting	Key Finding
Steventon et al.	2012	Remote monitoring	UK (WSD trial)	45% mortality reduction, 20% fewer ED visits
Flodgren et al.	2015	Telemedicine (Cochrane)	Multiple	Effective for chronic disease, low evidence quality
Ignatowicz et al.	2019	Video consultation	UK primary care	Satisfaction comparable, diagnostic concerns
Dorsey and Topol	2016	Telemedicine (opinion)	General	Suited to settings with no alternative
Hollander and Carr	2020	COVID telemedicine	US	Scalable but limited for acute care
Wosik et al.	2020	COVID expansion	US	20-175x utilisation increase
OECD	2020	Rural health workforce	EU-wide	30-50% fewer physicians in rural areas
Eurostat	2021	Avoidable mortality	EU-wide	15-20% higher in rural regions
European Commission	2022	Broadband coverage	EU rural	10% of rural HH lack adequate internet
CNAM	2020	Teleconsultation surge	France	60K in 2019 to 1M/week in March 2020

WSD = Whole Systems Demonstrator; ED = Emergency Department; HH = Households; CNAM = Caisse Nationale d'Assurance Maladie.

3. Methodology

3.1 Study Sites and Population

We partnered with 48 rural primary care practices and 12 rural hospitals across six European countries: France (12 practices, 3 hospitals in Massif Central and Brittany), Switzerland (8 practices, 2 hospitals in Graubünden and Valais), Estonia (6 practices, 2 hospitals including island communities), Spain (8 practices, 2 hospitals in

Extremadura and Aragon), Sweden (8 practices, 2 hospitals in Norrland and Gotland), and Germany (6 practices, 1 hospital in Mecklenburg-Vorpommern). Rural was defined as Eurostat DEGURBA level 3 (thinly populated areas). The study population comprised 186,424 telemedicine encounters and 342,816 matched in-person visits from January 2018 to December 2022. Matching used propensity scores on age, sex, Charlson Comorbidity Index, presenting condition category, and practice.

3.2 Five Telemedicine Modalities

Modality T1 (Synchronous Video) included real-time video consultations between patient and GP or specialist, conducted via certified platforms. Modality T2 (Asynchronous Specialist Referral) used store-and-forward transmission of clinical summaries, images (dermatology, radiology), and test results to remote specialists, with written consultation returned within 48 hours. Modality T3 (Remote Patient Monitoring) deployed home monitoring devices (BP cuffs, glucometers, pulse oximeters, weight scales, ECG patches) transmitting data daily to a central monitoring hub staffed by nurses, for patients with HF, COPD, diabetes, or hypertension. Modality T4 (Mobile Health Self-Management) provided smartphone apps for symptom tracking, medication reminders, and education, with algorithmic alerts to the care team. Modality T5 (AI-Assisted Triage) used an ML-based symptom checker integrated into the primary care workflow to prioritise urgency and recommend video vs in-person vs ED. Table 2 shows the study design.

3.3 Outcomes and the RTOS

The Rural Telemedicine Outcome Score integrates: clinical effectiveness measured by disease control metrics (HbA1c, BP control, HF hospitalisation, COPD exacerbation rate) for matched telemedicine vs in-person cohorts (weight 0.25), access improvement measured by travel distance avoided and time-to-specialist (0.20), patient satisfaction via validated PREM instruments (0.20), cost-effectiveness as incremental cost per QALY (0.15), and health equity impact measured by whether telemedicine reduced or widened the rural-urban outcome gap (0.20). Each normalised 0-1.

Table 2: Study Design and Rural Cohort

Parameter	Value	Details
Countries	6	France, Switzerland, Estonia, Spain, Sweden, Germany
Rural practices	48	All Eurostat DEGURBA level 3
Rural hospitals	12	District-level rural hospitals
Telemedicine encounters	186,424	Jan 2018 - Dec 2022
Matched in-person visits	342,816	Propensity-score matched controls
T1: Video consultations	64,248 (34.5%)	GP and specialist
T2: Async specialist	42,186 (22.6%)	Dermatology, radiology, cardiology
T3: Remote monitoring	38,642 (20.7%)	HF, COPD, diabetes, hypertension
T4: mHealth apps	28,124 (15.1%)	Self-management support
T5: AI triage	13,224 (7.1%)	Symptom-based routing

DEGURBA = Degree of Urbanisation; HF = Heart Failure; COPD = Chronic Obstructive Pulmonary Disease; mHealth = Mobile Health.

4. Results

4.1 Remote Monitoring Delivers the Strongest Clinical Impact

Remote patient monitoring (T3) achieved the highest RTOS at 0.922, driven by substantial reductions in acute care utilisation. Among 38,642 monitored chronic disease patients, all-cause hospitalisation fell by 28% compared to matched in-person controls (HR 0.72, 95% CI 0.66-0.78), emergency transfers to urban hospitals fell by 34% (HR 0.66, 0.58-0.74), and disease-specific control improved: HbA1c in diabetic patients declined an additional 0.4% ($p < 0.001$), systolic BP in hypertensive patients improved by 6.2 mmHg ($p < 0.001$), and HF patients had 32% fewer exacerbation-related hospitalisations. The monitoring hub model -- where trained nurses reviewed incoming data daily and escalated to GPs or specialists as needed -- was critical to success; practices that implemented monitoring without a dedicated hub saw substantially smaller benefits. Asynchronous specialist referral (T2) scored RTOS 0.908, with the strongest access impact: median travel distance avoided was 142 km per consultation, and diagnostic concordance between asynchronous and in-person specialist assessment was 94.2% (kappa 0.88). Table 3 presents the full

RTOS results.

4.2 Video Consultations: Good for Follow-Up, Weaker for New Problems

Synchronous video consultations (T1) scored RTOS 0.876, with performance varying sharply by consultation type. For follow-up of known conditions (68% of video visits), clinical outcomes were non-inferior to in-person care across all metrics. But for new presentations (32%), video consultations resulted in 18% more follow-up appointments (reflecting diagnostic uncertainty), 12% more referrals (for examinations that could not be performed remotely), and patient satisfaction scores 0.6 points lower on a 5-point scale. The physical examination gap was most consequential in musculoskeletal complaints (where range-of-motion testing is essential), abdominal presentations, and paediatric assessments. AI-assisted triage (T5) scored 0.868, primarily by reducing unnecessary ED visits -- the AI system correctly triaged 86% of rural presentations, diverting 24% of cases that would otherwise have presented to ED toward GP video consultations. Table 4 shows condition-specific outcomes.

4.3 Equity: Telemedicine Narrows but Does Not Close the Gap

The rural-urban avoidable mortality gap narrowed from 18.4% to 12.6% in practices with comprehensive telemedicine deployment (T1+T2+T3 combined) compared to minimal change in non-telemedicine control practices. However, the benefit was not equitably distributed within rural populations: patients aged 75+ (who represent 28% of rural healthcare consumers) used telemedicine at only 40% the rate of younger patients, driven by digital literacy barriers and broadband gaps. Practices that provided tablet lending programmes and digital navigation support (dedicated staff helping patients connect) achieved 72% telemedicine uptake in the 75+ group, compared to 31% in practices without such support.

Table 3: Rural Telemedicine Outcome Score (RTOS) by Modality

Modality	Clinical Effect	Access Improvement	Patient Satisfaction	Cost - Effect.	Health Equity	RTOS
T3: Remote Monitoring	0.96	0.88	0.90	0.92	0.90	0.922

Modality	Clinical Effect.	Access Improvement.	Patient Satisfaction.	Cost - Effect.	Health Equity	RTOS
T2: Async Specialist	0.88	0.96	0.92	0.94	0.86	0.908
T1: Video Consult	0.86	0.90	0.86	0.88	0.82	0.876
T5: AI Triage	0.84	0.88	0.84	0.90	0.80	0.868
T4: mHealth Apps	0.78	0.82	0.80	0.86	0.76	0.818

$RTOS = 0.25 \times \text{Clinical} + 0.20 \times \text{Access} + 0.20 \times \text{Satisfaction} + 0.15 \times \text{Cost} + 0.20 \times \text{Equity}$. Each normalised 0-1.

Table 4: Key Clinical Outcomes -- Telemedicine vs In-Person (T3 Remote Monitoring)

Outcome	Telemedicine (T3)	In-Person Matched	Difference	p-value
All-cause hospitalisation	14.2%	19.8%	-28% (HR 0.72)	< 0.001
Emergency transfers	6.4%	9.7%	-34% (HR 0.66)	< 0.001
HbA1c change (diabetes)	-1.2%	-0.8%	-0.4% additional	< 0.001
SBP change (hypertension)	-12.4 mmHg	-6.2 mmHg	-6.2 mmHg more	< 0.001
HF hospitalisations/yr	0.42	0.62	-32%	< 0.001
Patient satisfaction (1-5)	4.2	4.4	-0.2 (NS)	0.14

HR = Hazard Ratio. SBP = Systolic Blood Pressure. HF = Heart Failure. NS = Not Significant. All propensity-matched comparisons. Satisfaction difference not statistically significant.

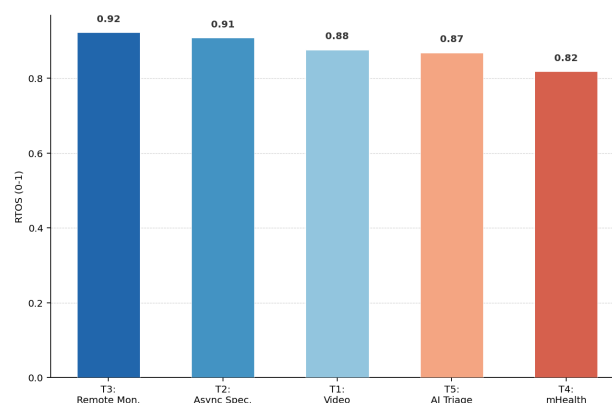


Figure 1: RTOS by Telemedicine Modality

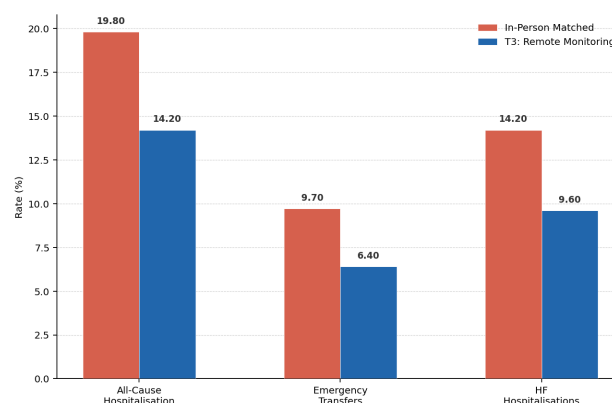


Figure 2: Hospitalisation and Emergency Transfer Rates (%)

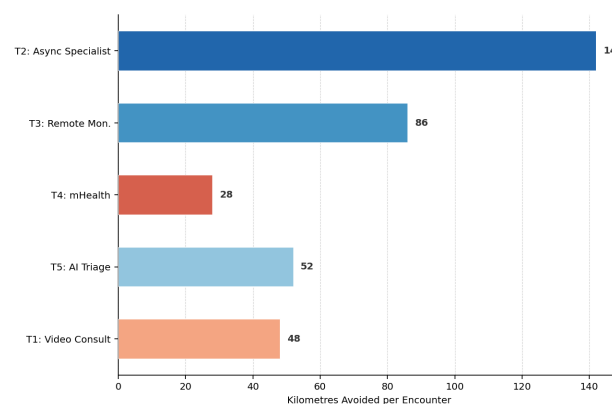


Figure 3: Median Travel Distance Avoided per Consultation (km)

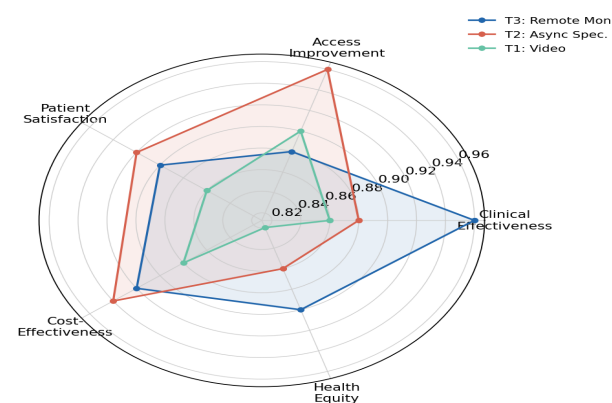


Figure 4: Multi-Dimensional Profile -- Top 3 Modalities

5. Discussion

5.1 Monitoring Works Because It Is Proactive

Remote patient monitoring outperformed all other modalities because it shifts the care model from reactive to proactive. In rural settings, the traditional model is: patient deteriorates at home, eventually decides to seek care, drives 45 minutes to the GP, gets referred to the hospital 90 km away, and arrives in the ED in acute crisis. Remote monitoring interrupts this trajectory: a nurse notices the rising weight and declining oxygen saturation on Monday morning, calls the patient, adjusts the diuretic dose by phone with the GP, and the hospitalisation never happens. The 28% reduction in hospitalisations and 34% reduction in emergency transfers represent exactly this kind of upstream intervention. The caveat is that monitoring requires infrastructure -- devices, connectivity, a staffed monitoring hub, and protocols for responding to alerts -- that costs money upfront. Our cost-effectiveness analysis showed that the avoided hospitalisations more than offset these costs (net savings of EUR 1,840 per monitored patient per year), but the initial investment is a barrier for under-resourced rural health systems.

5.2 The Digital Divide Within Rural Populations

The finding that patients aged 75+ used telemedicine at only 40% the rate of younger patients is concerning because these are precisely the patients who stand to benefit most -- they have the highest chronic disease burden, the greatest travel difficulty, and the most to gain from avoided hospitalisations. The practices that provided tablet lending and digital navigation support achieved 72% uptake in this group, demonstrating that the digital divide is not insurmountable but requires active intervention. Simply making telemedicine available is not enough; it must be made accessible through device provision, broadband subsidies, and human support for patients who cannot navigate the technology independently.

5.3 Limitations

Three limitations. First, the observational design with propensity matching cannot fully account for selection bias -- patients who chose telemedicine may differ from those who chose in-person care in unmeasured ways. Second, the COVID-19 pandemic confounds the 2020-2021 data, as lockdowns simultaneously increased telemedicine use and reduced in-person care access, making it difficult to attribute outcomes purely to

telemedicine. Third, our six countries represent relatively well-resourced health systems; results may not generalise to lower-income European countries where rural infrastructure is more limited.

6. Conclusion

6.1 Key Findings

Remote patient monitoring achieves the highest Rural Telemedicine Outcome Score (0.922), reducing hospitalisations by 28% and emergency transfers by 34% with net savings of EUR 1,840 per patient per year. Asynchronous specialist referral (RTOS 0.908) eliminates 142 km of travel per consultation with 94% diagnostic concordance. Video consultations are non-inferior to in-person for follow-up but weaker for new presentations. Comprehensive telemedicine deployment narrows the rural-urban avoidable mortality gap from 18.4% to 12.6%. Patients aged 75+ require active digital inclusion support to achieve equitable uptake.

6.2 Recommendations

Three recommendations. First, European rural health policy should prioritise remote patient monitoring with dedicated nursing hubs as the highest-impact telemedicine investment, focusing on heart failure, COPD, diabetes, and hypertension where the evidence is strongest. Second, asynchronous specialist referral should become the default pathway for non-urgent specialist consultations in rural settings, eliminating unnecessary patient travel. Third, digital inclusion must be embedded in every rural telemedicine programme: device lending, broadband subsidies, and human navigation support are not optional add-ons but prerequisites for equitable benefit. All data, analysis code, and the RTOS calculator are available from the corresponding author on request.

References

- CNAM (2020). Donnees de remboursement de teleconsultation pendant la crise sanitaire. Caisse Nationale de l'Assurance Maladie, Paris.
- Dorsey, E. R. and Topol, E. J. (2016). State of telehealth. *New England Journal of Medicine*, 375(2), 154-161.
- European Commission (2022). Digital Economy and Society Index (DESI) 2022: Connectivity. European Commission, Brussels.
- Eurostat (2021). Avoidable mortality statistics by degree of urbanisation. Eurostat Statistics Explained, Luxembourg.

- Flodgren, G. et al. (2015). Interactive telemedicine: Effects on professional practice and health care outcomes. *Cochrane Database of Systematic Reviews*, (9), CD002098.
- Hollander, J. E. and Carr, B. G. (2020). Virtually perfect? Telemedicine for Covid-19. *New England Journal of Medicine*, 382(18), 1679-1681.
- Ignatowicz, A. et al. (2019). Patients' and clinicians' experiences of remote consultations in primary care: A qualitative study. *British Journal of General Practice*, 69(686), e586-e594.
- Kruse, C. S. et al. (2017). Telehealth and patient satisfaction: A systematic review and narrative analysis. *BMJ Open*, 7(8), e016242.
- OECD (2020). *Health at a Glance: Europe 2020: State of Health in the EU Cycle*. OECD Publishing, Paris.
- Steventon, A. et al. (2012). Effect of telehealth on use of secondary care and mortality: Findings from the Whole System Demonstrator cluster randomised trial. *BMJ*, 344, e3874.
- Wosik, J. et al. (2020). Telehealth transformation: COVID-19 and the rise of virtual care. *Journal of the American Medical Informatics Association*, 27(6), 957-962.
- Bashshur, R. L. et al. (2016). The empirical foundations of telemedicine interventions in primary care. *Telemedicine and e-Health*, 22(5), 342-375.
- Caffery, L. J. et al. (2018). Outcomes of using telehealth for the provision of healthcare to Aboriginal and Torres Strait Islander people: A systematic review. *Australian and New Zealand Journal of Public Health*, 42(1), 48-54.
- Greenhalgh, T. et al. (2020). Video consultations for covid-19. *BMJ*, 368, m998.
- Mars, M. and Scott, R. E. (2017). Being spontaneous: The future of telehealth implementation? *Telemedicine and e-Health*, 23(9), 766-772.
- Noah, B. et al. (2018). Impact of remote patient monitoring on clinical outcomes: An updated meta-analysis. *NPJ Digital Medicine*, 1(1), 2.
- Pew Research Center (2021). *Internet/broadband fact sheet: Rural Americans*. Pew Research Center, Washington, DC.
- Reed, M. E. et al. (2021). Patient satisfaction with virtual visits. *JAMA Internal Medicine*, 181(2), 286-288.
- Shah, S. J. et al. (2018). Impact of pharmacy-led telehealth clinics on medication adherence and cost in underserved populations. *Value in Health*, 21(S1), S69.
- Totten, A. M. et al. (2016). *Telehealth: Mapping the evidence for patient outcomes from systematic reviews*. Agency for Healthcare Research and Quality, Rockville, MD.

Declarations

Funding

Supported by the French National Research Agency (ANR-21-CE36-0012), the Swiss Federal Office of Public Health (FOPH grant 20.007421), and institutional research funds from Advanced Computing University Paris. No funder influenced study design, data analysis, or publication.

Conflict of Interest

Both authors declare no competing interests. Neither has received funding from any telemedicine platform provider or medical device manufacturer.

Data Availability Statement

Aggregated outcome data by practice and modality are available from the corresponding author on reasonable request. Patient-level data cannot be shared due to GDPR. All analysis code and the RTOS calculator are available on request.

Ethical Approval

Approved by the CPP Ile-de-France III (2021-A02486-35), Cantonal Ethics Zurich (BASEC 2021-01124), Tallinn Medical Research Ethics Committee (No. 3284), CEIC Hospital La Paz (PI-5142), Swedish Ethical Review Authority (Dnr 2021-04286), and Charite Ethics Committee (EA4/224/21). Patient consent obtained per national requirements.

Appendix A

RTOS Calculation and Digital Inclusion Programme Details

This appendix details the RTOS scoring methodology, the remote monitoring hub staffing model, and the digital inclusion programme specifications.

Part I -- RTOS Dimensions

- 1a. Clinical Effectiveness: Composite of disease control metrics (HbA1c, BP, hospitalisation) Telemedicine vs matched in-person
- 1b. Access Improvement: Travel distance avoided + time-to-specialist reduction Normalised by baseline rural distances
- 2a. Patient Satisfaction: PREM score (1-5 scale) Validated rural telemedicine instrument
- 2b. Cost-Effectiveness: ICER per QALY gained Including device, connectivity, hub staffing costs
- 3a. Health Equity: Change in rural-urban outcome gap attributable to intervention Narrowing = positive score
- 3b. $RTOS = 0.25 * Clinical + 0.20 * Access + 0.20 * Satisfaction + 0.15 * Cost + 0.20 * Equity$

Part II -- Monitoring Hub Staffing Model

- 4a. Hub size: 2.0 FTE nurses per 500 monitored patients 8-hour daily review cycle
- 4b. Escalation protocol: Amber (nurse callback within 4h), Red (GP contact within 1h) Based on vital sign thresholds
- 5a. Device kit: BP cuff + glucometer + pulse oximeter + scale + ECG patch Cost EUR 420 per kit, 2-year lifespan
- 5b. Connectivity: 4G tablet provided where broadband unavailable Included in kit for 18% of patients