Development of an individual-level microsimulation model to assess the cost consequence of integrated cardiovascular-renal-metabolic screening policies from national payer and societal perspectives

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Introduction/Objectives

Cardiovascular, renal, and metabolic (CVRM) diseases are **interconnected conditions that share common risk factors and pathophysiology i**nterconnected conditions that collectively impose a major burden on health systems.

Despite clinical interdependence, current screening policies are often developed in isolation, potentially limiting overall effectiveness.

This study aimed to develop an individual-level microsimulation model to estimate the cost-consequence of integrated CVRM screening policies from both national payer and societal perspectives.

Methods: (see figures)

Design, population, progression

Microsimulation (Excel®/VBA); closed cohort; annual cycles; 20-year horizon; United Kingdom (UK)/France (FR)/Germany (DE)/Australia (AU). Tracks HTN, CKD, T2D, HF, obesity, DLD; MI/stroke. Baseline 16,000 adults/country; fixed seed; age/sex matched; biomarkers/comorbidities from calibrated distributions; calibrated to prevalence and longitudinal targets. Progression/events from validated, time-updated risk equations; multi-year risks → annual probabilities; CKD staged progression and ESKD pathways.

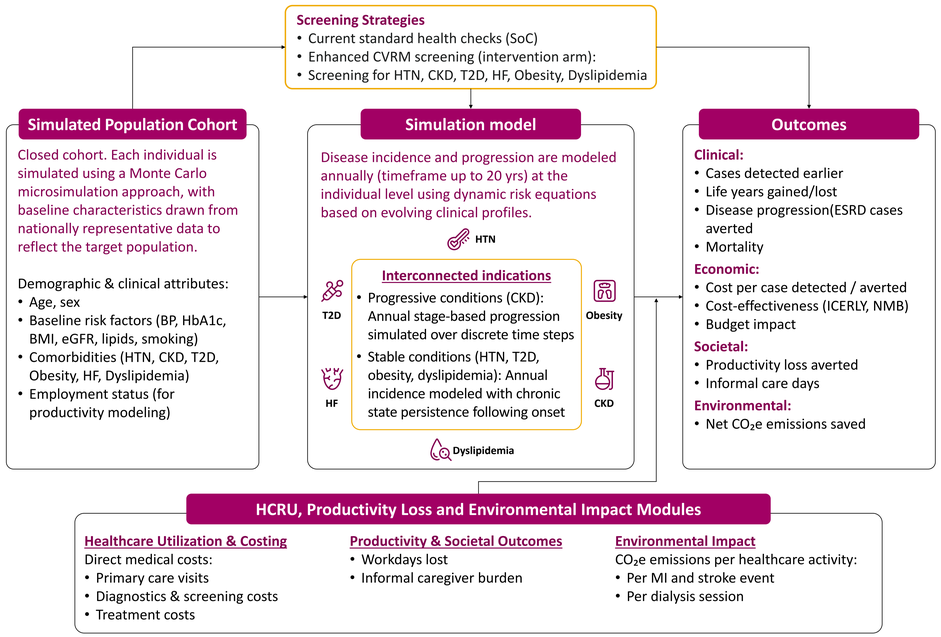
See: "Conceptual Structure of the Integrated CVRM Microsimulation" and "Key Drivers of the CVRM Microsimulation Model" figures.

Screening, treatment, outcomes, analysis

Comparator: enhanced CVRM screening vs country SoC; enhanced: q3y ages 35–74; HF screening in at-risk age ≥50 (NT-proBNP); test accuracy from literature; screen+confirm workflow; false positives cleared. SoC: UK NHS Health Check (q5y; ~9% annual completion; excludes most with prior CVRM Dx), Germany Check-up 35 (q3y; ~34% uptake), FR/AU opportunistic detection. Post-diagnosis treatment initiation 80.04% (standardized); targets via covariate updates. Outcomes: events, CKD/ESKD, costs (2024; direct+productivity), healthcare CO_2e; discounted per guidance. Scenarios + DSA (±20%); validation vs benchmarks.

See: "Population, Intervention, Comparator, Outcomes Framework" and "Gold Standard for CVRM Screening" figures.

Conceptual Structure of the Integrated CVRM Microsimulation



Patient-level annual-cycle model: screening → diagnosis/treatment → CV events and CKD progression (incl. ESKD pathways).

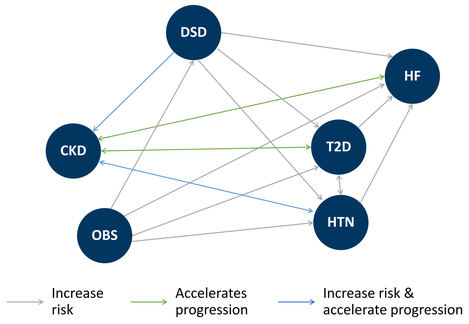
Population, Intervention, Comparator, Outcomes Framework

Microsimulation Model PICOs framework

P	I	C	O
Population Adults eligible for heart health screening in the UK, Germany, France and Australia, including individuals with varied risk profiles and comorbidities	**Intervention** Enhanced heart health screening programme following a global gold standard including optimized diagnostic testing and testing frequency, refined eligibility criteria (i.e., based on risk profile) and enhanced policy implementation (i.e., increase in uptake rates and adherence)	**Comparator** Current SoC provided heart health conditions screening that might deviate from the global gold standard	**Outcomes** Clinical - cases detected, life years gained, deaths averted Economic - direct healthcare costs, budget impact Societal - productivity loss, informal care Environmental - CO_2e emissions saved

Study framework comparing enhanced CVRM screening versus country SoC (UK/FR/DE/AU) for clinical events, costs, and healthcare CO_2e: Carbon Dioxide Equivalent: SoC: Standard Care.

Cardiovascular, Renal, Metabolic Disease Associations



Note: Dyslipidemia DSD; Heart Failure HF; Chronic Kidney Disease CKD; Type 2 Diabetes T2D; Obesity OBS; Hypertension HTN; Illustrates shared pathways linking cardiometabolic conditions to MI and stroke, supporting integrated CVRM modelling

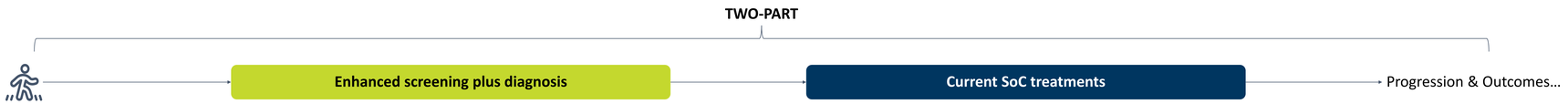
Key Drivers Components of the CVRM Microsimulation Model

The four key components of the model

Disease Progression and Interaction Model	Screening and Intervention Model	Healthcare Utilization and Cost	Societal and Environmental Impact
Simulates annual incidence and **progression of six** CVRM **related conditions** (HTN, T2D, HF, CKD, Obesity, Dyslipidemia) using dynamic **risk equations** that evolves with individual patient profiles.	Compares standard health checks with **enhanced CVRM screening** by varying condition coverage, **additional testing**, **screening frequency**, and **eligible age groups**.	Calculates the direct medical resource use and costs across primary care, diagnostics, hospitalizations **(general and ICU)** and dialysis based on modeled patient.	Assesses **productivity loss**, **informal care**, and **CO_2e** emissions tied to **healthcare utilization** under each scenario.
Supports realistic, tracking of multimorbidity and cumulative disease burden over time.	**Quantifies the health and economic value of enhanced screening programs versus current practice.**	**Translates clinical outcomes into cost and budget-impact estimates for payer decision-making.**	**Extends the framework to societal and environmental areas, informing equity and sustainability-oriented policies.**

CVRM Screening Standard Applied in Model

Standard Screening Applied in Model



Eligible population
- 35-80 yrs old
- Undiagnosed, healthy or diagnosed with one of the six conditions screened for

Eligible population
- Screening is available to all eligible every 3 years
- Uptake same as control (sensitivity analyses to be implemented varying uptake probability levels)

Eligible population
- Blood pressure
- Blood cholesterol
- Finger prick test (HbA1c)
- Serum creatinine (eGFR)
- Urinary Albumin to Creatinine ratio (uACR)
- NT-proBNP testing (at risk of HF over 50 yrs old)

Results

- The model simulates disease trajectories across six CVRM conditions (Figure Cardiovascular, Renal, Metabolic Disease Associations), estimating annual and lifetime health outcomes, healthcare utilization, and costs under alternative screening scenarios compared to Gold Standard the proposed CVRM Screening Model (Figure CVRM Screening Applied in Model).
- Comparative analyses estimate that integrated CVRM screening strategies are associated with improved health outcomes and potential long-term cost savings when compared to single-condition screening approachesa **non-holistic screening approach**.
- Results additionally support the assessment of return on investment and broader societal impacts across national health system contexts

Conclusions

- This novel economic model provides a robust framework for evaluating combined CVRM screening policies and their economic implications compared to standard screening in four countries.
- By integrating expert input and literature-based evidence, it informs national screening strategy design, supports resource allocation decisions, and enhances population health outcomes.
- Future applications include scenario testing for emerging screening technologies and evolving policy priorities.

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