# In Sickness and In Health:
## Motivating Improved Healthcare Using Holistic Patient Contracts

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**Abstract**

Using a system-wide experiment in Estonia, this paper examines the impacts of family doctors writing an explicit contract with at-risk patients for increased holistic primary care. We tracked healthcare utilization, diagnosis, prescription, hospitalization, and mortality outcomes through the universe of patient records. The intervention was designed to shift the relational contract between the two parties away from episodic curative care and towards a holistic plan for patient welfare. The program caused increased screening, diagnosis and treatment of chronic health issues among enrolled patients by about 10%. For doctor-identified "mild-risk" patients, we observed causal two-year reductions in all-cause mortality of 40%.

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# 1 Introduction

Effective primary healthcare requires high-quality curative care, but as the global burden of non-communicable diseases grows, it increasingly requires the effective identification and treatment of underlying long-term health issues between acute care episodes (Nishtar et al., 2018). A key element of the implicit contract in much healthcare has been the responsiveness of healthcare providers to patient signals of acute ill-health. A well-known problem that this creates is the lack of attention to prevention of disease (Chandra, Cutler and Song, 2011; Cutler and Zeckhauser, 2000).[1] Inadequate prevention leads to worse health for patients and higher costs and foregone economic benefits for society, yet it remains neglected by multiple actors within the health system.[2]

One strand of the health economics literature focuses on strengthening health systems by using explicit contracts between health system purchasers and health providers (Hanson et al., 2022; de Walque and Kandpal, 2022). However, these approaches overlook the relational contracting that takes place between doctors and patients themselves. This doctor-patient relationship is critical because, in many health domains, timely identification and management of underlying health issues requires a more personal and structured understanding of an individual patient's overall health, with optimal treatment beginning before a patient raises acute symptomatic concerns or even experiences notable discomfort.[3] The joint development of an explicit contract for proactive 'holistic' care between doctors and patients may encourage more effective communication, planning and prevention, including greater

[1]Patients covered by health insurance may underinvest in prevention since they do not bear the full financial costs of future treatment (Cutler and Zeckhauser, 2000; Zweifel and Manning, 2000; Fang and Gavazza, 2011; Zhou et al., 2017). Providers may neglect prevention if they are compensated more for curative procedures than for preventive actions (Chandra, Cutler and Song, 2011; Alexander, 2020).

[2]Policymakers seek to avoid this neglect of prevention in several ways. First, primary care providers may be compensated in ways which shift focus away from curative care, such as capitation, or may be directly incentivized, such as through quality bonuses, to provide specific preventive services (Kane et al., 2004; Town et al., 2005). Intermediaries such as insurance companies or health maintenance organizations may also be financially incentivized to prioritize prevention in their patient population through per patient rather than per procedure payment or reimbursement schemes. However, despite these efforts healthcare systems continue to significantly underprovide prevention services (Hanson et al., 2022), and more broadly allocate care across patients inefficiently (Chandra and Staiger, 2020).

[3]Recent evidence has emphasized the importance of the quality of service delivery by health providers (Das and Hammer, 2005; Doyle, Ewer and Wagner, 2010; Currie and MacLeod, 2017; Chen, 2021; Card, Fenizia and Silver, 2023; Das and Do, 2023; Posso, Saravia and Tamayo, 2024), specifically in the areas of effective doctor-patient communication (Freimuth and Quinn, 2004; Schoenthaler et al., 2012; Young et al., 2017; Becker et al., 2021), diagnosis (Abaluck et al., 2016; Currie and MacLeod, 2020; Chan, Gentzkow and Yu, 2022; Conner et al., 2022), and supporting patient adherence to relevant prescription medications (Iizuka, 2012; Curtis et al., 2013; Koulayev, Simeonova and Skipper, 2017; Simeonova, Skipper and Thingholm, 2024).

screening and treatment, before a patient would self-identify as being in acute ill-health.

High-quality evidence on experimental and causal interventions to stimulate these behaviors is scarce, however (Rowe et al., 2018). This paper fills that gap with a uniquely situated, large-scale experimental evaluation of explicit provider-patient 'care plan' contracts for more holistic primary care. For this study, we worked with the single-payer Estonian Health Insurance Fund (EHIF) to randomly enroll at-risk patients at participating primary care clinics nationwide. This setting has several unique advantages. First, as a single-payer system, we observe the entire eligible population of primary care providers and the entire care-seeking population. Second, the providers are private for-profit entities and are therefore behaviorally responsive, in addition to maintaining complete billing records of care activities. Third, in the Estonian context, people register with family doctors and there is close to no patient movement or selection across providers; and these physicians are regulated to have roughly similarly-sized patient populations.

As a result, we were able to randomize clinic enrollment offers in a first stage, ultimately enrolling 56 of 410 eligible clinics and 72 of 785 eligible doctors nationwide. In a second stage, we randomized patient enrollment *within* clinics, assigning 1,781 of these providers' 5,056 eligible patients to treatment and the rest to control, producing internally and externally valid estimates of the program impact. At the core of this "Enhanced Care Management" (ECM) intervention, chronically-ill patients were identified through national insurance records. During the program, they and their doctors would fill out a contract 'care plan' template together, identifying key themes in the patient's health and agreeing on proactive areas of action to be taken by both parties. They would then have regular check-ins on progress towards the commitments they made in the contract.[4]

The ECM program thereby attempts to shift patient care from an implicit 'reactive' focus on salient ailments to an explicit contract between the patient and doctor based on a forward-looking and broader 'holistic' conception of welfare of the patient (Kurowski et al., 2017). This has dual potential effects on the relationship between doctors and their patients, analogous to the "twin problems of clarity and credibility" at the core of relational contracting (Gibbons and Henderson, 2011). First, it widens the lens of focus during medical consulta-

[4]The intervention evaluated in this paper relates to medical research on 'patient contracts' and to a lesser extent on 'shared decision-making' processes. Reviews of the associated research within medicine have typically concluded that existing evaluations are small-scale and provide insufficient measurement to effectively evaluate the impacts of such interventions Bosch-Capblanch et al. (2007); Desroches (2010); Gallagher et al. (2022); Montori et al. (2023). As such, this paper builds on the nascent work on related ideas in the medical literature.

tions to a more extensive set of domains of patient health, similar to parties working through a comprehensive set of contract stipulations. Second, explicitly writing down a care plan helps to organize and to some extent strengthen the accountability regime across both sides of the patient-doctor relationship. However, no system of formal accountability was put in place to punish deviation from the care plan by either the doctor or the patient.[5] Rather, the care plan intervention attempts to use the process of contracting to shift the relationship of doctor and patient, investigating how changes in relational contracting affect healthcare provision and patient outcomes (Blader et al., 2015; Blader, Claudine and Prat, 2019; Cuevas and Zuñiga, 2021; Macchiavello, 2022; Macchiavello and Morjaria, 2023; Simeonova, Skipper and Thingholm, 2024). As such, this paper explores the intersection of how innovations in (relational) contracting affect economic behaviors, and an understanding of how contracting in healthcare interactions determines patient outcomes.[6]

Using the universe of Estonian national health insurance records, which cover 95% of the population (Habicht et al., 2023), we are able to track the impacts of the program through screening and treatment channels to impacts on hospitalization and two-year all-cause mortality. By precisely tracking the content of care, especially screening, diagnoses, and prescriptions, we are able to identify significant changes in the care provided by doctors in response to program enrollment. These changes are especially notable given that the intervention targeted patients who were already heavy users of the health system. The share of ECM patients receiving core diagnostic tests is 3 to 5 percentage points higher than for control patients at the same clinics. This leads to corresponding increases in diagnosed conditions and prescription provision. For ECM patients, formal diagnosis of heart failure increases by 10% (+3p.p.); hyperlipidemia by 25% (+10p.p.); and overweight by 40% (+6p.p). Similar results are observed for prescriptions for key chronic conditions. Additionally, by comparing control patients at treated clinics with patients at clinics that were randomized out of treatment, we identify positive spillovers on control patient care within treated clinics and we rule out effort reallocation as an effect channel. As such, we argue that the within-clinic estimates are a lower bound on total treatment effects. The spillovers also hint at mechanisms for our effects, with both knowledge gains in effective treatment approaches for the doctor and direct impacts of writing the care plan playing a role.

[5]Since patient welfare is unpredictable and influenced by numerous factors beyond the scope of the healthcare system, there are severe limits on top down forms of provider accountability for holistic care for patient outcomes.

[6]The intervention is analogous to a management intervention, the most comparable of which in a medical setting is the application of checklists in relational contracting settings (Bosk et al., 2009; Singer and Vogus, 2013; Jackson and Schneider, 2015; Semrau et al., 2017; Martinez et al., 2020; Tietschert et al., 2024).

We then assess the downstream impacts on health outcomes of ECM patients. We focus on hospitalization and mortality as the most significant health events. For ECM-assigned patients, the incidence of any inpatient hospitalization declined by 2.1 percentage points over the period, or an eight-percent decline relative to a control risk of 25.5%. Leveraging our stratified randomization based on each doctor's assessment of whether a patient's risk level corresponded to their being 'mild to moderately ill' or 'severely ill', we are further able to assess health outcomes for both groups separately. We find reductions in hospitalization for both groups. However, we detect reductions in mortality for mild-risk patients only, with severe-risk patients closely tracking the mortality rates of control patients. The reductions in mortality for mild-risk patients are substantial: We estimate a 40% decline ($-1.3$ percentage points against a control risk of 3.2%). We interpret these results as ECM generating a better overall quality of life for patients, but with a limited ability to extend lifespan for patients whose health was already severely compromised.

These sizable impacts indicate the potential power of restructuring relational contracts within healthcare. As the global community makes further progress on reducing infectious diseases and other drivers of premature mortality, non-communicable or 'chronic' diseases such as diabetes, hypertension, and cardiovascular diseases have come to account for over 70% of deaths worldwide (WHO, 2020).[7] These shifts in population health imply major new demands on the health system, as patients with multiple chronic conditions typically require more care, from multiple levels of the health system, over extended periods of time. Yet in many countries, primary health systems are not well-prepared to face these challenges. The results from ECM hint at a more proactive and comprehensive primary care model for complex patients founded in relational contracting approaches.

The rest of the paper is organized as follows. Section 2 presents a conceptual framework for

[7]Noncommunicable diseases, also known as chronic diseases, are broadly defined as health conditions or diseases that are of long duration (for example, lasting 1 year or more) and require ongoing medical attention or limit activities of daily living or both. WHO (2023) states that roughly three-quarters of all global fatalities are due to non-communicable diseases, and this proportion is rising. High and middle income countries in particular have faced rapidly rising burdens of chronic disease, including as improving social conditions and advanced medical treatments enable populations to survive into old age. In these populations, co-occurrence of multiple chronic illness, also known as multi-morbidity, is also growing. For example, 60% of the adult population in the US and over 91% of the population above the age of 65 have two or more morbidities (King, Xiang and Pilkerton, 2018), while in the European Union (EU), 20-40% of the population have been diagnosed with at least one chronic illness, of which 25-50% have multiple chronic conditions (Rijken et al., 2014). In the case of Estonia, hypertension is the most common illness for the oldest age cohorts, followed by chronic pain associated with arthritis (Jürisson et al., 2021). This rise in multi-morbidity is in part a result of population aging, and can lead to premature mortality, high expenditure on inpatient and ambulatory services, and reduced functionality and quality of life (Van den Akker et al., 1998; Walker, 2007; Gijsen et al., 2001).

differentiating between reactive and holistic approaches to patient care. Section 3 provides background to the setting, care plan intervention, and RCT design. Section 4 lays out the data and analytical approach used. Section 5 presents the results, and Section 6 concludes with a discussion of the implications of our findings.

# 2 A conceptual model of holistic versus reactive care

A simple conceptual framework illustrates the approach of holistic care programs, the full exposition of which is provided in the Appendix. A vector of stochastic latent variables, $h_{ki}$, characterize patient $i$'s health across each of $k$ domains. Optimally, for any health domain, treatment should begin at $h_k < h_k^*$. Patients only observe stochastic realisations of $h_{ki}$. At threshold $E[h_{ki}] < \hat{h_k}$, a patient identifies that their health level requires treatment independent of a doctor's diagnostic test. For a cost, $c$, a doctor can run a diagnostic test to assess the true value of $h_{ki}$. The doctor must choose when to invest $c$ into a diagnostic test.

In reactive care, suppose the doctor assigns the ex-ante value (before diagnostic tests) of $h_{ki}$ to the population average. In most domains, $E[h_k] > h_k^*$, and the average member of the population does not need treatment. Doctors wait for patients to signal that $h_k < h_k^*$, which happens when $E[h_k] < \hat{h_k}$. However, this is a sub-optimal level of treatment for the population. The issue in this case is that without further information the doctor does not know who in the population should be targeted for costly diagnostic tests. As a result, doctors make systematic errors in test targeting (Mullainathan and Obermeyer, 2022). The social costs of this sub-optimal treatment are borne by the patient and wider society rather than by any individual doctor.

Care plans, or relational contracts, motivate doctors to invest $c$ in diagnostics for more patients for three reasons. The first is that communication to fill in the broad range of stipulations that must be covered in the contract act as a new technology for efficiently generating a patient profile. The characteristics of that profile, $x$, allow the doctor to identify more precisely when $E[h_k|x] < h_k^*$. Second, the repeated interactions of doctor and patient allow both actors to relationally 'punish' the other when they deviate from agreements over stipulations, leading to a broader set of potential outcomes of any strategic game. This incentivizes the doctor to invest more in diagnostics for a particular patient, and for the patient to adhere to any treatment recommendations.

The concept behind holistic care plans is that by incentivizing primary care doctors and

teams to increase their engagement with and testing of patients, those individuals whose health is in the $\hat{h_k} < h_k < h_k^*$ bracket can be more effectively identified and appropriate treatment initiated. This logic is of particular relevance for domains for which $h_k^* - \hat{h_k}$ is 'large'; for example, in the case of pre-diabetes (Davidson et al., 2021). It is in this case that the information value of a diagnostic test is most valuable since patient experience and therefore patient signals are a poor predictor of the distance of true health to $h_k^*$.

Similarly, at higher levels of health within a domain, treatment may be cheaper and more effective, implying a curvature in $h_{ki}$ functions that underlines the utility of early detection. There may be less need for secondary and tertiary services such as (avoidable) inpatient hospital admissions and re-admissions, and ambulatory specialist services. And by definition, by initiating treatment before health status falls further, patients will experience better health and associated higher quality of life.

# 3 Estonian health system context and the ECM intervention

## 3.1 The Estonian health system

Estonia's 1.3 million people have a life expectancy close to the European average, though with significant inequality in health outcomes (OECD, 2021). For example, men die 8.5 years earlier than women; the third largest gender gap in life expectancy in Europe. Similarly, there are wide variations across regions, localities and households in disease burden. As in many countries, Estonia has an increasing prevalence of non-communicable disease. 50% of the population has at least one chronic illness, and multi-morbidity is a growing problem, with 71% of over 45-year olds having more than one chronic illness (World Bank, 2015). The Estonian government has estimated that chronic disease accounts for more than 40% of the loss in total disability adjusted life years (DALYs) in the country (University of Tartu, 2004).

Estonia's health system is based on a national single-payer insurance model anchored in the independent Estonian Health Insurance Fund (EHIF). EHIF's mandate and insurance model covers virtually the whole of the population and is funded through the country's social health insurance system (Sotsiaalministeerium, 2012).[8] Primary care is provided by approximately

[8] Approximately 1.5% of the population are not registered within the EHIF system.

800 independent private for-profit family doctors who contract directly with EHIF (Atun et al., 2016), roughly 70% of whom work in a solo practice clinic (Kurowski et al., 2015). All Estonians covered by EHIF are assigned to a private family doctor. Having reformed its Soviet-era model of primary healthcare to one based on private family doctors, national healthcare policy works through EHIF's requests of, and reimbursements to, these private clinics (Habicht, Kasekamp and Webb, 2023).[9]

Much healthcare in Estonia is free at point-of-use for patients covered by EHIF's insurance, or requires a minimal co-pay. Doctors are primarily paid by EHIF through a combination of a base allowance (13% of provider income in 2021), annual capitation fees per patient (€5-11 per person, 48%), and fees for service related to a specific 'episode of care' (24%).[10] The model allocates substantial responsibility for the quality of healthcare services to independent doctors. The centrality of EHIF as a medium of payment for healthcare in Estonia implies that their stipulations over what services should be offered to patients are taken seriously – but ultimately remain a product of the financial incentives facing the providers. It also ensures a relatively consistent application of healthcare policies across providers. However, the disaggregated nature of delivery itself means that there is substantial room for variation in healthcare delivery that is a product of the activities of individual doctors.

Amongst the population of interest for this study – older patients with at least one chronic disease – we observe relatively regular contact between care providers and patients at baseline. Engagement with a patient's primary doctor in-person or by phone occurs roughly once a quarter, with the patient also seeing, and having a separate call with, the nurse once a year.[11] Patients in this group have approximately 3 outpatient episodes of care, and a one-in-six chance of experiencing an inpatient episode within a year. As such, these patients are already relatively heavy users of the healthcare system. Alongside a set of standardized medical checks undertaken by a doctor, the implicit contract in these consultations is that a patient requests assistance for a specific ailment and cooperates by undertaking the course of treatment that the doctor prescribes. This approach echoes most healthcare provision

[9] Additional reforms included introduction of the pay-for-performance Quality Bonus Scheme (QBS) to incentivize preventive care provision in 2006, expansion of nurse services, establishment of a digital health system to enable digital access to health services such as prescriptions, lab tests and health records in 2008, and adoption of primary healthcare development plans which increased service provision by primary health care providers and focuses on chronic illness management and improving care continuity (Atun et al., 2016; Habicht and van Ginneken, 2010; Koppel et al., 2008).

[10] The remaining 16% is made up of allowances for patient distance, nursing support, and the variable QBS payment. Outside of primary care, EHIF is also liable for the payment of tertiary costs, such as in- or out-patient episode at a tertiary health institution.

[11] Amongst OECD nations, Estonia is towards the bottom third of the ranking in intensity of patient consultations with doctors, but similar to other Scandinavian countries (OECD, 2021).

around the world, with only ad hoc attempts to provide holistic care in some advanced health systems.

## 3.2 Enhanced Care Management (ECM) intervention

Between 2021 and 2023, EHIF piloted a system for chronically ill patients that attempted to shift the nature of patient-doctor interactions towards a more holistic treatment approach.[12] The core goal of the Enhanced Care Management (ECM) program is to improve the overall quality of care provided to vulnerable patients, including by increasing the use of preventive care, improving coordination of care across health system levels, and increasing patient involvement in proactive care. These elements can improve patient health and quality of life, and may reduce the need for curative medical services. For example, supporting patients with type 2 diabetes to improve their diet and increase physical activity in ways that they are most likely to take up may limit further deterioration in their health. Similarly, detecting the need for prescription statins can reduce the threat of cholesterol-related health complications.

The ECM intervention consists of coaching family doctors and their teams to develop holistic care and proactive outreach plans for chronically ill patients (World Bank, 2022). The core of the ECM intervention is the development of a 'care plan' for each enrolled patient that outlines the joint responsibilities of doctor and patient, and sets achievable, time-bound targets for care. The ECM care plans can be seen as a form of 'contract' between the doctor and patient, and might include improved tracking of tests and referrals, follow-up by doctors or their teams after hospital discharges, tracking of medication adherence, monitoring of patients between clinic visits, and greater focus on clinical quality.[13] The appendix presents three examples of such care plans from the trial.

[12] An initial pilot of the ECM program was first conducted in 2017 with 10 providers, focused on patients with multiple chronic conditions including cardiovascular disease (CVD), hypertension, diabetes, and elevated blood lipids and other conditions. A non-experimental evaluation of the pilot showed that providers made 40% more calls to patients; were 11% more likely to have patients on appropriate statin prescriptions; had patients 25% less likely to be hospitalized for CVD-related conditions; and were 11% more likely to follow up within 30 days in the event of an acute CVD incident (Kurowski et al., 2017). This pilot was conducted with a purposely-selected group of 10 doctors who were expected to be highly motivated early adopters, limiting the possibility of inference about the causal impact of the program, or its likely effectiveness at scale. It was co-designed by EHIF, the World Bank, and Harvard University's Ariadne Labs. Pilot clinics were excluded from the current study.

[13] The broader ECM program includes four elements: identifying high-risk patients through risk stratification, developing care management plans by the primary care doctor in consultation with the patient, proactively linking care providers together, and developing a team approach between patients and their caregivers. ECM reflects global primary care reforms that aim to focus the health system's attention on high-risk groups and improve the continuity of care for these patients (Peikes et al., 2018).

A survey of doctors implementing the scheme indicated that the vast majority of doctors discussed the care plans with patients once every three months, and a fifth of clinic teams discussed the care plan with the patient once a month.[14] All care teams reported that they had done multiple follow-ups of some kind. These discussions included assessments of patients' self-management goals, reviewing information from specialist care visits, and updating targets and treatments in response.[15]

An assessment of the care plans by EHIF staff implies that they were tailored to patient's individual health needs, with 93% of plans assessed as satisfactory or above in terms of being tailored 'to the needs of the individual patient'.[16] 83% of care plans had an explicit action plan to achieve the goals set.[17] Together, these statistics imply that ECM was successfully rolled out in participating clinics. When asked what the most effective element of the ECM program was in the survey, 91% of doctors stated it was the construction of the care plan. 94% of doctors felt that patients enrolled in ECM followed the practices and guidelines in their care plans 'easily' or only 'with some difficulty'. 78% of doctors stated that they had observed differences in the behavior of ECM patients and 74% believed they had observed changes in their ECM patient's physical health.[18]

## 3.3 Randomization approach

We worked with EHIF to implement a randomized control trial of ECM. A random subset of 93 clinics were invited to be part of ECM, and 282 clinics were randomized into what we will refer to as 'pure control;' i.e. doctors in these clinics had little to no exposure to ECM. After discussions around the requirements of the scheme and eligibility assessments of patients, 56 of the original 93 clinics enrolled, with 72 doctors (and their lists of patients) making up our study sample. Amongst the 72 doctors that agreed to participate, 5,056 patients were identified as eligible for inclusion in the ECM program by EHIF according to pre-set rules using administrative data. 1,973 individuals were classified as facing severe risk to their health, and the remaining 3,087 individuals were classified with mild to moderate

[14] More details on the survey of doctors can be found in the appendix.

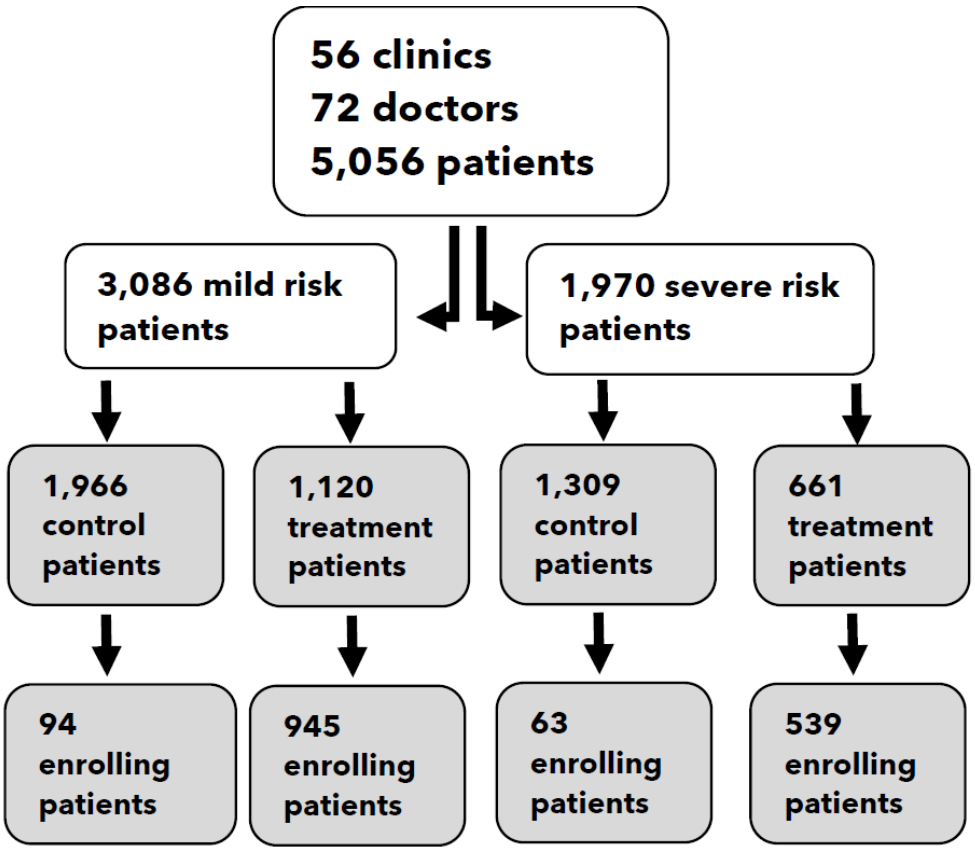
[15] Very few doctors reported coordinating with social care services, indicating that any impacts of ECM are driven by changes in medical behaviors.

[16] More details on the care plan assessments can be found in the appendix.

[17] The same assessment reported that 82% of care plans addressed the patient's health holistically, 93% of plans were 'easy to grasp and understandable from the patient's point of view', and 93% had information relevant to the patient.

[18] In the same survey, 94% of doctors stated that they were motivated to continue using the ECM approach after the pilot ended.

Figure 1: Within-provider patient stratification, randomization, and compliance




risk.

We then followed the randomization protocol outlined in Figure 1.[19] For each doctor, up to 25 individuals were included in ECM after this risk stratification. Fewer than 25 individuals were included into the ECM treatment group only when the doctor had fewer than 25 eligible patients; this occurred in 3 out of 72 cases (Figure A2b). For all other providers, the 25 patients were subject to stratified randomization into ECM treatment.[20]

This approach resulted in 661 severe risk patients enrolled in ECM, of whom 539 (81.1%) eventually participated in the formulation of a care plan. Similarly, it resulted in 1,121 mild to moderate risk patients enrolled in ECM, of whom 945 (84.2%) eventually formulated a care plan with their doctor. Contamination by the control groups was rare, with only 157 cases

[19] A fuller elaboration of the sampling process from the Estonian population to our final study sample is illustrated in Figure A1.

[20] Though it was felt important to separately identify the impact of ECM on these risk groups, stratification based on risk-type complicates our ability to undertake analysis of hypertension, the medical guidelines for which denote distinct approaches for different risk-levels, making it challenging to undertake a coherent analysis across patients in different risk groups.

in which an individual who had been assigned to the "ECM control" group participating in the ECM program, most of whom enrolled only in the last months of the observation period. The main results in this paper are analyzed as intent-to-treat outcomes based on initial treatment assignment with fixed effects for doctor-risk strata groups (effectively, comparing assigned-to-treatment and assigned-to-control patients within each risk level for each doctor). Corresponding treatment-on-the-treated instrumental variables estimates are reported as complementary to this core analysis.

# 4 Data and statistical approach

## 4.1 Data

To assess the impacts of ECM on the nature of healthcare and on broader patient health, we track patient treatment and outcomes over time using EHIF's administrative records. Since EHIF is liable for reimbursing providers for every episode of care, every billable activity undertaken within the formal health system is recorded within EHIF's records.[21] We merged these billing records over eight health care services categories – primary health care, day care, outpatient care, outpatient nursing care, outpatient rehabilitation care, inpatient care, inpatient nursing care, and inpatient rehabilitation care – over a 14 year period spanning 2009 until 2023. For each type of care, we obtained the International Classification of Disease (ICD) codes of diagnoses related to the episode and the procedures or treatments provided. The summary of the key outcomes used in this study, grouped by treatment groups, is shown in Table 1.[22]

From the patient-level linked data set we created from these billing records, we are able to assess a range of primary and secondary outcomes related to treatment. For example, we observe the number of primary health care interactions in distinct periods; undertaking of diagnostic work, such as monitoring of cholesterol levels, glucose/glycosulated Hb and creatinine; number of outpatient (ambulatory) services utilized; number and nature of follow-ups by doctor and nurse; counselling sessions with the family nurse; and so on.

To assess health outcomes, we created indicators that follow the Organization for Economic

[21] There is little that is not billable, with EHIF's data even including e-mails and calls to patients by doctors and nurses.

[22] Further details on the billing data are provided in the appendix. Note that we do not have access to electronic medical records with relevant clinical measures such as HbA1C, blood pressure, or BMI.

Co-operation and Development (OECD)'s quality of care outcomes indicators for primary care (OECD, 2021). These indicators include avoidable hospital admissions for asthma, chronic obstructive pulmonary disorder, diabetes, congestive heart failure, and hypertension, defined as the number of hospital admissions with any of the above as primary diagnosis; emergency department visits (for any condition); inpatient readmission within 30 and 90 days after any previous inpatient admission; share of prescriptions purchased out of all the prescribed medications by provider; and mortality outcomes.

In addition, EHIF's Mini Information System Portal is used by EHIF to list patients who have been diagnosed with chronic illnesses and are therefore at risk of deteriorating health (see Section A3 for further details on this process). We matched this dataset to the claims data to generate identifiers for higher-risk patients. We also asked all doctors in the study to provide an additional risk score for each of the patients identified as having a chronic disease in terms of their severity of illness. Within their list of chronically-ill patients, all doctors were required to rate their patients' risk of becoming either 'mild to moderately ill' or 'severely ill'.

## 4.2 Statistical approach

Our core analysis uses the below specification:

$$Y_{ik,t} = \beta_0 + \beta_1 ECM_i + \beta_2 Strata_k + \beta_3 \gamma + \beta_4 \bar{Y}_{i,2021} + \epsilon_{ik,t}$$

where $Y_{ik,t}$ is the outcome of patient $i$ at time $t$, with risk group and ECM doctor indicated by the strata $k$ to which the individual belongs. $ECM_i$ is an indicator that the patient was randomly assigned to the ECM treatment group, and $\beta_1$ is therefore the treatment effect parameter of interest. $\gamma$ is a vector of controls – including where appropriate, patient age and gender. In ANCOVA specifications, $\bar{Y}_{i,2021}$ additionally represents a control for the annualized mean of the dependent variable for patient $i$ in the pre-treatment period of 2018-2021 inclusive, up to the initiation of the ECM program. $\epsilon_{ik,t}$ is the error term. Since the size of the population a doctor serves varies across doctors, the probability of treatment is unequal across patients across doctors. As such, we weight treated observations by the inverse of the proportion of treated individuals in each stratification block (Gerber and Green, 2012).

Our design allows us to investigate a number of potential identification threats. Foremost, while our within-doctor design ensures many other features of the patient environment are

held constant, it raises the concern that there will be spillovers within doctor across treatment and control patients. These may take the form of either (a) attenuated differentials driven by provider-wide improvements in chronic disease management; or (b) exaggerated differentials due solely to reallocation of provider effort from control patients to treatment patients. We exploit the richness of the EHIF data to address both possibilities. With a substantial number of doctors randomized out of treatment, and whose patient outcomes are summarized in Table 1, we can make comparisons between ECM control patients and a set of 'pure control' patients – patients who would have been eligible for ECM randomization had their providers been included – to assess the possibility of both types of spillovers. To do so, we assume that conditional on pre-existing differences between 'pure control' and 'ECM control' patients highlighted in section 3.3, the changes in patient outcomes in the pure control group are a fair counterfactual for those of the ECM control patients. We use a nearly identical ANCOVA specification for these regressions, with fixed effects at the provider randomization block level (comparing across similar providers) instead of the provider-risk level (comparing within individual providers).

# 5 Results

## 5.1 Balance and representativeness in ECM randomization

Table 1 reports patient-level balance tests between three separate groups using annualized counts of patient outcomes from 2018-2021 (up to the start of the ECM program). These include a 'pure control' group, which is comprised of all patients who would have been eligible for the ECM program in clinics assigned to control; the ECM control group, comprising individuals at an ECM participating provider who were randomized to *not* receive the program; and the ECM treatment group, comprising individuals at an ECM participating provider who were randomized to receive the program. We report balance between the ECM control and pure control group to assess representativeness of our patient sample within the wider population; and the ECM control and treatment groups to assess experimental balance. When making experimental comparisons, we include randomization strata fixed effects. When making comparisons to pure control patients, we use fixed effects for the blocks we used in the clinic-level randomization.[23]

[23]At the clinic and provider level randomization and enrollment stage, about half of selected providers declined participation in the program; see a complete description of this process in the Appendix. Due to concerns about self-selection, we exclude refusing providers from *both* the treatment and 'pure control' groups. One consequence is that comparisons to 'pure control' include a large number of providers who

Relative to the full set of patients at non-treatment clinics, ECM patients were somewhat younger at the start of the intervention and were also somewhat more likely to be male. They displayed higher utilization of some types of primary healthcare, key prescriptions and monitoring tests, but lower utilization of both inpatient care (including ambulatory hospitalization and short-term readmission) and inpatient and outpatient nursing/rehabilitation services. Relative to the pure control group, ECM patients were also less likely to seek healthcare due to heart failure, but more likely to do so for hyperlipidemia. This may be explained by the fact that those doctors who agreed to be part of ECM could might differ from those in the rest of the system, either because they are more motivated doctors, or because their patients were in a position to benefit more significantly from the program. This could account for many of the described differences between their patients, who seem to re-balance their healthcare utilization towards doctor-provided primary services, with their associated monitoring and prescriptions, and away from other types of healthcare.

The final column of Table 1 reports differences between treatment and control patients in treatment clinics, conditional on randomization strata. In general, the ECM control and treatment groups are well balanced at baseline across a range of characteristics, including their current health status, as measured by tracer diagnoses; by their utilization of the health system, including at the primary level; and, by the prescriptions they received for management of their conditions.[24] There is a slight imbalance on age, though with age and gender the most natural determinants of chronic health outcomes, they are natural controls in our core specifications. ECM treatment patients are also very slightly (4%) more likely to have had an in-person doctor visit in the last year, and are slightly less likely to use primary care away from their assigned clinic. This, along with the gains in efficiency available from the panel structure of the data, motivate our use of an ANCOVA specification in our core analysis, with controls for baseline (lagged) levels of outcome variables at the patient level.

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would non-compliers to treatment. However, since there are no relevant provider covariates there is little we can do to adjust for this: We present comparisons with this group 'as they are'.

However, since we paired randomization *across* providers with stratified randomization *within* providers, we obtain a valid experimental design among compliant providers in the patient-level randomization, which is the ultimate focus of our study. There are several viable interpretations of our effect sizes in this lens. A provider-level intention-to-treat effect size would result in a substantial reduction in the effect sizes we estimate; a patient-level treatment-on-the-treated effect size would result in a substantial increase. We take a middle ground approach throughout and generally report intention-to-treat results based on the internally valid within-provider patient randomization. Which estimand is relevant for external generalizability depends on the context and design of a similar program, which we leave to the interpretation of readers.

[24] An expanded set of balance checks across a wider range of pre–ECM characteristics is reported in the appendix given the substantial records we have access to, but these variables are secondary to our main analysis.

Table 1: Pre-treatment balance across patient groups (2018-2021)

| Variable | Means | | | Differences | |
|---|---|---|---|---|---|
| | Pure Control | Control | Treatment | Representativeness | Balance |
| | (1) | (2) | (3) | (2)-(1) | (3)-(2) |
| **Panel A: Demographics** | | | | | |
| Age | 70.8 | 68.7 | 67.3 | -2.10*** (0.419) | -0.643* (0.343) |
| Male | 0.404 | 0.436 | 0.462 | 0.034** (0.014) | 0.016 (0.016) |
| Mild risk | - | 0.629 | 0.629 | - | 0.000 (0.000) |
| **Panel B: Outcomes (annualized counts)** | | | | | |
| **Primary care (assigned clinic)** | | | | | |
| Doctor in-person chronic care | 0.329 | 0.414 | 0.448 | 0.067** (0.034) | 0.018** (0.009) |
| Doctor phone | 3.50 | 3.70 | 3.45 | 0.060 (0.193) | -0.111 (0.080) |
| Nurse in-person | 1.02 | 0.980 | 0.992 | -0.049 (0.063) | -0.013 (0.028) |
| Nurse phone | 0.988 | 1.44 | 1.60 | 0.415** (0.168) | -0.004 (0.047) |
| Any consultation | 5.88 | 6.57 | 6.52 | 0.493** (0.246) | -0.125 (0.125) |
| Primary | 1.99 | 2.08 | 2.02 | 0.145* (0.077) | 0.008 (0.051) |
| Outpatient | 0.357 | 0.304 | 0.293 | -0.009 (0.025) | -0.011 (0.011) |
| **Primary care (not assigned clinic)** | | | | | |
| Primary | 0.344 | 0.247 | 0.285 | -0.103 (0.065) | -0.063** (0.029) |
| Outpatient | 2.90 | 3.05 | 3.14 | 0.148 (0.095) | 0.090 (0.083) |
| **Other care** | | | | | |
| Inpatient | 0.193 | 0.174 | 0.175 | -0.015* (0.009) | -0.002 (0.009) |
| Inpatient (via ambulance) | 0.061 | 0.047 | 0.046 | -0.013*** (0.003) | -0.000 (0.005) |
| Inpatient re-admission (30) | 0.056 | 0.046 | 0.052 | -0.009 (0.006) | 0.006 (0.006) |
| Inpatient re-admission (90) | 0.086 | 0.071 | 0.076 | -0.013** (0.006) | 0.003 (0.009) |
| Daycare healthcare | 0.081 | 0.084 | 0.089 | 0.003 (0.004) | 0.005 (0.006) |
| Inpatient nursing/rehabilitation | 0.037 | 0.017 | 0.015 | -0.018*** (0.003) | -0.004 (0.003) |
| Outpatient nursing/rehabilitation | 0.231 | 0.146 | 0.145 | -0.090*** (0.018) | 0.004 (0.017) |
| **Panel C: Outcomes (share of patients)** | | | | | |
| Covid incidence | 0.074 | 0.094 | 0.086 | 0.021** (0.010) | -0.004 (0.009) |
| Covid vaccine | 0.602 | 0.686 | 0.648 | 0.075*** (0.026) | -0.037*** (0.013) |
| **Screening** | | | | | |
| Glycohemoglobin | 0.677 | 0.727 | 0.747 | 0.048** (0.023) | -0.002 (0.012) |
| Creatinine | 0.973 | 0.986 | 0.985 | 0.011*** (0.003) | 0.003 (0.003) |
| Cholesterol | 0.951 | 0.980 | 0.978 | 0.024*** (0.005) | 0.002 (0.005) |
| Glucose | 0.944 | 0.963 | 0.972 | 0.019** (0.009) | 0.006 (0.005) |
| TSH | 0.741 | 0.789 | 0.796 | 0.050** (0.020) | 0.010 (0.012) |
| **Diagnosed conditions** | | | | | |
| Heart failure | 0.436 | 0.366 | 0.339 | -0.075*** (0.024) | -0.004 (0.013) |
| Stroke | 0.008 | 0.008 | 0.008 | -0.001 (0.002) | 0.002 (0.002) |
| Myocardial infarction | 0.022 | 0.026 | 0.025 | 0.003 (0.004) | -0.002 (0.005) |
| Hyperlipidemia | 0.448 | 0.526 | 0.521 | 0.079*** (0.025) | -0.006 (0.017) |
| Overweight/obese | 0.155 | 0.177 | 0.171 | 0.019 (0.014) | 0.002 (0.012) |
| **Prescriptions** | | | | | |
| Diabetes | 0.226 | 0.234 | 0.244 | 0.003 (0.010) | 0.007 (0.014) |
| Anti-hypertensive | 0.056 | 0.048 | 0.051 | -0.008 (0.009) | 0.004 (0.006) |
| Beta-blockers | 0.644 | 0.655 | 0.666 | 0.010 (0.011) | 0.014 (0.016) |
| Statins | 0.523 | 0.585 | 0.599 | 0.057*** (0.017) | 0.016 (0.018) |
| Any key | 0.835 | 0.854 | 0.867 | 0.017* (0.009) | 0.018 (0.012) |
| Any other | 0.997 | 0.998 | 0.999 | 0.001* (0.001) | 0.001 (0.001) |
| **FE** | - | - | - | Block | Strata |
| **N** | 47,323 | 3,275 | 1,781 | - | - |

*** $< 1\%$; ** $< 5\%$; * $< 10\%$.

**Notes:** The table measures pre-treatment balance of demographic variables and outcomes of interest for the ECM intervention at the patient level. The **means columns** (1-3) in Panel A show the mean age of patients in each group at the start of the intervention (28/05/2021) and the share of male and mild-risk patients. Panel B shows mean annualized counts of the outcomes of interest in the pre-treatment period, running from 01/01/2018 to 27/05/2021. Those values are calculated from

healthcare billing data, by summing up all instances of occurrence of a given variable (interaction, diagnosis or procedure) for each patient in the pre-treatment period; annualizing and winsorizing the outliers (at 99.9th percentile) the resulting values; and then calculating the arithmetic averages for relevant groups. Panel C shows the share of patient with at least one occurrence of a given outcomes in the same period. Sub-panel headings are used to group outcome categories. Standard deviations are shown in the parentheses. Pure control group is missing values for mild risk variable, as the health risk class was not evaluated for this group of patients.

The **differences columns** (4-5) display differences between respective groups on each variable as estimated in a WLS regression, inclusive of the fixed effects for the stratification level of the randomization procedure, which is clinic-level randomization block in column 4 and patient-level strata, i.e. doctor interacted with patient risk classification level, in column 5. Standard errors of the coefficients are clustered by doctor and shown in parentheses.

The treatment groups are defined as follows: **Pure Control** - all patients classified by EHIF as eligible for ECM, but at clinics not assigned to ECM intervention (see 'Pure control' group in the randomization chart in Figure A1); **ECM Control** - patients selected to be in the ECM control at participating doctors, irrespective of their actual treatment status; **ECM Treatment** - patients selected to receive ECM treatment at participating doctors, irrespective of their actual treatment status. The exact **coding definition** of each outcome variable is provided in Table A3.

## 5.2 ECM impacts on utilization, diagnosis, and management

Table 2 presents the impacts of ECM on the nature of patient care over the period of the program, from May 2021 to March 2023. Across key indicators of patient care, the table presents both (a) binary 'extensive margin' measures as to whether the service was ever provided within the study period and (b) annualized 'intensive margin' counts of the number of times that service was provided. Our estimation results do the same.[25] It presents mean levels for the control (Columns 1 and 2), design-adjusted comparisons between the ECM treatment and control groups (our primary analysis; Columns 3 and 4) and comparisons between the ECM control group and 'pure control' patients in clinics that were randomized out of treatment (to assess potential spillovers; Columns 5 and 6). In comparisons between ECM treatment and control, the specifications we report are conditional on randomization strata fixed effects, age, gender and the mean of the dependent variable for the 2018 to 2021 period up to the initiation of the ECM program.

The first two rows of the table indicate that there was a successful inclusion of over 80% of randomized patients into the program. Treatment patients are 76 percentage points more likely to have a care plan; about 6% of control patients received one. Then, broadly, the first panel indicates that ECM enrolled patients used significantly more primary care than non-ECM enrolled patients at their assigned providers. Patients randomized into the control group accessed any form of primary care consultations about 7.5 times annually during the post treatment period, of which six interactions were phone calls and two interactions per year were for primary/outpatient care. ECM-assigned patients averaged about 0.7 (9.5%) more interactions per year; with the increase split roughly evenly across phone calls and in-person interactions. Of these new interactions, two-thirds were with nurses, either in person or by phone; and one-third were with doctors directly. Overall, the coefficients related to primary care at the assigned clinic represent approximately a 10% increase in primary care utilization for recipients of the ECM program, relative to control individuals of the same risk level, age and gender at the same doctor. [26]

[25] Specifically, outcome variables in the 'Means' and 'Count' columns (1,2,4,6) are measured as annualized and winsorized (at 99.9th percentile) sums of a given outcome (diagnosis, procedure, or consultation) per patient and period. 'Any' columns (3,5) measure the same variables converted to 0/1 dummy values, meaning they take values of 1 if a patient had a particular diagnosis, procedure, or consultation at any point during the treatment period, and 0 otherwise.

[26] We present alterative modeling strategies for robustness in the Appendix. We estimate several heterogeneity analyses across the risk groups (Tables A4 and A5), doctor and ECM care plan quality, as well as pre-treatment health profile (Table A6), in addition to using treatment-on-the-treated (IV) estimation (Table A8) and correcting our inferences using multiple hypothesis adjustments and randomization-inference p-values (Table A9). All estimates are qualitatively the same as in Table 2 (see Section A6).

These results indicate that while the scheme had clinically meaningful impacts on the intensity of patient care, the increase in case load for clinical staff was moderate. An immediate concern is that these results merely reflect ECM providers shifting effort to ECM patients from control patients. Columns 5 and 6 therefore report an almost-identical ANCOVA regression estimate comparing control individuals at ECM providers to the 'pure control' group of ECM-eligible individuals at control providers. Echoing the contamination outlined in Figure 1, roughly 6% of ECM control patients were enrolled in ECM; typically towards the end of the program.

We do see slightly more in-person engagement with ECM control patients than with patients in 'pure control' clinics on the extensive margin. However, we also see decreases in care on the intensive margin that suggest some effort-shifting within the program. The within-provider relative increases in doctor phone calls to ECM patients, for example, may be entirely the product of control group declines, and about half the increase in nurse phone calls are similarly offset by control group declines. By contrast, *in-person* visits were higher for ECM control patients than pure control patients, suggesting a null overall net difference. In other words, the scale of the differences between ECM controls and outside controls are not large enough for our treatment effects to arise purely from shifting care capacity to ECM-randomized patients away from control patients.

The second and third panels of Table 2 investigate changes in the utilization of care services at locations other than the ECM provider. Focusing on the core treatment effects of ECM, there appears to be no impact on the use of primary care outside the ECM doctor. These results suggest that changes in primary care patterns arose from within the specific relationship between ECM patients and ECM providers. In terms of broader (non-primary) care, ECM reduces the likelihood that patients are hospitalized by 8% (2p.p.), an important effect that we will investigate further in the following section. We also see a reduction in readmission rates to hospital of roughly a quarter of the baseline frequency, but no changes in the utilization of services such as day-care or rehabilitation.[27]

The fourth panel, titled 'Screening', indicates that additional testing for key conditions was undertaken as a result of the ECM program. We observed significant increases in the proportion of ECM patients who were tested for glycohemoglobin, creatinine, cholesterol,

[27]Critically, we also observe no differences across any groups in either Covid incidence or vaccination rates, ruling out a potential channel for differences in hospitalization or all-cause mortality between groups based on differences in intensity of primary care treatment that would lead to differences in those mediators. As a result, we can anticipate that differences in downstream outcomes arise from detection and management of NCDs here and not incidental preventive care during the pandemic.

glucose, and total blood counts. It seems likely that these tests were often undertaken as a panel, since the share of individuals receiving this test in the treatment group increased by approximately 3 to 5 percentage points for each of these tests. The coefficients in Column 4 imply that for some conditions there is also an intensification of screening under ECM. The results are in-line with the approach of 'holistic care' outlined in section 2. A goal of holistic care is that doctors should be motivated to undertake more diagnostic work, which is precisely the effect we observe. The corresponding spillover estimates in Columns 5 and 6 suggest the program induced a broader intensification of screening at ECM providers, as ECM control individuals were screened for many conditions at significantly higher rates than the similar 'pure control' eligible individuals at non-ECM providers. Since the spillover impacts are positive, the within-doctor estimates are lower bounds on the true effects of the program on treated individuals, if there are also broad-based knowledge effects across the whole patient population.

Effects estimated and reported in the fifth panel, titled 'Diagnosed Conditions', is a direct consequence of the diagnostic work. These results imply large and significant increases in the diagnosed prevalence of heart failure, hyperlipidemia, and overweight status among the treatment group. In particular, extensive diagnosis of heart failure increases by 10% (+3p.p.); hyperlipidemia by 25% (+10p.p.); and overweight by 40% (+6p.p) overall. Of these, only heart failure diagnoses showed any decline among the control group, again suggesting that these are genuine increases in total detection of medical needs and not reflective of effort reallocations. The corresponding positive increases in the count of diagnosis implies that there was a sustained screening regime across the multiple years of the program.[28] This panel indicates that ECM doctors have focused their most significant diagnostic efforts on conditions that are harder for the patient themselves to detect, such as heart failure and hyperlipidemia. This is once again consistent with the conceptual framework presented in Section 2.

Finally, these diagnoses induced increases in the rate of prescription medication offered to individuals among the ECM treatment group – namely, statins (which treat hyperlipidemia). We estimated that an additional 3% of patients a year received such a prescription (with

[28]See Figure A3 for details on the timing of outcome differences. Among the treatment groups, there are substantial jumps in consultations immediately and at 1- and 2-year post-intervention intervals; there is persistent increase in formal diagnosis of obesity following the program; and there are similar out-year effects at 1- and 2-years post program launch for statin prescription renewal. We contrast these dynamic and ongoing effects to, for example, a one-time intervention aimed at improving specific aspects of primary care. We argue that these results demonstrate that these long-term *relational* effects on patient commitment and follow up has an important role in the program's achievement of better health outcomes.

60% of the control group already having one) and an additional 2% of patients receiving diabetes medication (27% in control). While other prescription increases were not significant, altogether, the total number of prescriptions managing key conditions (diabetes medication, antihypertensives, beta blockers, and statins) increased for the average individual enrolled in the ECM program by about one-quarter of a prescription a year. Along with this increase, 0.7 further additional prescriptions were induced on average, for a net increase of about one prescription per person (a 6% increase). There were also potentially large spillovers to non-ECM patients in these outcomes, with ECM control patients having similarly-sized advantages over pure control patients in the follow-up period.

Together, these results indicate that the shift in the underlying contract of care induced by ECM, from reactive to holistic healthcare, has real effects on doctor activities both for their entire population and for ECM-enrolled patients especially.[29] For a relatively modest increase in work effort, there is a substantial increase in diagnostic work, identified conditions, and prescriptions. The spillover results provide clues as to what is driving our impacts. We might interpret the spillover effects (Columns 5 and 6) as the impacts of knowledge the doctor receives from entering and being coached on the scheme. The additional ECM treatment effect (Columns 3 and 4) can be interpreted as the direct effect arising from the care plan construction and the relational contracting approach.

[29] As will be seen in the next section, the downstream impacts of ECM on health outcomes differ for mild- and severe-risk patients. As such, Appendix Tables A4 and A5 present the analysis of Table 2 separately for the two risk groups. Both groups receive similar changes in their care utilization in response to ECM as described in this section. However, whereas severe-risk patients had a wide range of additional diagnoses and prescriptions (namely, new detection of already-existing heart failure and diabetes), by contrast, the mild-risk patients almost exclusively were diagnosed with hyperlipidemia and obesity and prescribed corresponding statins without much else changing. Incorporating the mediation analysis from Table A7, we estimate that this hyperlipidemia-statin channel is mechanically the largest biomedical channel for the reduction in preventable mortality. This mechanism, however, might simply be insufficient to meaningfully affect the mortality profile of the severe-risk patients, who already suffer from a range of serious comorbid health issues.

Table 2: **ECM Impact:** On patient's care (ANCOVA)

| Variable | Means (control) | | ECM treatment vs. control | | ECM control vs. pure control | |
|---|---|---|---|---|---|---|
| | *Any* | *Count* | *Any* | *Count* | *Any* | *Count* |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| **Primary care (assigned clinic)** | | | | | | |
| ECM inclusion | 0.049 | 0.027 | 0.764*** (0.033) | 0.453*** (0.024) | 0.049*** (0.007) | 0.027*** (0.004) |
| ECM care plan | 0.048 | 0.058 | 0.784*** (0.033) | 0.923*** (0.073) | 0.048*** (0.006) | 0.058*** (0.009) |
| Doctor in-person chronic care | 0.471 | 0.384 | 0.110*** (0.026) | 0.148*** (0.032) | 0.067** (0.033) | 0.033 (0.031) |
| Doctor phone | 0.912 | 4.078 | 0.006 (0.006) | 0.118 (0.078) | 0.007 (0.026) | -0.141 (0.212) |
| Nurse in-person | 0.767 | 1.066 | 0.042** (0.016) | 0.175*** (0.057) | 0.099** (0.038) | 0.164** (0.078) |
| Nurse phone | 0.728 | 1.911 | 0.093*** (0.021) | 0.285*** (0.070) | 0.070** (0.031) | -0.131 (0.126) |
| Any consultation | 0.968 | 7.485 | 0.003 (0.003) | 0.717*** (0.136) | 0.012 (0.023) | -0.010 (0.306) |
| Primary | 0.867 | 1.472 | 0.029*** (0.008) | 0.102*** (0.031) | 0.046* (0.024) | 0.102 (0.072) |
| Outpatient | 0.537 | 0.597 | 0.127*** (0.021) | 0.229*** (0.032) | -0.014 (0.026) | -0.064 (0.048) |
| **Primary care (not assigned clinic)** | | | | | | |
| Primary | 0.106 | 0.148 | 0.000 (0.007) | 0.005 (0.010) | -0.015 (0.034) | -0.016 (0.067) |
| Outpatient | 0.845 | 3.436 | 0.016 (0.013) | 0.003 (0.081) | -0.001 (0.010) | 0.091 (0.195) |
| **Other care** | | | | | | |
| Inpatient | 0.255 | 0.221 | -0.020* (0.012) | -0.016 (0.013) | 0.003 (0.008) | -0.002 (0.010) |
| Inpatient (via ambulance) | 0.107 | 0.073 | -0.009 (0.009) | -0.009 (0.007) | -0.012** (0.006) | -0.008* (0.004) |
| Inpatient re-admission (30) | 0.038 | 0.032 | -0.005 (0.006) | -0.009** (0.005) | -0.004 (0.005) | -0.001 (0.004) |
| Inpatient re-admission (90) | 0.059 | 0.054 | -0.001 (0.007) | -0.007 (0.007) | -0.005 (0.005) | -0.003 (0.005) |
| Daycare healthcare | 0.117 | 0.097 | 0.003 (0.011) | 0.006 (0.012) | 0.011* (0.007) | 0.011* (0.006) |
| Inpatient nursing/rehabilitation | 0.04 | 0.036 | 0.004 (0.007) | -0.000 (0.009) | -0.017*** (0.004) | -0.011** (0.005) |
| Outpatient nursing/rehabilitation | 0.142 | 0.181 | -0.005 (0.011) | -0.015 (0.025) | -0.014** (0.007) | -0.109*** (0.021) |
| Covid incidence | 0.202 | 0.131 | 0.017 (0.014) | 0.020* (0.011) | -0.001 (0.010) | -0.005 (0.007) |
| Covid vaccine | 0.723 | 0.825 | -0.005 (0.013) | -0.033 (0.022) | 0.013 (0.016) | -0.004 (0.029) |
| **Screening** | | | | | | |
| Glycohemoglobin | 0.683 | 0.765 | 0.050*** (0.014) | 0.113*** (0.026) | 0.044** (0.018) | 0.039* (0.021) |
| Creatinine | 0.929 | 2.545 | 0.038*** (0.007) | 0.111 (0.117) | 0.033*** (0.007) | 0.086 (0.097) |
| Cholesterol | 0.882 | 1.098 | 0.052*** (0.009) | 0.152*** (0.032) | 0.045*** (0.009) | 0.051* (0.031) |
| Glucose | 0.844 | 2.065 | 0.035*** (0.011) | 0.049 (0.126) | 0.034 (0.022) | 0.062 (0.079) |
| TSH | 0.636 | 0.898 | 0.050*** (0.013) | 0.139*** (0.045) | 0.033** (0.017) | 0.048 (0.037) |
| **Diagnosed conditions** | | | | | | |
| Heart failure | 0.302 | 0.723 | 0.032*** (0.012) | 0.161*** (0.041) | -0.021* (0.012) | -0.073** (0.029) |
| Stroke | 0.005 | 0.005 | 0.003 (0.002) | 0.001 (0.002) | -0.001 (0.001) | -0.001 (0.001) |
| Myocardial infarction | 0.018 | 0.024 | -0.001 (0.004) | 0.001 (0.006) | 0.001 (0.002) | 0.001 (0.004) |
| Hyperlipidemia | 0.428 | 0.631 | 0.097*** (0.017) | 0.279*** (0.036) | 0.037*** (0.013) | 0.044* (0.027) |
| Overweight/obese | 0.136 | 0.176 | 0.057*** (0.013) | 0.150*** (0.027) | 0.008 (0.009) | 0.002 (0.013) |
| **Prescriptions** | | | | | | |
| Diabetes | 0.266 | 1.898 | 0.018** (0.007) | 0.099 (0.072) | 0.006 (0.005) | 0.073 (0.050) |
| Anti-hypertensive | 0.036 | 0.081 | -0.004 (0.005) | -0.000 (0.012) | -0.001 (0.004) | -0.005 (0.006) |
| Beta-blockers | 0.619 | 2.534 | 0.001 (0.012) | 0.043 (0.050) | 0.018*** (0.007) | 0.058 (0.038) |
| Statins | 0.597 | 2.34 | 0.028** (0.011) | 0.124** (0.056) | 0.022** (0.009) | 0.150*** (0.044) |
| Any key | 0.844 | 6.862 | 0.010 (0.009) | 0.261** (0.128) | 0.026*** (0.007) | 0.247** (0.100) |
| Any other | 0.985 | 17.828 | 0.003 (0.003) | 0.706*** (0.234) | 0.004* (0.002) | 0.341** (0.157) |
| **FE** | - | - | Strata | Strata | Block | Block |
| **Controls** | - | - | Age, sex, $DV_{18-21}$ | Age, sex, $DV_{18-21}$ | Age, sex, $DV_{18-21}$ | Age, sex, $DV_{18-21}$ |
| **N** | 3,275 | 3,275 | 5,056 | 5,056 | 50,598 | 50,598 |

*** $< 1\%$; ** $< 5\%$; * $< 10\%$.

**Notes:** The table measures patient-level health outcomes in the post-treatment period (28/05/2021 - 31/03/2023). Outcome variables in 'Count' columns (2,4,6) are measured as annualized and winsorized (at 99.9th percentile) sums of a given outcome (diagnosis, procedure, or consultation) per patient and period. 'Any' columns (1, 3,5) measure the same variables converted to 0/1 dummy values, meaning they take values of 1 if a patient had a particular diagnosis, procedure, or consultation at any point during the treatment period, and 0 otherwise.

All regression models are estimated controlling for patients' values age and sex, as well as the value of a given outcome

variable in pre-treatment period (01/01/2018 - 27/05/2021). The only exception is 'ECM inclusion' and 'ECM care plan', which are estimated as WLS, i.e. without pre-treatment values as controls, as those procedures are introduced as a part of the intervention. The pre-treatment values are recorded in parallel with their post-treatment equivalents as either counts or dummies in the respective columns. All models include fixed effects as specified in the bottom panel, where strata refers to doctor interacted with patient risk classification level and block to clinic-level randomization block. Fully empty rows code variables that after winsorizing resulted in all values being 0. Models in columns 3-4 are also weighted by strata-level inverse probabilities of treatment assignment, whereas those in columns 5-6 are unweighted due to lack of equivalent weights for the 'Pure control' group. Standard errors of the coefficients are clustered by doctor and provided in parentheses.
The treatment groups are defined as follows: **Pure Control** - all patients classified by EHIF as eligible for ECM, but at clinics not assigned to ECM intervention (see 'Pure control' group in the randomization chart in Figure A1); **ECM Control** - patients selected to be in the ECM control at participating doctor, irrespective of their actual treatment status; **ECM Treatment** - patients selected to receive ECM treatment at participating doctors, irrespective of their actual treatment status. The exact **coding definition** of each of the variables is provided in Table A3.

## 5.3 ECM impacts on hospitalization and mortality

This section turns to downstream impacts on health outcomes of ECM. Specifically, we focus on hospitalization and mortality as the most significant health events in our data.[30] Since these are low frequency events, both are presented as WLS estimates on a dummy determined at the end of the treatment period, and as Cox proportional-hazards models. We begin by presenting a pooled estimate for patients of all risk categories in Table 3, and we then present the results by risk category in two ways. First, we present an interaction estimate for patients classified as mild risk by their healthcare providers within that table; second, Table 4 reports separate regressions by risk classification. Since we stratified randomization by risk category, all coefficients we present can be interpreted as causal in nature for these sub-strata.

In both tables, Columns 1-3 describe the impacts of the ECM program on inpatient hospitalization over the treatment period. For ECM-assigned patients, the incidence of any inpatient hospitalization declined by 2.1 percentage points relative to a control risk of 25.5% (Panel A of Table 3). Although this effect is similar in size (an 8% reduction) to our other effects, it is not significant at the usual levels in the separated samples, as presented in Table 4. These declines are observed for both mild-risk patients, where the incidence of hospitalization decreased by 1.4 percentage points relative to control rate of 21.9%, and for the severe-risk patients where the corresponding decline was 3.2 percentage points against the control rate of 30.9%. Similarly, in the Cox approach, neither model estimates statistically significant effects on the expected hazard of hospitalization (Panels B and D).

We also illustrate the emergent impacts of ECM over time by plotting corresponding survival curves in Figure 2. Even though the results are not significant for hospitalization, there are clear differences towards the end of study period between mild-risk and severe-risk patients as the time at risk increases. For mild-risk patients, the program gradually builds towards a clearly reduced likelihood of hospitalization, with larger differences appearing after roughly a year and a half of treatment. For severe-risk patients, episodes of lower hospitalization rates do not seem to be effectively sustained throughout the period.

Columns 4-6 describe the impacts of the ECM program on mortality over the post-treatment period. For ECM-assigned patients, the average of mortality declined by 0.8 percentage points over the period relative to a control risk of 3.7%. Unlike for hospitalization, this effect

[30]Note that due to data protection regulations, we do not have access to patient clinical information, e.g., HbA1C, blood pressure, BMI.

appeared entirely driven by mild-risk patients. Specifically, mortality among such patients declined by a statistically significant 1.3 percentage points against a control risk of 3.2%. Severe-risk patients in the control group saw a decline of 0.3 percentage points, relative to the control group's mortality risk of 4.5%.

The proportional-hazards models in Panels B and D present even clearer patterns in changes in mortality among ECM patients, which are substantial, again driven fully by mild-risk patients. The interaction term in Panel D of Table 3 show that for ECM-assigned mild-risk patients the mortality risk is reduced to a factor of 0.599. Severe-risk patients had no such decline in hazards rates. In separate regressions (4), the survival model for mild-risk patients (Panel B) indicates consistent ECM effects of similar magnitude, i.e. over 40% reduction in mortality.[31]

Figure 3 illustrates these estimates as survival curves over the ECM period. We observe a growing gap between the effect size on the mild-risk patients versus the randomized control group. By contrast, we observe near-zero impact of the ECM program on outcomes for the severe risk group, which closely tracks the control group across the entire period.[32]. Our data allows us to explore a range of mechanisms that may be underlying the improved health outcomes we observe. At the point treatment is initiated for a patient, we observe a substantial jump in the number of healthcare interactions treatment patients have with their primary healthcare clinic, and concurrently, a jump in registered diagnosis of obesity and hyperlipidemia. The likelihood of receiving a number of screening tests, in particular for cholesterol and glycohemoglobin, also jumps up for the treatment group in the first months of ECM, before reverting back to the control group values in the later months. A similar dynamic can also be seen for key prescriptions, especially statins.

In Section A6.4, we undertake mediation analysis to assess the extent to which the variation in mortality can be ascribed to features of ECM, such as more frequent consultations at

[31]Comparing Table A4 and Table A5, we see that whereas severe-risk patients had a wide range of additional diagnoses and prescriptions (namely, new detection of already-existing heart failure and diabetes), by contrast, the mild-risk patients almost exclusively were diagnosed with hyperlipidemia and obesity and prescribed corresponding statins without much else going on. Incorporating the mediation analysis from Table A7, we estimate that this hyperlipidemia-statin channel is mechanically the largest biomedical channel for the reduction in preventable mortality, which however might be insufficient to meaningfully affect the mortality profile of the severe-risk patients, who already suffer from serious health issues.

[32]Though our period of study does overlap with the period of the Covid pandemic, mortality differences are extremely unlikely to be attributable to differential care for Covid-19. First, ECM patients were in fact *less* likely to receive a Covid vaccination at baseline (Table 1) Second, they are *more* likely to be recorded as having had Covid at endline (Table 2). And third, the increasing survival differential indicates that our treatment effects arise from longer-term exposure to the program which occurred post-pandemic.

the primary level and greater uptake of key prescriptions. We find that roughly half of the variation in our treatment effect on mortality for mild-risk patients is explained jointly by three core features of ECM: consultations, monitoring and prescriptions. These results are in line with recent literature emphasizing the importance of doctor engagement and the role of prescriptions in improving patient survival rates (Simeonova, Skipper and Thingholm, 2024; Chandra, Flack and Obermeyer, 2024; Posso, Saravia and Tamayo, 2024).

Taking this evidence together, the ECM program convincingly shifted doctor activities across their entire practice towards more holistic care and a more frequent recognition of some underlying health issues, and for ECM-enrolled patients, the additional effects of the relational change led to persistent and growing outcome differentials over the subsequent two years. These changes in care patterns had substantial impacts on the downstream mortality of mild-risk patients, but were unable to have impacts on mortality for patients with advanced conditions. As expressed in our conceptual framework, the elasticity of response of health to the interventions induced by ECM for patients with a higher $h_{ki}$ is simply higher. We interpret the difference between risk-classes as patients with higher risk being locked into a low-health status before the intervention. Moving patients, even those with pre-existing chronic conditions as in our study, towards a more holistic care plan is more effective the earlier the intervention.

Table 3: ECM Impact: On hospitalizations and mortality

| Variable | Hospitalization | | | Mortality | | |
|---|---|---|---|---|---|---|
| | Design | Controls | IV | Design | Controls | IV |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| **Panel A: Pooled OLS** | | | | | | |
| ECM patient | -0.021* | -0.020* | -0.025* | -0.009 | -0.008 | -0.011 |
| | (0.011) | (0.011) | (0.015) | (0.006) | (0.006) | (0.008) |
| Age (years) | - | 0.003*** | 0.003*** | - | 0.002*** | 0.002*** |
| | | (0.001) | (0.001) | | (0.000) | (0.000) |
| Sex (male) | - | 0.059*** | 0.060*** | - | 0.027*** | 0.027*** |
| | | (0.016) | (0.016) | | (0.008) | (0.008) |
| **Panel B: Pooled Cox Proportional-Hazards** | | | | | | |
| ECM patient | 0.912* | 0.918 | 0.897 | 0.748 | 0.802 | 0.754 |
| | (0.84, 0.99) | (0.85, 0.99) | (0.81, 0.99) | (0.6, 0.93) | (0.64, 1) | (0.58, 0.99) |
| Age (years) | - | 1.01*** | 1.01*** | - | 1.08*** | 1.08*** |
| | | (1.01, 1.02) | (1.01, 1.02) | | (1.07, 1.09) | (1.07, 1.09) |
| Sex (male) | - | 1.36*** | 1.37*** | - | 2.62*** | 2.63*** |
| | | (1.25, 1.49) | (1.25, 1.49) | | (2.1, 3.26) | (2.11, 3.27) |
| **Panel C: Interacted OLS** | | | | | | |
| ECM patient | -0.032 | -0.028 | -0.036 | -0.003 | -0.001 | -0.001 |
| | (0.023) | (0.024) | (0.031) | (0.012) | (0.012) | (0.015) |
| ECM assigned x Mild risk | 0.017 | 0.013 | 0.018 | -0.010 | -0.013 | -0.016 |
| | (0.032) | (0.032) | (0.041) | (0.012) | (0.012) | (0.016) |
| Age (years) | - | 0.003*** | 0.003*** | - | 0.002*** | 0.002*** |
| | | (0.001) | (0.001) | | (0.000) | (0.000) |
| Sex (male) | - | 0.059*** | 0.060*** | - | 0.027*** | 0.027*** |
| | | (0.016) | (0.016) | | (0.008) | (0.008) |
| **Panel D: Interacted Cox Proportional-Hazards** | | | | | | |
| ECM patient | 0.897 | 0.914 | 0.892 | 0.945 | 1.13 | 1.17 |
| | (0.8, 1.01) | (0.81, 1.03) | (0.77, 1.04) | (0.76, 1.18) | (0.91, 1.41) | (0.89, 1.53) |
| ECM assigned x Mild risk | 1.03 | 1.01 | 1.01 | 0.599*** | 0.478*** | 0.395*** |
| | (0.88, 1.21) | (0.86, 1.18) | (0.83, 1.24) | (0.45, 0.8) | (0.36, 0.64) | (0.28, 0.55) |
| Age (years) | - | 1.01*** | 1.01*** | - | 1.08*** | 1.08*** |
| | | (1.01, 1.02) | (1.01, 1.02) | | (1.07, 1.09) | (1.07, 1.09) |
| Sex (male) | - | 1.36*** | 1.37*** | - | 2.68*** | 2.68*** |
| | | (1.25, 1.49) | (1.25, 1.49) | | (2.15, 3.34) | (2.16, 3.34) |
| **FE** | Strata | Strata | Strata | Strata | Strata | Strata |
| $\hat{x}_{\text{control}}$ | 0.255 | 0.255 | 0.255 | 0.037 | 0.037 | 0.037 |
| **N** | 5,056 | 5,056 | 5,056 | 5,056 | 5,056 | 5,056 |

*** $< 1\%$; ** $< 5\%$; * $< 10\%$.

**Notes:** Table shows estimates of the ECM treatment assignment on survival until the first hospitalization and on survival overall. Effects estimated as per the regression model listed in the panel headings.

**Dependent variable** in WLS models is defined as a dummy, with 1 assigned to patients who were hospitalized (columns 1-4) or those who died (5-8). Cox Proportional-Hazards Models measures survival times (in days) from the time of ECM onset (28/05/2021) to the first occurrence of the hospitalization (columns 1-4) or to death (columns 5-8). For all columns it is right-censored at the end of the observation period (31/03/2023). For columns 1-4 it is additionally right-censored at the time of death for patients who died without being hospitalised. Standard errors of the coefficients are clustered by doctor and provided in parentheses for (column 1-4). Cox proportional-hazards values are exponentiated to show hazard ratios and the values in parentheses show 95% confidence intervals.

All columns compare **ECM Treatment to ECM control patients**, controlling for fixed effects on the strata level, i.e. doctor interacted with patient risk classification level. All columns, apart from 1 and 5, also include controls for patients' age and sex. Columns (1)-(2) and (4)-(5) estimate the effect of being assigned to ECM. Columns (3) and (6) estimate the effects of enrolling into ECM, i.e. taking up the assigned treatment, using IV specification. In Panels A and B, ECM uptake is instrumented with a single first-stage model using ECM assignment as an instrument. Panels C and D use two first stages models - one predicting ECM uptake using ECM assignment as instrument and a second one adding ECM assignment interacted with risk class as a predictor of ECM uptake (this accounts for the interaction term between ECM uptake and risk class in the second stage model). Standard errors of the coefficients are clustered by doctor and provided

in parentheses. Columns (4) and (8) additionally compare the effects of ECM assignment across participating and selected, but non-participating doctors.

The treatment groups are defined as follows: **ECM Control** - patients selected to be in the ECM control at participating doctors, irrespective of their actual treatment status; **ECM Treatment** - patients selected to receive ECM treatment at participating doctors, irrespective of their actual treatment status. The exact **coding definition** of each of the variables is provided in Table A3.

Table 4: ECM Impact: On hospitalizations and mortality

| Variable | Hospitalization | | | Mortality | | |
|---|---|---|---|---|---|---|
| | Design | Controls | IV | Design | Controls | IV |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| **Mild-risk patients** | | | | | | |
| **Panel A: Pooled WLS** | | | | | | |
| ECM patient | -0.014 | -0.015 | -0.018 | -0.013** | -0.013** | -0.017** |
| | (0.016) | (0.016) | (0.020) | (0.006) | (0.005) | (0.007) |
| Age (years) | - | 0.004*** | 0.004*** | - | 0.002*** | 0.002*** |
| | | (0.001) | (0.001) | | (0.000) | (0.000) |
| Sex (male) | - | 0.059*** | 0.059*** | - | 0.015** | 0.015* |
| | | (0.018) | (0.018) | | (0.008) | (0.008) |
| **Panel B: Pooled Cox Proportional-Hazards** | | | | | | |
| ECM patient | 0.926 | 0.922 | 0.903 | 0.566** | 0.546** | 0.467** |
| | (0.83, 1.03) | (0.83, 1.03) | (0.79, 1.04) | (0.41, 0.79) | (0.39, 0.76) | (0.31, 0.71) |
| Age (years) | - | 1.02*** | 1.02*** | - | 1.09*** | 1.09*** |
| | | (1.02, 1.03) | (1.02, 1.03) | | (1.07, 1.11) | (1.07, 1.11) |
| Sex (male) | - | 1.40*** | 1.40*** | - | 2.11** | 2.12** |
| | | (1.24, 1.57) | (1.24, 1.57) | | (1.49, 2.98) | (1.5, 3) |
| $\hat{x}_{\text{control}}$ | 0.219 | 0.219 | 0.219 | 0.032 | 0.032 | 0.032 |
| **N** | 3,086 | 3,086 | 3,086 | 3,086 | 3,086 | 3,086 |
| **Severe-risk patients** | | | | | | |
| **Panel C: Pooled WLS** | | | | | | |
| ECM patient | -0.032 | -0.030 | -0.039 | -0.003 | -0.000 | -0.000 |
| | (0.023) | (0.024) | (0.031) | (0.012) | (0.012) | (0.015) |
| Age (years) | - | 0.002 | 0.002 | - | 0.002*** | 0.002*** |
| | | (0.001) | (0.001) | | (0.001) | (0.001) |
| Sex (male) | - | 0.058** | 0.059** | - | 0.048*** | 0.048*** |
| | | (0.023) | (0.024) | | (0.015) | (0.014) |
| **Panel D: Pooled Cox Proportional-Hazards** | | | | | | |
| ECM patient | 0.898 | 0.903 | 0.876 | 0.943 | 1.10 | 1.14 |
| | (0.8, 1.01) | (0.8, 1.02) | (0.75, 1.02) | (0.7, 1.27) | (0.81, 1.5) | (0.76, 1.69) |
| Age (years) | - | 1.01 | 1.01 | - | 1.07*** | 1.07*** |
| | | (1, 1.01) | (1, 1.01) | | (1.05, 1.09) | (1.05, 1.09) |
| Sex (male) | - | 1.31*** | 1.31*** | - | 3.32*** | 3.31*** |
| | | (1.15, 1.49) | (1.16, 1.5) | | (2.36, 4.66) | (2.36, 4.64) |
| **FE** | Strata | Strata | Strata | Strata | Strata | Strata |
| $\hat{x}_{\text{control}}$ | 0.309 | 0.309 | 0.309 | 0.045 | 0.045 | 0.045 |
| **N** | 1,970 | 1,970 | 1,970 | 1,970 | 1,970 | 1,970 |

*** $< 1\%$; ** $< 5\%$; * $< 10\%$.

**Notes:** Table shows estimates of the ECM treatment assignment on survival until the first hospitalization and on survival overall, for mild-risk (Panels A and B) and severe-risk patients (Panels C and D). Effects estimated as per the regression model listed in the panel headings.

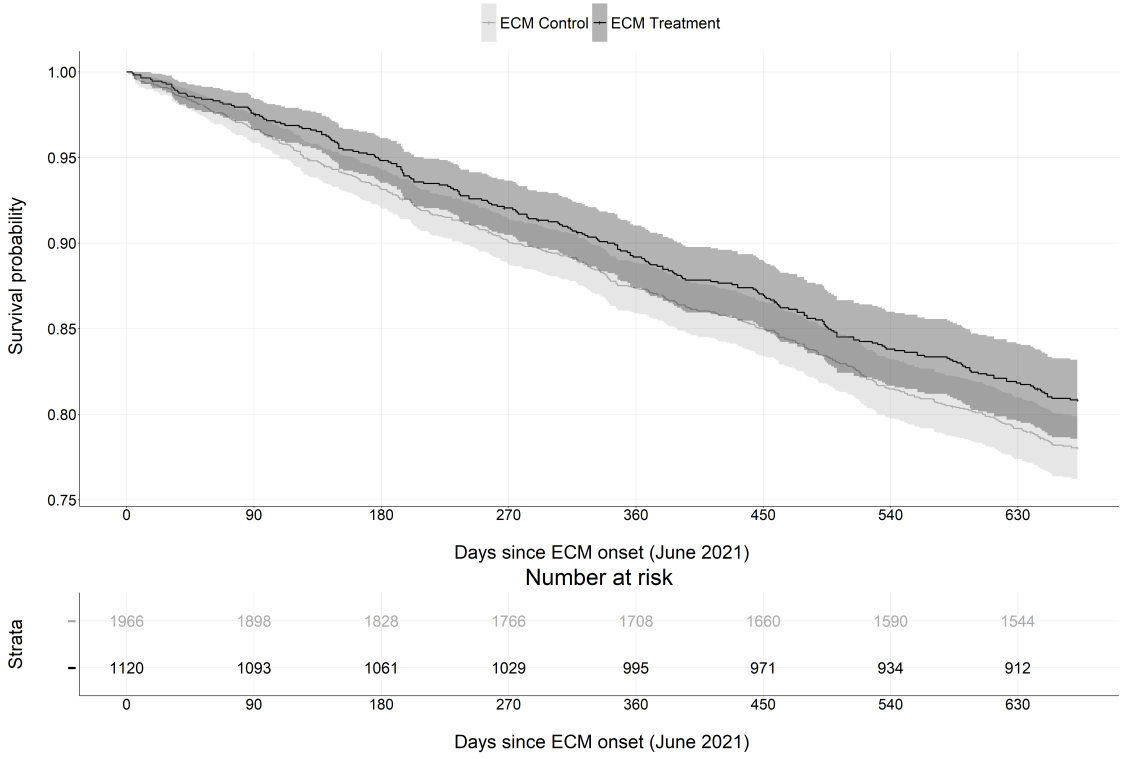
**Dependent variable** in WLS models is defined as a dummy, with 1 assigned to patients who were hospitalized (columns 1-4) or those who died (5-8). Cox Proportional-Hazards Models measures survival times (in days) from the time of ECM onset (28/05/2021) to the first occurrence of the hospitalization (columns 1-4) or to death (columns 5-8). For all columns it is right-censored at the end of the observation period (31/03/2023). For columns 1-4 it is additionally right-censored at the time of death for patients who died without being hospitalised. Standard errors of the coefficients are clustered by doctor and provided in parentheses for (column 1-4). Cox proportional-hazards values are exponentiated to show hazard ratios and the values in parentheses show 95% confidence intervals.

All columns compare **ECM Treatment to ECM control patients**, controlling for fixed effects on the strata level, i.e.

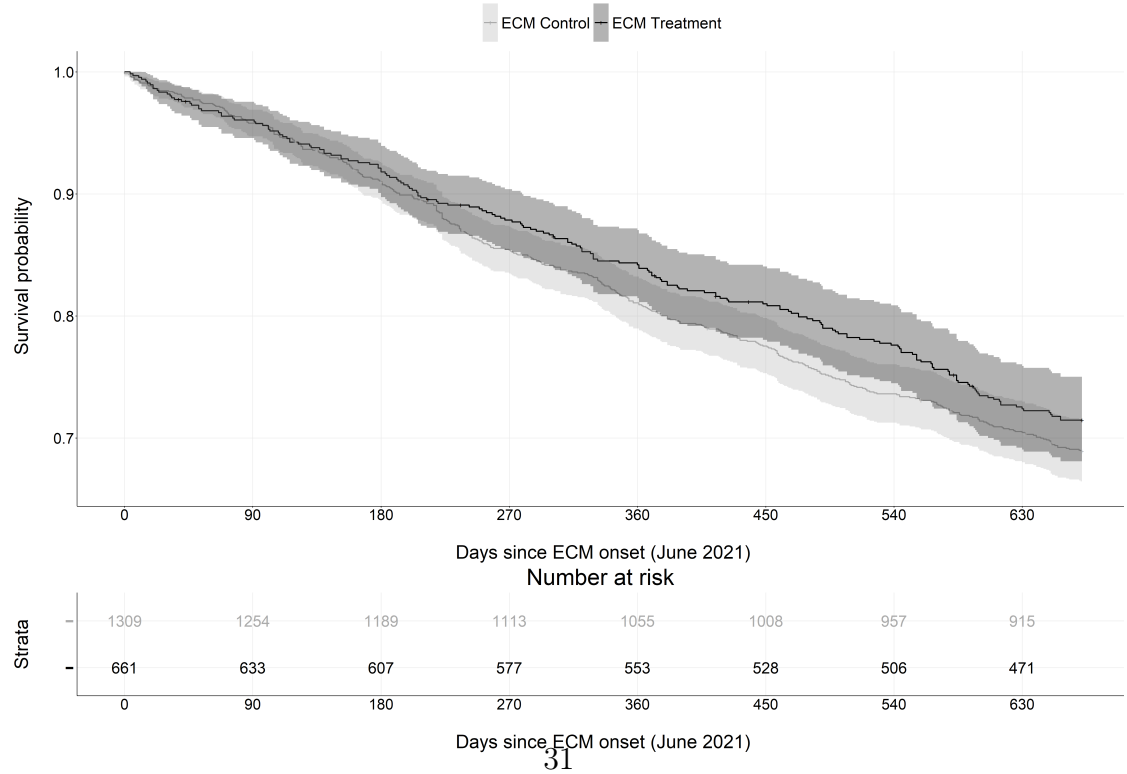
doctor interacted with patient risk classification level. All columns, apart from 1 and 5, also include controls for patients' age and sex. Columns (1)-(2) and (4)-(5) estimate the effect of being assigned to ECM. Columns (3) and (6) estimate the effects of enrolling into ECM, i.e. taking up the assigned treatment, using IV specification. ECM uptake is instrumented with a single first-stage model using ECM assignment as an instrument. Columns (4) and (8) additionally compare the effects of ECM assignment across participating and selected, but non-participating doctors.
The treatment groups are defined as follows: **ECM Control** - patients selected to be in the ECM control at participating doctors, irrespective of their actual treatment status; **ECM Treatment** - patients selected to receive ECM treatment at participating doctors, irrespective of their actual treatment status. The exact **coding definition** of each of the variables is provided in Table A3.

Figure 2: Hospitalization survival curve

(a) Mild-risk patients




(b) Severe-risk patients



# 6 Discussion

The implicit contract structure in most healthcare provision has been based around responsiveness of providers to actute patient concerns. Such a 'reactive' healthcare approach does not systematize a broader plan for patient welfare. Though most doctors advise 'healthy eating and exercise' broadly, there may be substantial gains in health outcomes from reframing the implicit contract between doctor and patient to one that targets the overall health of the patient and makes an individualized care plan towards that end. By broadening the doctor's lens of focus to systematically go beyond individual, currently salient, ailments to identifying and treating issues that may be latent or emerging, a broader plan of care may enable proactive treatment options for improving health outcomes. A frequent sentiment in healthcare is along the lines of 'an ounce of prevention is worth a pound of cure'. The question is how to economically systematize that approach within a modern healthcare system (Newhouse, 2021). While primary care systems in general – and family medicine oriented systems such as Estonia's in particular – are designed to create holistic, longitudinal patient-provider relationships, in practice much primary care remains focused on episodic curative care.

Primary care, especially in family medicine-based systems such as Estonia, now seeks to go beyond such reactive curative care by creating longitudinal patient-doctor relationships. Yet even in such systems, most primary care is de facto focused on specific complaints of acute ill-health by patients. This model does not maximize patient health especially for patients with latent chronic conditions. Individual patients may not identify these conditions at the point at which treatment optimally begins. Inadequate treatment imposes obvious burdens upon patients. Furthermore, given the externalities associated with individual ill-health, there may be a social cost of this sub-optimal level of treatment. Inducing doctors to undertake more holistic care including early diagnostics, particularly for those populations that are vulnerable to complications arising from chronic health conditions, may increase the likelihood of detection and treatment.

This paper evaluates the large-scale implementation of a holistic care program in Estonia – Enhanced Care Management (ECM) – using an RCT that was nationally block-randomized across all primary health care providers ("family doctors"), combined with participatory risk stratification of eligible patients by the doctors and a within-doctor patient-level randomization for final program inclusion. Eligible patients were identified using a common standard of risk of chronic disease using records from the national health insurance fund, which covers

95% of people in the country. For ECM-enrolled individuals, the program shifts the intended relationship between the doctor and patient by the joint development of an explicit contract of care between the doctor and patient. Since there are no punishments for reneging on contract stipulations – as these would be impractical and inconsistent with the nature of the doctor-patient relationship – the intervention aimed to shift the relational contract between the two parties towards a holistic plan for long-term patient welfare.

The availability of comprehensive data for medical claims, diagnoses, and prescriptions – including hospitalization and mortality – for the universe of covered citizens in Estonia allows us to obtain well-powered estimates of ECM program effects on provider behavior and patient outcomes across treatment and control patients at the same clinic. We are further able to investigate spillovers by comparing untreated patients at treatment clinics with eligible patients at control clinics; and to disaggregate effects by the provider-assessed patient health status within treatment clinics. These allow us to bound potential downward biases for within-doctor comparisons (driven by doctor-wide treatment effects relative to non-ECM doctors) as well as potential upward biases (driven by reallocation of effort from control to treatment patients by the same doctors). We identify very minor possible upward biases due to effort reallocation; however, we identify substantial potential spillovers to non-enrolled patients at ECM doctors, suggesting that our within-doctor comparisons are a lower bound of total treatment effects.

We find that the introduction of a patient contract for holistic care meaningfully increases screening, diagnosis, and prescriptions for key chronic tracer conditions by an average of about 10% among treated individuals, at relatively low additional cost to clinics in terms of doctor or nurse time. Rather, the contract seems to shift the nature of care provided. We further observe meaningfully sized (8%) but statistically insignificant downstream effects on patient health outcomes (hospitalization); and we identify a large and significant reduction in mortality risk (as large as 40% reductions) for mild-risk patients in spite of the relatively short follow-up data period. These shifts are in-line with a simple conceptual framework in which relational incentives for holistic care induce doctors to identify health problems earlier than patients and begin treatment closer to an optimal level (Porter et al., 2013). This is effective where the elasticity of response of health status to intervention is higher; typically conceived of being at higher levels of baseline health.

Turning to potential spillovers, we observe evidence of spillovers in a number of realms of care that reduced the need for any patient at a treated clinic to use hospital or nursing services, as well as increases in screening and medication for the same key tracer conditions

among control patients at treated doctors. Downstream, reductions in the likelihood of hospitalization even amongst ECM control patients imply that treated doctors provided both treatment and control patients with guidance that reduced their likelihood of having to use non-primary care services, particularly nursing and rehabilitation services. The precise extent to which doctors sustainably changed their service patterns for their entire patient roster is worthy of further additional examination, as the intervention was not meaningfully aimed at the development of new knowledge for providers. The fact that both knowledge effects and additional relational effects of similar magnitudes can be hypothesized from these results warrants further investigation.

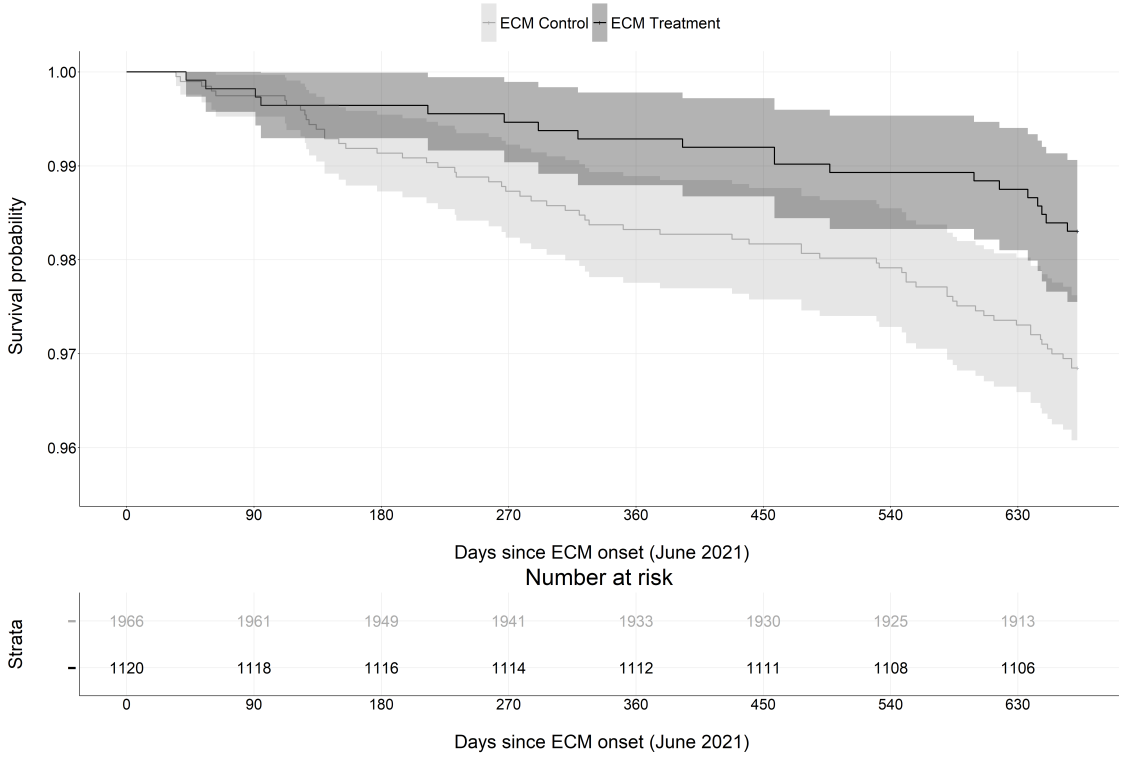
While similar interventions have been implemented in settings with large populations facing multiple chronic conditions, high quality evidence about the effects of these programs is still relatively rare (Stokes et al., 2015; Powers et al., 2020; Smith et al., 2021). This study is relatively unique in being able to connect shifts in relational contracts to changes in service provision to impacts on agent welfare. It does so at a national scale, presenting estimates with strong external validity to the wider health system.[33] It indicates that a relatively limited intervention, focused on shifting the nature of relational contracting, can have substantial impacts on healthcare and public service delivery.

Beyond assessing holistic care plans in a range of other settings, future work might better understand the nature of relational contracting between doctors and patients, and how that relationship can be formulated for better health outcomes. There is a need to understand the response of patients to care plans and holistic care relationships. And given the limited two-year window in which this study was undertaken, a broader assessment of how relational contracting might evolve over time between doctors and patients is an area of research that will strengthen both our understanding of health systems and the value of social interaction in an individual's human capital investments.

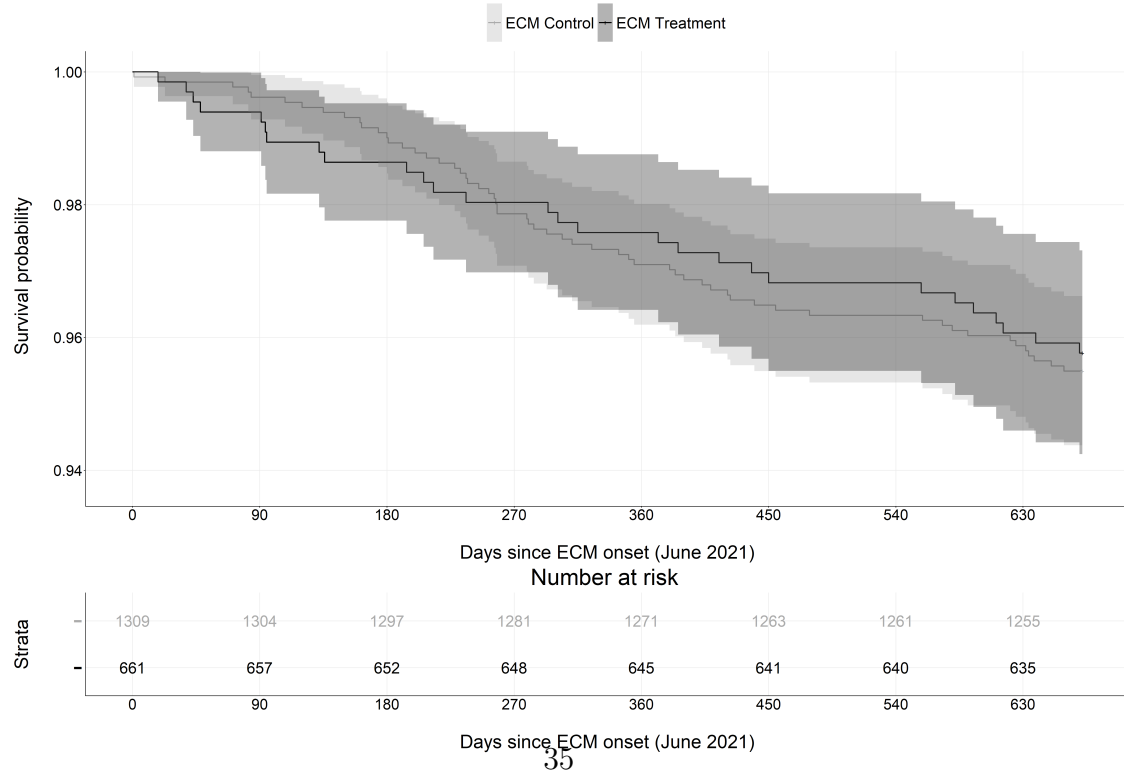
[33]Another strength is the trial's reliance on health system billing records. Using this administrative data source has reduced the cost of the trial and means that the methods and outcomes can be used in other studies and the treated cohorts can be studied longitudinally using the same administrative data source.

Figure 3: Overall survival curve

(a) Mild-risk patients




(b) Severe-risk patients



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# Appendix: For Online Publication

## A1 Conceptual framework

Let a patient's health status $h$ across $k$ domains be $h_{ki}$, in which the optimal treatment approach is where treatment is activated when $h_k < h_k^*$. $h_{ki}$ is stochastic and follows a distribution $f(h_k)$, with $prob[h_k < h_k^*] = \alpha$. The patient reports their health status has dropped to $\hat{h}_k$ when $h_k < \hat{h}_k < h_k^*$, at a health status strictly less than when treatment optimally begins. This occurs with probability, $prob[h_{ki} < \hat{h}_k] = \beta$.

Let us assume that the doctor is motivated by the linear sum of her patient's health. Without information on the health of a patient in a particular domain, the doctor assigns its expectation to an individual, $h_{ki} = E[h_k]$, where in most domains, $E[h_k] > h_k^*$. For simplicity we assume that at baseline the doctor does not pay for diagnostics nor recommend treatment for any of her patients based on this fact.

Suppose that the care plan provides the doctor with a technology to collect data on a series of characteristics, $x_i$, for each patient. For some set of characteristics, $x'$, $E[h_k|x'] < h_k^*$. In this case, the doctor refers the patient with characteristics $x'$ to treatment. Where $\hat{h}_k < E[h_k|x'] < h_k^*$, treatment begins before the patient themselves would have requested it. This can be seen as a direct informational benefit of the care plan intervention.

The doctor can also pay $c$ to identify $h_{ki}$ precisely through undertaking a diagnostic test.[34] If the diagnostic indicates that $\hat{h}_k < h_k < h_k^*$ then treatment can begin and the doctor (and patient) receives a positive benefit from treating the patient before the patient would have requested initiation. If the diagnostic indicates that $h_k > h_k^*$, there is no supplement in patient health and the doctor has invested $c$ without return.

In a similar logic to the above, where the care plan provides a novel means of learning $x_i$, the doctor gains motivation to undertake a diagnostic test when the conditional expectation of health status falls within a strict subset of the distribution that includes $\hat{h}_k < E[h_k|x'] < h_k^*$.

[34] We can conceive $c$ as being made up of a financial component, $c_f$, and a personal component, $c_p$, that is the effort cost of diagnosis including the cognitive, emotional and administrative resources the doctor must invest to engage with the diagnostic process. For example, there is evidence that doctors are sensitive to cost shocks for diagnostic processes (Clemens and Gottlieb, 2014), as well as being sensitive to aspects of their inter-personal relations with patients (Schoenthaler et al., 2012).

The relational aspect of the interaction arises from the fact that once diagnosed, the patient must decide whether to adhere to treatment, or not. Adherence costs the patient $\gamma_{ki}$, which is idiosyncratic to the patient, follows a distribution $g(\gamma_k)$, and is only observed after the diagnostic investment has been made and treatment begun. The patient adheres to the treatment if they perceive the benefits greater than the cost. If the patient adheres to treatment, which occurs with probability $g(\gamma_{ki} < \gamma_k^*)$, the actors get a payoff normalized to 1. If the patient does not adhere to treatment, they get a payoff of 0.[35]

As such, the doctor maximizes,

$$U_D = -c \sum_i T_{ki} + (\alpha' - \beta')A_i \sum_i T_{ki} + \beta' A_i$$

where $T_{ki} \in \{0, 1\}$ is investment in a diagnostic test for domain $k$ of the health of $i$, $A_i \in \{0, 1\}$ is the adherence of patient $i$ to treatment, $prob[h_k < h_k^* | x'] = \alpha'$, and $prob[h_{ki} < \hat{h}_k | x'] = \beta'$.

And the patient maximizes,

$$U_i = (\alpha' - \beta')T_{ki}(-\gamma_{ki}A_i + A_i) + \beta'(-\gamma_{ki}A_i + A_i)$$

In this scenario, the patient wants the doctor to undertake the diagnostic since it costs them nothing and then provides them with an option value of treatment, but wants to then decide whether to adhere to treatment or not based on their individual experience of the treatment. The doctor wants to invest in diagnostics only when $\hat{h}_k < h_k < h_k^*$ and the patient will adhere to treatment.

In a one-shot interaction, the doctor undertakes diagnostics for domain $k$ when $c < [(\alpha' - \beta')g(\gamma_{ki} < \gamma_k^*)]$. Note that where $\alpha - \beta$ (equivalently $h_k^* - \hat{h_k}$) is large, the doctor is more likely to invest in a diagnostic. It is in this case that the information value of a diagnostic test is most valuable since patient signals are a poor predictor of the distance of true health to $h_k^*$.

The care plan introduces both a direct information and a repeated game element in which the doctor and patient can monitor and (relationally) punish each other for a lack of adherence to the care plan. Suppose that the patient discounts next period utility by $\delta$ and we use trigger strategies to illustrate the point. As such, the patient must now weight the cost of adherence today against the option value of diagnostics and potential health gains from

[35] While the conditional distributions of the parameters could be distinct to the unconditional, we leave the interaction out of the discussion for simplicity.

treatment tomorrow.

The patient now values today's adherence at $1/(1-\delta) > 1$ of the one-shot utility from adherence, inducing the patient to adhere to treatment with a higher probability, and the doctor to undertake greater diagnostic work, since the probability of a positive payoff is greater. The doctor now undertakes diagnostics when $c < [(\alpha' - \beta')(1/1-\delta)g(\gamma_{ki} < \gamma_k)]$.

This discussion indicates the various features of the care plan's impact: the first is to make more precise identification of patients who may benefit from diagnostics; the second can be seen as an indirect informational feature, in which the doctor is induced to undertake greater diagnostic work due to the patient's adherence behavior; and the third is that there is a greater incentive for the patient to adhere to treatment once it is prescribed.

## A2 ECM care plans (in Estonian with English translations)

In this subsection we present three examples of care plans developed as a part of the ECM. They serve as illustrations of the contracts the ECM program induced doctor-patient teams to co-develop.

**Treatment plan**

[redacted]

PATSIENT

[redacted]

LÄHEDANE

24h Perearsti nõuandetelefon 1220

**Next consultation**

JÄRGMINE KONSULTATSIOON: 22.02.2024

# Raviplaan

**Health indicators**
Health indicator

Blood pressure right arm
Body weight
Body mass Index (BMI)
Blood pressure right arm
Body weight
Body Mass Index (BMI)

## TERVISENÄITAJAD

**Individual goal**

**Value**

| TERVISENÄITAJA | INDIVIDUAALNE EESMÄRK | VÄÄRTUS |
|---|---|---|
| Vererõhk parem käsi | 120(100-140) / 80(70-90) | 166/91 (03.08.2023) |
| Kehakaal | | 96 (03.08.2023) |
| Kehamassiindeks (KMI) | 18.5-25 | 37 (03.08.2023) |
| Vererõhk parem käsi | 120(100-140) / 80(70-90) | 115/72 (22.11.2023) |
| Kehakaal | | 93 (22.11.2023) |
| Kehamassiindeks (KMI) | 18.5-25 | 35.9 (22.11.2023) |

**Diseases**
Disease

Hypertension, essential, primary
arterial, hypertensive disease
Obesity

## HAIGUSED

| HAIGUS | KOOD |
|---|---|
| Hüpertooniatõbi e essentsiaalne e primaarne arteriaalne hüpertensioon e kõrgvererõhktõbi | I10 |
| Rasvumus | E66 |

**Medications**
Medicine

## RAVIMID

**Active substance**

**Dosage**

**Disease**

**Note**

| RAVIM | TOIMEAINE | ANNUSTAMINE | HAIGUS | MÄRKUS |
|---|---|---|---|---|
| | Perindoprilum+Indapamidum, 2,5mg+0,625mg | 1 tablett 1 korda päevas | I10 | |

1 tablet 1 time a day

## NÕUANNE JA TEGEVUSKAVA

Helistage 112, kui Te ei saa hingata, tekib tugev äkkvalu või ei saa liigutada kätt, jalga, nägu (ei saa vilistada). Muu erakorralise terviserikke korral pöörduge lähima haigla erakorralise meditsiini osakonda (EMO). Esimesel võimalusel teavitage tekkinud olukorrast perearsti

**Advice and action plan**
Call 112 when you can't breathe, you experience severe sudden pain or you can't move your head, leg, or face (you can't whistle), in case of other emergency health problems go to the emergency department of the nearest hospital (ER). As soon as possible inform your family doctor about the situation.

---

Söön regularselt ja väikeseid koguseid, õhtul piiran suurte toidukoguste söömist.
Jätkan igapäevaselt liikumist, et kehakaal langeks. Ujun 3x nädalas.
Proovin liikuda päevas 6000 sammu. Ravimeid võtan regulaarselt.
Mõõdan ja jälgin kodus vererõhku.
Vähendan toidus, soola, suhkru ja kõvade rasvade sisaldust.
Proovin langetada kuus 1-2 kg kehakaalu. 1 kg juba langenud
Kaal langenud 3 kuuga 3 kg, RR raviga normaliseerunud, RR kodus 115/75 mmhg piires, ujub 1 x nädalat. õhtul toidukogust piiranud. Jätkab kaalu langetamist. Kontroll 3 kuu möödudes.

Kui täheldan enesetundes muutusi (rindkerevalu, peavalu vm), teavitan koheselt oma perearsti/pereõde.

Erakorralise haiglasse sattumise korral
teavitan sellest ka oma perearsti/pereõde.

OLULISED KONTAKTID

Perearstikeskus [redacted]
perearstid
Perearst [redacted]
Abiarst [redacted]
Pereõde [redacted]
Pereõde [redacted]
Tel. [redacted]
E-R 8.00 – 16.00
24h avatud Perearstide nõuandeliin 1220

Kiirabi 112

I eat regularly and in small amounts, in the evening I limit eating large amounts of food.
I continue to exercise daily to lose weight. I swim 3 times a week.
I measure and monitor my blood pressure at home.
I try to walk 6000 steps a day. I take medicine regularly
I reduce the content of salt, sugar and hard fats in food. I try to lose 1-2 kg of weight per month. 1 kg already dropped
Weight lost 3 kg in 3 months, normalized with RR treatment, RR at home within 115/75 mmhg, swims once a week. limited the amount of food in the evening. Continues to lose weight. Check after 3 months.
If I notice changes in how I feel (chest pain, headache, etc.), I immediately inform my family doctor/family members.
In the event of an emergency hospitalization, I will also inform my family doctor/family nurse
IMPORTANT CONTACTS
Family doctor's centre Family doctor [redacted]
family doctors
Family doctor [redacted]
Assistant doctor [redacted]
Family nurse [redacted]
Family nurse [redacted]
Tel [redacted]
Mon-Fri 8:00-16:00
24-hour family doctor advice line 1220

Helistage 112, kui Te ei saa hingata, tekib tugev äkkvalu või ei saa liigutada kätt, jalga, nägu (ei saa vilistada). Muu erakorralise terviserikke korral pöörduge lähima haigla erakorralise meditsiini osakonda (EMO). Esimesel võimalusel teavitage tekkinud olukorrast perearsti

Call 112 when you can't breathe, you experience severe sudden pain or you can't move your head, leg, or face (you can't whistle), in case of other emergency health problems go to the emergency department of the nearest hospital (ER). As soon as possible inform your family doctor about the situation.

**Treatment plan**

# Raviplaan

[redacted]

Viimane perearsti või pereõe visiit08.11.2023

**Next consultation**

**JÄRGMINE KONSULTATSIOON:**

## TERVISENÄITAJAD

**Health indicators**
Health indicator

Blood pressure
Body weight
Body Mass Index (BMI)

**Individual goal**

**Value**

| TERVISENÄITAJA | INDIVIDUAALNE EESMÄRK | VÄÄRTUS |
|---|---|---|
| Vererõhk | 120(100-140) / 80(70-90) | 140/100 (21.09.2022) |
| Kehakaal | | 110.000 (21.09.2022) |
| Kehamassiindeks (KMI) | 18.5-25 | 32.1 (21.09.2022) |

## HAIGUSED

**Diseases**
Disease

Non-insulin dependent diabetes mellitus
Disorders of lipoprotein metabolism and other lipidaemia
Panic disorder
Hypertension essential arterial hypertension
Gastroesophageal reflux disease without esophagitis

| HAIGUS | KOOD |
|---|---|
| Insuliinisõltumatu suhkurtõbi | E11 |
| Lipoproteiinialainevahetuse häired ja muud lipideemiad | E78 |
| Paanikahäire | F41.0 |
| Hüpertooniatõbi e essentsiaalne arteriaalne hüpertensioon | I10 |
| Ösofagiidita gastro-ösofageaalne tagasivooluhaigus | K21.9 |
| Prostatahüperplaasia e eesnäärmesuurenemus | N40 |

## RAVIMID

**Medications**
Medicine

**Active substance**

**Dosage**

**Disease**

**Note**

| RAVIM | TOIMEAINE | ANNUSTAMINE | HAIGUS | MÄRKUS |
|---|---|---|---|---|
| | Vortioxetinum 5mg 56TK, õhukese polümeerikattega tablett | 1 tablett 1 x päevas | F32.1 | meeleolule |

1 tablet 1 time a day

mood

Helistage 112, kui Te ei saa hingata, tekib tugev äkkvalu või ei saa liigutada kätt, jalga, nägu (ei saa viilstada). Muu erakorralise terviserikke korral pöörduge lähima haigla erakorralise meditsiini osakonda (EMO). Esimesel võimalusel teavitage tekkinud olukorrast perearsti [redacted]

Call 112 when you can't breathe, there is a sudden severe pain or you can't move your head, leg, face (can't whistle), in case of other emergency health problems go to the emergency department of the nearest hospital (ER). As soon as possible inform your family doctor about the situation.

| | | | | |
|---|---|---|---|---|
| | Esomeprazolum 40mg 56TK, gastroresistentne kõvakapsel | 1 kapsel 1 x päevas raviminfo järgi | K21.9 | maokaitse |
| | Metforminum 500mg 120TK, õhukese polümeerikattega tablett | 1 tablett 2 x päevas | E11 | alustab diabeediravi |
| | Moxonidinum 0.4mg 60TK, õhukese polümeerikattega tablett | 1 tablett 1 x päevas | I10 | vererõhule |
| | Atorvastatinum 20mg 60TK, õhukese polümeerikattega tablett | 1 tablett 1 x päevas õhtul | E78 | kolesterooli alandav |
| | Metforminum+Empagliflozinum 1000mg+12.5mg 120TK, õhukese polümeerikattega tablett | 1 tablett 2 x päevas | E11 | diabeediravi tõhustamine, uus kombineeritud preparaat lisatud |

Gastric protection
Begins diabetes treatment
To blood pressure
Cholesterol lowering
Diabetes treatment enhancement, new combined preparation added

1 capsule 1 x day, see drug information; 1 tablet 2 x day; 1 tablet 1 x day
1 tablet 1 x day evening' 1 tablet 2 x day

## NÕUANNE JA TEGEVUSKAVA

Eesmärk I alustab diabeediravi, lähieesmärk normaliseerida veresuhkru näitajad,võiks ravi foonil olla vahemikus 6-6,3 mmol/l
II hoida sidet psühhiaatriga, tarvitada meeleolu rohtu ja tagasilanguse korral kindlasti taaspöörduda psühhiaatrile. Pats toetab pere ja teavitatud ka võimalusest psühholoogi seansse saada perearsti teraapiafondi kaudu. Uuus kontakt 6 nädala pärast.
III eesmärk alustada uuesti või jätkata statiinraviga.
19.12.2022 II visiit - pats 6kuud suitsuvaba, on motiveeritud jätkama elustiili muutust. Vereanal ravi foonil üldkolesterool, LDL, glükoos languses, kolester isegi eesmärkväärtuses. Teadlik ravimitest ja jätkab ravimite tarvitamist. Antidepr ravi foonil meeleolu parem, tagasilangust ei ole hetkel olnud. Eesmärk hoida hetketulemust. Uus visiit 03.2023 kokku lepitud
*27.03.2023 Riskipats III visiit, kokkuvõtete tegemine. Meeleolu pos dünaamikaga. 03.2023 viimane psühhiaatri visiit, suunatud edasi vaimse tervise õe jälgimisele. Suitsetamine ei, alkohol ei. HbA1c 7,4 %
Glükoos 13,3 mmol/l. Glükoosiväärtused 3 kuu jooksul hüppeliselt tõusnud. D vit väärtus madal, pole D vit juurde tarvitanud. Uus eesmärkväärtus on tõhustada diabeediravi. Kolesterooliväärtused eesmärkväärtuses ravi foonil. Diabeediravi tõhustatud, lisatud kombineeritud ravipreparaat. Kontroll 2kuu pärast

### Advice and action plan

Goal I is to start diabetes treatment, the main goal is to normalize blood sugar levels in the background of treatment. Should be in the range of 6-6.3 mmol/l. I keep in touch with the psychiatrist, use mood medicine and in case of relapse, definitely return to the psychiatrist. Patient supports the family and has also been informed of the possibility of receiving psychologist sessions through the family doctor's therapy fund. New contact in 6 weeks.
Objective III restart or continue statin therapy
19.12.2022 II visit - patient 6 months smoke-free, is motivated to continue the lifestyle change. Against the background of intravenous treatment, total cholesterol, LDL, glucose are decreasing, cholesterol is even at the target value. Aware of medication and continues to take medication. The mood is better on the background of Antidepr treatment, there has been no relapse at the moment. The goal is to keep the current result. New visit 03.2023 arranged
27.03.2023 Risky patient III visit, making summaries. Mood pos. with dynamics. 03.2023 last psychiatrist's visit, forwarded to follow-up by a mental health nurse. No smoking, no alcohol. HbA1c 7.4% Glucose 13.3 mmol/l. Glucose values have skyrocketed within 3 months. D vit value low, did not take more D vit. The new target value is to enhance diabetes treatment Cholesterol values in the target value against the background of treatment. Diabetes treatment enhanced, added combined treatment preparation. Check after 2 months.

**Treatment plan**

# Raviplaan

[redacted]

Viimane perearsti või pereõe visiit: 08.11.2023

**Next consultation**

**JÄRGMINE KONSULTATSIOON: 24.11.2023**

## TERVISENÄITAJAD

**Health indicators**
Health indicator

**Individual goal**

**Value**

| TERVISENÄITAJA | INDIVIDUAALNE EESMÄRK | VÄÄRTUS |
|---|---|---|
| Vererõhk | 120(100-140) / 80(70-90) | 180/120 (31.08.2023) |
| Vööümbermõõt | <102 | 110.00 (15.10.2021) |
| Kehakaal | | 113.500 (30.08.2023) |
| Kehamassiindeks (KMI) | 18.5-25 | 35.4 (30.08.2023) |

Blood pressure
Waist circumference
Body weight
Body Mass Index (BMI)

## HAIGUSED

**Diseases**
Disease

| HAIGUS | KOOD |
|---|---|
| Hüpertooniatõbi e essentsiaalne arteriaalne hüpertensioon | I10 |

Hypertension essential arterial hypertension

## RAVIMID

**Active substance** | **Dosage** | **Disease** | **Note**

| RAVIM | TOIMEAINE | ANNUSTAMINE | HAIGUS | MÄRKUS |
|---|---|---|---|---|
| Perindoprilum+Amlodipinum 10mg+5mg 30TK, tablett | | 1 tablett 1 x päevas | I10 | Vererõhule 1x H |
| Olmesartanum medoxomilum 20mg 28TK, õhukese polümeerikattega tablett | | 1 tablett 1 x päevas | I10 | Uus vererõhu preparaat, 1 tbl H |

**Medications**
Medicine

1 capsule 1 x day
1 capsule 1 x day

For blood pressure 1 x H
New blood pressure preparation 1 tbl H

## NÕUANNE JA TEGEVUSKAVA

Riskipats I visiit: RR 180/120 mmHg, kaal 113,5 kg, KMI 35,4. Pikemas perspektiivis sooviks ise kaaluda 99 kg. Lähieesmärk 2-3 kg kuus kaalu langetada. Abikaasa toetus

**Advice and action plan**

Risky patient I visit: RR 180/120 mmHg, weight 113.5 kg, BMI 35.4. In the long term, I would like to weigh 99 kg. The immediate goal is to lose weight by 2-3 kg per month. Spousal support…

olemas, pidasid plaani alustada septembris Fitlapi toitumisprogrammi järgi. See oleks pats eriti mugav variant kui teine pereliige ka toitumist jälgib ja toidu valmistab. Alkoholi osas pigem eelistab kokteili kange alkoholiga. Alkoholiühikut ei oska välja tuua. II eesmärk: tervisekampaania "Septembris ei joo" on suurepärane võimalus kaasa minekuks ja pidada 4 nädalat alkoholipaastu.
Eesmärk III: Hoida RR väärtused kontrolli all. Alustab ravi uue RR preparaadiga, jälgida RR väärtuseid, võimalusel RR päevik. Uus visiit 4 nädala pärast.
29.09 vahevisiit, RR ravim kõrvaltoimega+ raviefekt väike. Vahetame preparaadi. RR 150/113 mmHg, saatekiri kardioloogile, uuringud

…available, planned to start following the Fitlap nutrition program in September. This would be a particularly convenient option if another family member also monitors the diet and prepares the food. Regarding alcohol prefers a cocktail with strong alcohol. Can't figure out the alcohol unit. Goal II: the health campaign "Don't drink in September" is a great opportunity to go along and observe an alcohol fast for 4 weeks. Goal III: Keep RR values under control. Starts treatment with a new RR preparation, track RR values, if possible RR diary. Another visit in 4 weeks. 29.09 intermediate visit, RR drug with side effect + treatment effect small. Let's change the preparation. RR 150/113 mmHg, referral to a cardiologist, examinations

## A3 Chronic patients' registry

In this subsection we present the step-by-step approach taken by EHIF to determine whether a patient is 'chronically ill' and therefore eligible for the ECM programme.

1. **Aim**

Aim of the current development request is to generate chronic condition patient's registry based on EHIF (Estonian Health Insurance Fund) data. New registry and tool will help FP (family physician) better identify, treat and follow-up patients with chronic conditions.

2. **Changeable business process. Source data**

Generate web based registry that consists of patients´ **data presented by EHIF.**
**Displayed on dashboard as following (marked in bold in Estonian):**

- **Isikukood** (patient national id)
- **Patsiendi nimi** (patients name)
- **Vanus** arvutatakse isikukoodist (päringu tegemise hetkel) (Age, calculated from national ID code on each query)
- **Patsiendi kontaktid** (aadress, telefon) pärineb kindlustatute registrist (Personal info: address, phone etc.) from the Registry of the Insured
- **Jälgimisel** – väärtused jah/ei (Type of Patient - Known or unknown),
- **Metaboolse triaadi kombinatsioon** - ("Combination of Triad )-
  Displayed in 3 separately columns, by dgn of following diseases (accordinf to ICD-10 classificator):
  1. E10-E14 (diabeet),
  2. I10-I15 (hüpertensioon),
  3. E78 (hüperlipideemia)
- **Ravi järgimine (triaadiga seotud)** (Adherence to treatment)
  - If a patient did not buy any of prescribed medicaments from class A10A or A10X or A10B for diagnosis E10-14 during 90 days, display notification sign in report.
  - If a patient did not buy any of prescribed medicaments from class C02-C03, C06-C09 diagnosis I10-I15 during 90 days, display notification sign in report, exclude C01, C04 ja C05.
  - If a patient did not buy any of prescribed medicaments from class C10AA, C10BA, C10BX diagnosis E78 during 90 days, display notification sign in report.

  *Interval of 90 days is due to the fact that the majority of them belonging to the group of medicines are available in large (90 tbl) packs.

- **Sihtrühma kuulumine (surnud, vahetanud nimistut)**

Identify whether patient belongs to list or not, died during pilot. Data is received/collected from the register. Display one of the exclusion reasons – doctor cannot change it.

- **Arhetüüp** (Distribution of Patients Across Different Archetypes):
- **Kaasuvad haigused** (Total Number of Comorbidities) – kuvatakse NR, võimalik näha ka täpsemalt haiguseid patsiendi kohta
- **Viimane haiglaravi ehk statsionaarne** ("Last hospital discharge between 01.01.2015-today)"
- **Viimane perearsti visiit** (ajavahemikul 01.01.2015-today) = "Last FP visit at pilot start")
- **Sotsiaalne staatus (**Social & behavioural conditions), Identify whether patient is insured with insurance type 11, 27, 26, 34 12, 42,44,45,49,50. **Displayed on dashboard as**

| | |
|---|---|
| X | ✓ |

Näidata koodi (võimalusel)

And **data inserted by FP**:

**Patsiendi välistamise põhjus, valida sobiv põhjus loendist: (Välista need patsiendid, kellel on vähem kasu piloodis osalemisest)** ("Patient to be excluded, Reason for exclusion (from drop-down list)", süsteem talletab muudatuse kp – muuta saab korduvalt, piiranguid ja kontrolle ei ole

- **Psüühika probleemide tõttu ettearvamatu/ohtlik** (Safety considerations)
- **Ravi taktikaliselt liiga keeruline** (Severity)
- **Sotsiaalselt/käitumuslikult liiga suurte erivajadustega** (Patients in complete denial/unable to understand their condition(s)
- **Ei soovi osaleda/tuleb iseseisvalt toime** (Patients well-versed and knowledgeable about their needs with a high ability for self-care may not benefit from additional resources)

    - **Mujal ravil** (Existing relationships with other providers such as specialist physicians (e.g. oncologist), private care managers, or institutional care providers (group homes, assisted living)
- **Osalemise kutse edastamine** ("Patient Invited (Date)"
- **Patsiendi nõustumine** ("Patient Accepted (Date)"
- **Raviplaan** (Hyperlink – eraldi avatav vaade kus osaliselt sisestatavad väljad) (Care plan) consisted of following 16 fields, sama vorm prinditavana pdf-s:
  ***Patsiendi nimi** –use same data that found previously
  ***Isikukood** –use same data that found previously
  ***Patsiendi tel nr** - use same data that found previously
  ***Patsiendi sugulase tel nr** – inserted by FP
  ***Ravimid** (Nimekiri kõigist ravimitest, mida patsient hetkel võtab) – data from "EHK Retseptikeskus". Ainult ATC koodid, viimane väljaostmise kuupäev, ajavahemikul 01.01.2015-31.12.2016
  ***Patsiendi tervise vajadused** (Kokkuvõte kõikidest aktiivsetest meditsiinilistest probleemidest ja põhiküsimustest, mida patsient soovib lahendada; patsiendi tervisevajadused, sealhulgas sotsiaalsed probleemid ja kaasuvad haigused) (free text field –inserted by FP (max 200 signs)
  ***Patsiendi eesmärgid** (Sõnastage iga eesmärk konkreetse, mõõdetava ja täitmise tähtajaga) (free text field inserted by FP, max 200 signs)
  ***Perearsti meeskonna koosoleku viimane kuupäev** – dates for case management meetings inserted by FP during the 01.02-31.08.2017
  ***Tegevusplaan** (selge tegevuskava, mida patsient ja ravimeeskond peaks kokkulepitud eesmärkide saavutamiseks järgima) (free text field inserted by FP (max 200 signs)
  ***Oluliste kontaktide nimekiri** (Nende hulka kuuluvad perearstikeskuse telefoni number, tööajaväline telefoninumber, ravimeeskonna õe kontaktinformatsioon) (free text field inserted by FP (max 200 signs)
  ***Ravi ülekandumine (**Sõnastage, mida patsient peaks tegema haiglasse sattumisel (nt helistama ravimeeskonnale, teavitamaks perearsti/õde) (care transitioning free text field inserted by FP (max 200 signs)
- **Haiglaravi kuupäev (piloodi ajal) (Hospital Discharge Dates)**
- **Viimane telefonikõne patsiendile** (kpv) (Phone Call Dates)
- **Järgmise visiidi kuupäev (**"Next appointment", Date)
- **Sotsiaalsete vajaduste tuvastamise kp (**"Social Need Identified (Date)"
- **KOV/Sotsiaaltöötajaga suhtlemise viimane kp (**Social Resource Connection Made (Date)

**Main terminology through the whole document**

- 24 months preceding the reference period of the algorithm = 01.01.2013-31.12.2014
- The reference period for the algorithm (i.e. timeframe over which diagnoses are considered) is the last 24 months = 01.01.2015-31.12.2016
- The reference date is the date of running the algorithm (e.g. the date when the pilot is supposed to start) = 01.02.2017
- **FP** = Family practitioner (perearst/PA)
- **Claim** = claim for provided treatment (**RTA** haigekassa mõistes) not prescription nor card for medical device)
- **Date of claim =** in current document we use **closing/completion date of claim** (raviarve lõpetamise kp)

**Claims for specialist care**
Ravitüüp 1; 2; 15; 16; 18; 19; 20
Pakitüüp: 70;71;20;85

**Claims for FP**:
Pakitüüp: 80
Kõik arved (ka nullarved)

- **Target group** consists of people aged ⩾18 (need, kes 01.01.2013-31.12.2014 lõppenud arvetel olid juba 18a vanad)

**Step I (Esimene valim)**

1.1. Identify patients with primary OR secondary diagnoses of E10-E14 (ie diabetes/DM), I10-I15 (ie hypertension/HTN), E78 (ie hyperlipidaemia/Lipidm) for the period 01.01.2015-31.12.2016. – form a list of all found patients – mark column HTN/Lipidm/DN with X when corresponding diagnose is found, these patients are **Patsient jälgimisel (KNOWN)**

**Triad Displayed on dashboard in 3 columns**

**Step II (teine valim)**

1.2. Identify patients with primary OR secondary diagnoses of E10-E14 (ie diabetes/DM), I10-I15 (ie hypertension/HTN), E78 (ie hyperlipidaemia/Lipidm) for the period 01.01.2013-31.12.2014. – form a list of all found patients – mark column HTN/Lipidm/DN with X when corresponding diagnose is found and same patients are not found in step 1.1

1.3. For these patients (step 1.2) determine the amount of FP visits they had between 01.01.2015-31.12.2016 (meaning: total amount of services with codes: 9001, 9002, 9003, 9004, 9015, 9017 (teenused kokku))

Exclude patients that had over 4 FP visits (patsiendid kuni 4 külastusega jäävad valimisse) during the 01.01.2015-31.12.2016. As explained above, the reason for doing so is that we want to exclude unknown patients that only fall into this category due to coding issues
Remaining patients are: **Patsient ei ole jälgimisel (UNKNOWN)**

**StepIII (Kolmas valim):**
Exclude from the list patients that have received treatment due to any diagnose during 01.07-31.12.2016 of:
**pahaloomuline kasvaja** acute cancer C00-C97, D0, D4, D37, D38, D39 and Z51

and from period 2015-2016:
**skisofreenia:** F20
**neerupuudulikkus ja neerudialüüs:** N17-N19, Z49, Y84.1, Z99.2
**kaasasündinud väärarengud**: Q0-Q8
**harvaesinevad haigused**: F01.1, D21.9, D47.4, D48.9, D56.0, D82.4, E70.3, E75.5, E80.0, E85.0, G47.3, H16.3, H49.8, I78.8, K90.8, M60.9, N04.1, R23.8

**Step IV (Neljas valim)**
Identify whether patients had any diagnosis in any care setting during 01.01.2015-31.12.2016 belonging to the different chronic conditions with primary, secondary diagnoses displayed on dashboard – Estonian text in bold:

1) **aneemia:** D50-D53, D55, D58, D61, D63, D64, D59.0, D59.1, D59.2, D59.4, D59.5, D59.6, D59.7, D59.8, D59.9, D60.0, D60.8, D60.9
2) **kilpnäärme haigusseisundid:** E01-E05, E07, E06.1, E06.2, E06.3, E06.5, E06.9
3) **rasvumus:** E66
4) **astma** J45-J46
5) **alumiste hingamisteede kroonilised haigused**: J40-J44, J47
6) **krooniline südamepuudulikkus:** I11.0, I13.0, I13.2, I50.0, I50.1, I50.9
7) **südamehaigused**: I44, I45, I47, I49
8) **peaaju transitoorse isheemia atakk (TIA) ja peaaju veresoonte haigused**: G45, I60-69
9) **kodade virvendus ja laperdus**: I48
10) **ainete sõltuvus**: F11-F19, F55, Z71.5, Z81.3, Z81.4
11) **alkoholi kuritarvitamine**: F10, Z71.4, Z81.1
12) **meeleoluhäired**: F30-F39
13) **dementsus**: F00-F03, G30-G31, R54, F05.1
14) **nägemise ja kuulmishäired**: H54.1, H54.2, H54.0, H54.9, H90, H91,
15) **funktsiooni nõrkus ja sellest tulenevad riskid**: R54, W00, W04-W08, W10, W18, W19, R41.81, Z91.8
16) **artroosid**: M15-M19
17) **puriini- ja pürimidiiniainevahetuse häire, podagra**: E79, M10
18) **prostatiit**: N40
19) **alajäsemete veenilaiendid** : I83, I87.2
20) **maksahaigused**: K70, K73-K74, K76, K71.3, K71.4, K71.5, K71.7, K72.1, K72.7, K72.9
21) **ateroskleroos**: I65, I66, I70, I67.2, I73.9
22) **osteoporoos**: M80-M82
23) **koletsüstiit**: K80, K81.1
24) **somatoformsed häired**: F45

25) **hemorroidid**: I84
26) **soole divertiikul- e sopististõbi**: K57
27) **reumatoidartriit**: M05-M06, M79.0
28) **südameklappide haigusseisundid**: I34-I37
29) **neuropaatiad**: G50-G64
30) **vertiigo e peapööritus**: H81-H82, R42
31) **inkontinentsus e kusepidamatus**: R32, N39.3, N39.4
32) **neeru- ja ureeteri- e kusejuhakivi**: N20
33) **psoriaas**: L40
34) **migreen**: G43-G44
35) **parkinsoni tõbi**: G20-G22
36) **mao-söögitoru haigused**: K21, K25.4, K25.5, K25.6, K25.7, K25.8, K25.9, K26.4-K26.9, K27.4-K27.9, K28.4-K28.9, K29.2-K29.9
37) **hüpotensioon**: I95
38) **kõne ja keele spetsiifilised arenguhäired**: F80
39) **söömishäired**: F50, R63.0
40) **epilepsia**: G40
41) **ärevushäire**: F40-F41
42) **südameisheemia**: I20-I25

Displayed on dashboard as **Kaasuvad haigused** (Total Number of Comorbidities), display number and option to display text for all found comorbidities
**1-7** – write down informations so this can be displayed in detail to FP
(Lugeda kaasuvad haigused kokku (ridu), ja need kellel on üle 7 jäävad valimist välja).

**Step V**
For the list of all remaining patients conditions considered for the algorithm during the 01.01.2015-31.12.2016 find relevance of below 4 groups of Archetype (arhetüüp)
**Kardiovaskulaarne/CVD:**

- G45,
- I20-I25,
- I48.0,
- I11.0, I13.0, I13.2, I50.0, I50.1, I50.9

**Hingamisteed/Resp.**

- J40-J44, J47,
- J45-J46

**Vaimsed häired/Mental**

- F10, Z71.4, Z81.1,
- F00-F03, G30-G31, R54, F05.1,
- F11-F19, F55, Z71.5, Z81.3, Z81.4;
- F30-F39

**Funktsionaalne häire/Functional**

- H54.1, H54.2, H54.0, H54.9, H90, H91,
- R54, W00, W01, W04-W08, W10, W18, W19, R41.81, Z91.8

**Exclude patients who:**

- **Have no conditions from group CVD AND group Resp**
- **Have over 2 CVD conditions**
- **Have over 1 mental conditions**

**Täienda leitud valimit andmetega:**

1. Date of their **last acute hospital visit** for the period 01.01.2015-today (Displayed on dashboard as „Viimane haiglaravi“ **dd.mm.yyyy** (date of "Last hospital discharge”)
2. Date of the **last FP visit (**Displayed on dashboard as “Viimane visiit perearsti juurde” **dd.mm.yyyy** (date of "Last PHC visit)"**)** between 01.01.2015-today.

## A4 Experimental design of RCT

At the start of the Enhanced Care Management (ECM) program, the Estonian Health Insurance Fund (EHIF) identified 410 clinics (containing 766 doctors) who were eligible for participation. The study team then excluded 13 clinics which had participated in the pilot study, 3 clinics with a single practicing doctor, 19 clinics with five or more practicing doctors, as well as 3 clinics that were not operational at the time. The last of these constraints arose from the fact that Estonia's larger clinics are operated on a distinctive business model to smaller clinics, with greater specialization in roles and a more distributed management of patient experience.

The research team was provided with a dataset of all the clinics, linked providers, with their annual QBS score.[36] This was the basis for construction the sampling frame for the provider randomization. In order to construct performance blocks for randomization of non-excluded clinics, we used the QBS data and management scores for 2019. QBS is Estonia's performance-based incentive program. Table A1 provides an overview of QBS compliance guidelines.

We constructed a need-adjusted QBS score re-weighting each indicator based on the experience of the scheme, awarding proportional credit to providers at an indicator level and adjusting the coverage rates for providers based on the patient need (Daniels et al., 2024). For sampling stratification, we use the 'need-adjusted' scores for Domain II. The management score is a sum of points awarded on 15 indicators about the clinic's working and managerial practices. The average score per clinic on management indicators is 10 and the average need-adjusted QBS score per clinic is 306. Because the management score was only available at the level of clinic, we use the average QBS score of the clinic and the total management score of the clinic for the sampling.

At the first stage, clinics were stratified into randomization blocks using coarsened exact matching (CEM), by which clinics were grouped according to their performance on QBS and management scoring, the two primary pre-existing methods of evaluation employed by EHIF for performance metrics. The coarsened exact matching algorithm allowed us to create

[36]To motivate providers to provide quality services as determined by the Estonian Health Insurance Fund, a small performance-based element is included in doctor payments called the Quality Bonus System (QBS). It accounts for a relatively small amount (2-4%) of total provider compensation (World Bank, 2018). The initial goal of the QBS system was to signal to family doctors that in a new family medicine system of primary care, it was their responsibility to focus on improving preventive care and management of chronic disease.

Table A1: QBS compliance guidelines

| Category | Indicator | Description | Measurement |
|---|---|---|---|
| Diabetes - type II | Monitoring | Glycosylated haemoglobin | 1 X year |
| | | Creatinine values | |
| | | Cholesterol values | |
| | | Cholesterol fraction values | 1 X 3 years |
| | | Counselling for chronic patient | 1 X year |
| DIabetes - type II | Medication | Prescribed for all type II diabetes patients | 6 prescriptions in 14 months |
| Hypertension I (low risk) | Monitoring | Glucose or glycosylated haemoglobin | 1 x in 3 years |
| | | Cholesterol | |
| | | Counselling for chronic patient | 1 X year |
| | | Appointment by family nurse | |
| Hypertension II (moderate risk) | Monitoring | Cholesterol determined for patients under 80 years of age | 1 X year |
| | | Cholesterol fractions determined for patients under 80 years of age | |
| | | Glucose or glycosylated haemoglobin | |
| | | Creatinine | |
| | | ECG | 1 x in 3 years |
| | | Counselling for chronic patient | 1 X year |
| | | Appointment by family nurse | |
| Hypertension III (high risk) | Monitoring | Cholesterol determined for patients under 80 years of age | 1 X year |
| | | Cholesterol fractions determined for patients under 80 years of age | |
| | | Glucose or glycosylated haemoglobin | |
| | | Creatinine | |
| | | Counselling for chronic patient | |
| | | Appointment by family nurse | |
| Hypertension medication 1 | Medication | Percentage of active ingredients based prescriptions for hypertension patients (all risk levels) | 1 X year |
| Hypertension medication 2 | Medication | Prescriptions for moderate or high-risk hypertension patients | 6 prescriptions in 14 months |
| Myocardial Infarction (MI) | Monitoring | Cholesterol | 1 X year |
| | | Glucose or glycosylated haemoglobin | |
| | | Cholesterol fractions | |
| | | Counselling for chronic patient | |
| Myocardial infarction (MI) | Medication | Prescription of beta-blockers treatment group (incl combination drugs) | 6 prescriptions in 14 months |
| | | Prescription of statins treatment group (incl combination drugs) | 6 prescriptions in 14 months |
| Hypothyroidism | Monitoring | TSH (thyroid stimulating hormone) determined | 1 X year |
| **Total** | | | |

sampling blocks of clinics, among which we could then randomize, such that 1/4 of clinics that were not excluded were selected to be approached for enrollment in the ECM program. Clinics were excluded for three reasons: either they had been part of the initial pilot; they were considered a large clinic with more than four providers; or they had no other clinics in their strata block (see Figure A2a).

At this stage, 93 clinics were selected for enrollment in ECM and 282 were selected as controls. The ECM-eligible patients at the latter clinics are considered the 'pure control' group, which is used for comparisons with the 'ECM control' group for spillover analysis.

Next, of the 93 clinics selected for enrollment in the ECM program, 21 clinics refused to participate in the program when approached at the facility level. These clinics contained 4,266 eligible individuals. In addition, 8 doctors did not have any ECM-selected patients. Those two groups of patients are included neither in the 'pure control' group, nor in the 'ECM control' group,. Similarly, of the 72 clinics which agreed to participate, 26 of 98 providers at those clinics also refused to participate – producing a similar group of 'excluded' patients who are neither in the 'pure control' nor 'ECM control' groups.

Table A2 shows that there are no notable differences between ECM and non-ECM clinics and providers in the size of each clinic, QBS and management scores. The only difference is found on the number of ECM-eligible patients, which tends to be significantly larger for both not assigned and not participating clinics.

Table A2: Pre-treatment balance across clinics and doctors

| Variable | Not assigned v. assigned to ECM | | | Not participating v. participating in ECM | | |
|---|---|---|---|---|---|---|
| | Not assigned (1) | Assigned (2) | Balance (2)-(1) | Not participating (4) | Participating (5) | Balance (5)-(4) |
| **Panel A: Clinics** | | | | | | |
| Lists (N) | 1.43 (0.842) | 1.56 (0.890) | 0.123 (0.100) | 1.59 (1.01) | 1.54 (0.808) | 0.101 (0.232) |
| QBS score | 305 (67.5) | 306 (64.7) | 3.02 (2.03) | 291 (73.7) | 316 (56.5) | 5.53 (4.82) |
| Management score | 10.8 (6.69) | 10.9 (6.78) | 0.072 (0.124) | 8.84 (7.16) | 12.2 (6.23) | -0.094 (0.264) |
| Eligible patients (N) | 168 (121) | 136 (95.1) | -33.0** (13.3) | 173 (127) | 111 (54.2) | -45.5* (24.4) |
| Sample size (N) | 282 | 93 | - | 37 | 56 | - |
| **Panel B: Doctors** | | | | | | |
| QBS score | 364 (58.8) | 363 (62.6) | 4.54 (2.77) | 352 (68.5) | 374 (54.3) | 7.16 (5.67) |
| N Eligible patients (N) | 118 (62.2) | 88.5 (42.8) | -34.1*** (5.44) | 101 (49.3) | 76.3 (31.1) | -15.4 (10.4) |
| Sample size (N) | 400 | 143 | - | 71 | 72 | - |

*** $< 1\%$; ** $< 5\%$; * $< 10\%$.

**Notes**: The table measures pre-treatment balance of the outcomes of interest for the ECM intervention at the clinic and doctor levels. The shows averages of the outcome variables for relevant groups of clinics/doctors as of the latest pre-treatment (pre-June 2021) measurement. Standard deviations is shown in the parentheses. The **balance columns** compare balance across different groups of clinics/doctors on each variable as estimated in an OLS regression, inclusive of assignment (column 3) or participation (column 5) dummy and fixed effects for the clinic-level randomization bloc. Standard errors are shown in parentheses. They are also clustered by clinic in Panel B.

The treatment groups are defined as follows: **Assigned to ECM** - clinics/doctors selected to be in the ECM, irrespective of their actual treatment status' **Not assigned to ECM** - clinics/doctors not selected into ECM (excluding those not fitting the criteria - pilot, list number; **Participating in ECM** - clinics/doctors assigned and participating in ECM; **Not participating in ECM** - clinics/doctors assigned and NOT participating in ECM.

In the sample of clinics that chose to participate, EHIF identified all the patients who have (one or multiple) chronic illnesses using pre-existing algorithms and the patient data in their Mini Information System Portal. The details on this process can be seen in Section A3. The list of those patients identified as in some way 'chronically ill' from this approach were sent to the corresponding doctor for confirmation that: i) all relevant patients were included in the list; ii) that all included patients could be considered 'chronically ill'; and, iii) that no patients should be excluded for reasons that were not contained in patient records, such as peculiar challenges of working with the patient.

Doctors were asked to assign each eligible patient in the resulting list to a further category of health status risk score, as follows:

- 1-Mild/moderate risk of deteriorating health
- 2-Severe risk of deteriorating health

Given the mix of mild/moderate and severe patients within each provider, we conducted a stratified random sampling of patients into ECM based on the risk classification, such that every patient within each risk classification group has equal probability of selection, and there are at most 25 patients selected into the ECM program from each doctor. The limitation of 25 patients was based on EHIF's budgetary limitations for the program. Five providers had identified fewer than 25 patients who had a risk of deteriorating health. For these providers, all the patients were included in treatment. Figure **A2b** shows the randomization outcome at the patient level (for participating providers), including risk classifications, while Figure **A1** shows the mapping of patient randomization and provider dropout at different stages of the patient randomization.

## A5 Further details on data

Much healthcare in Estonia is free at point-of-use for patients covered by EHIF's insurance, or requires a very minimal co-pay. All Estonians covered by EHIF are assigned to a private family doctor.[37] Doctors are primarily paid through a mix of capitation fees (51%), allowances (21%), and fee for service (23%) (Kasekamp, Habicht and Kalda, 2022). Fee-for-service payments are all related to an 'episode of care', such as the provision of a consultation or prescription. As such, every billable activity undertaken within the primary health system is recorded within EHIF's administrative records.

EHIF is also liable for the payment of tertiary costs, such as in- or out-patient episode at a tertiary health institution. As such, EHIF maintains electronic health records describing every billable episode of care in the formal health system for the Estonian population since 2009. There is little that is not billable, with EHIF's data even including e-mails and calls to patients by doctors and nurses.

### A5.1 EHIF billing data

Since EHIF is a payer, and not a care provider, its records are organized as *billing claims* records, and do not have qualitatively detailed case histories. Bill numbers uniquely identify any episode of care between a single provider and patient (both of whose unique identifiers are associated with the bill number). A billing claim is closed when the provider requests reimbursement for the episode.

Each claim contains contains general information on a given 'episode of care'. It provides a summary of each episode of care identified by the bill number and includes the duration of treatment, type of admission[38], type of care, type of healthcare facility, code of doctor's speciality, and the family doctor for the patient in reference to the care episode.

Each billing claim is further linked to diagnosis and procedure information, stored in separate files. The diagnosis data describe all the diagnoses which were relevant to the given care episode. Each diagnosis is identified using the International Classification of Disease

[37] People are assigned to mother's family doctor at the time of their birth, (re-)register with a chosen family doctor themselves; or are "designated by the Board of Health on the basis of the residential address of the Estonian population register" (Gazette 2001 §8)

[38] There are 12 admission types identified by EHIF, including arrival by oneself, by ambulance, and via referral from a family doctor. See §55 in `https://www.riigiteataja.ee/a` for details.

Figure A1: Randomization chart

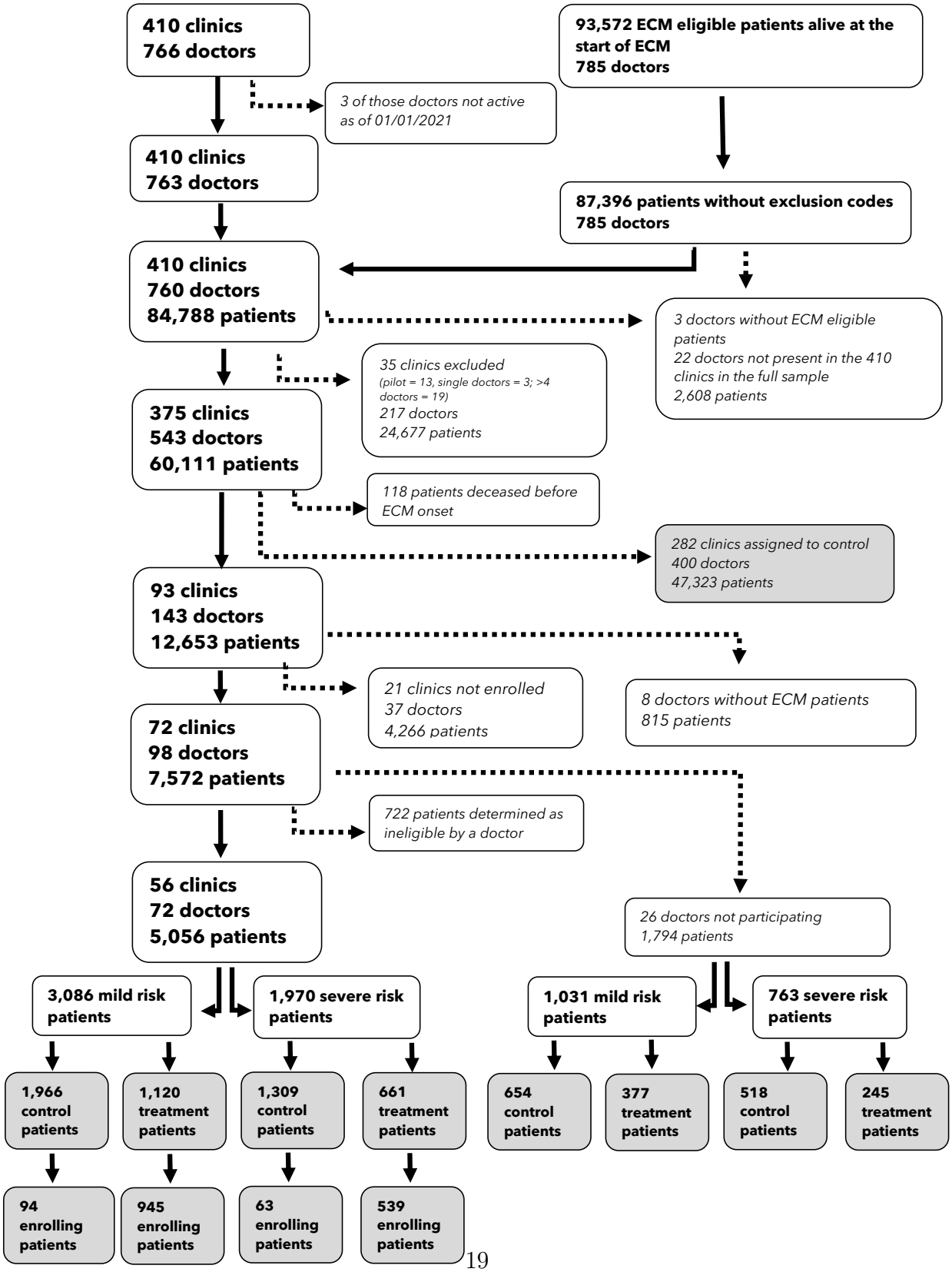
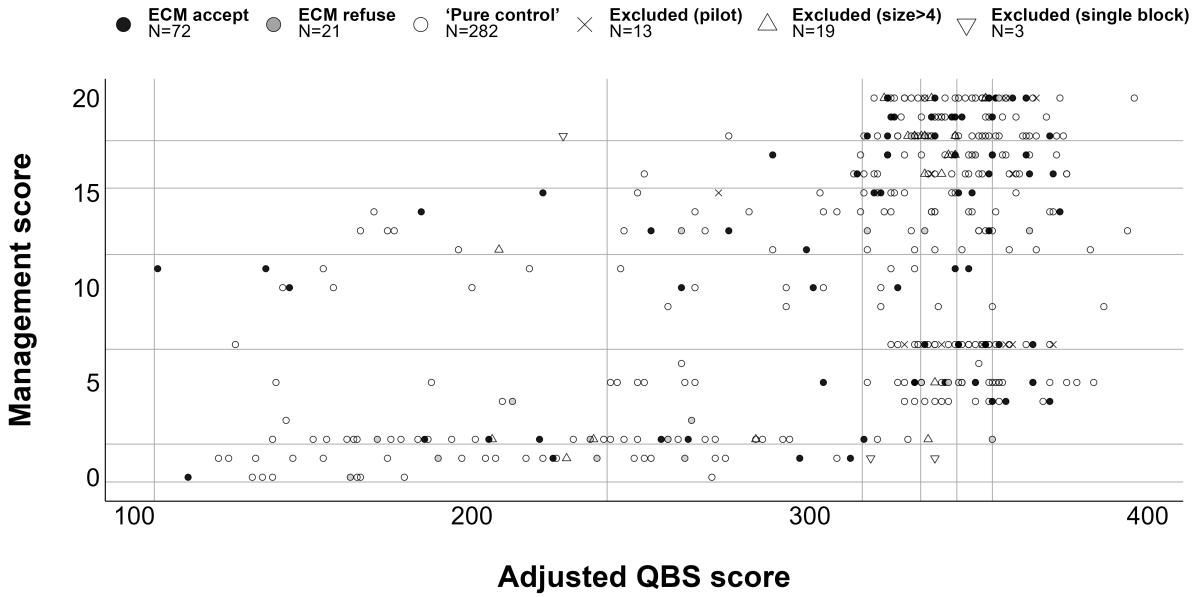


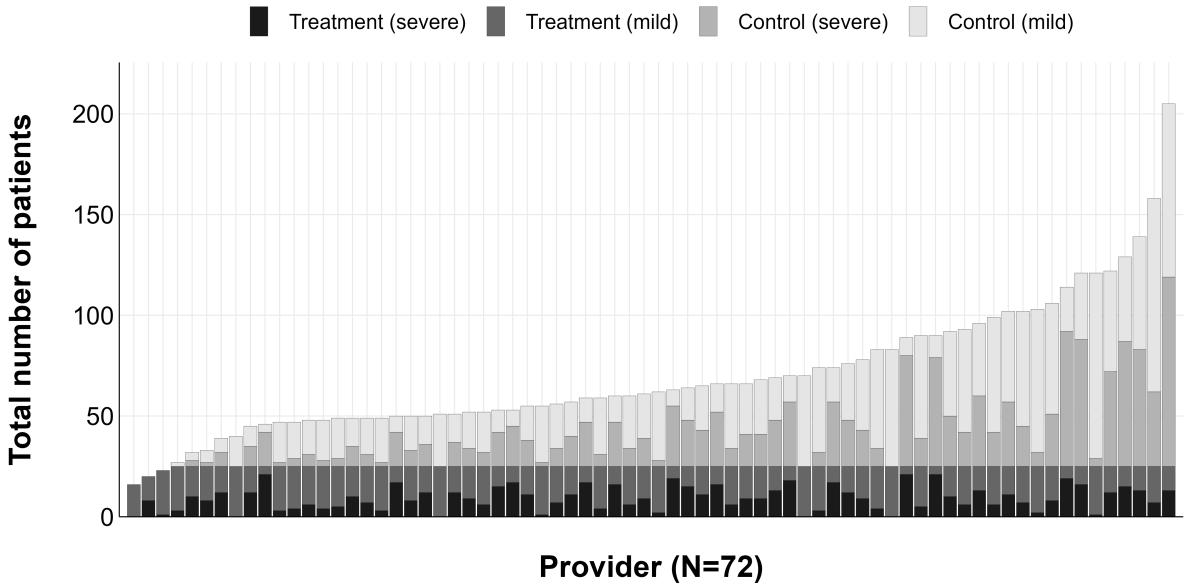
Figure A2: Clinic randomization blocks and patient strata

(a) Clinic blocks




Notes: The above figure shows the randomization outcome at the clinic level. Each point represents a single clinic. The color and shape of the point correspond to the ECM status of each clinic as per the legend. X-axis records clinic-average QBS score and Y-axis records clinic-average management quality score. Horizontal and vertical lines show threshold boundaries of the randomization strata that were used to randomize the non-excluded clinics into ECM treatment and control.

(b) Patient strata (provider x risk)




Notes: The above figure shows the randomization outcome at the patient level. Each bar represents a single provider participating in the ECM program. The vertical axis represents the total number of patients in the sampling frame from each provider. The area of each bar in lightgrey represents the patients who are not selected in ECM, and the area of the bar in darkgrey represents the patients who are selected in ECM. For both types of patients, the darker shade represent the patients with a severe risk classification. The lighter shade represent patients with a mild-risk classification.

(ICD). The diagnosis dataset also allows for distinguishing between primary diagnosis and accompanying diagnosis. This data system further allows provider to indicate whether a diagnosis is new.

The data on procedures describe all the medical procedures that were conducted within a given episode of care, including their frequency. Each procedure can be matched against EHIF-determined prices prevalent in a period in which a procedure was undertaken. Any billing claim can contain multiple procedures, as well as diagnoses.

This 3-tier system of data - billing, diagnoses, and procedures - is interlinked based on unique bill numbers. Each part of the data is also sub-divided into eight types of care. These are: day care services, inpatient services, inpatient nursing services, inpatient rehabilitation services, outpatient services, outpatient rehabilitation services, outpatient nursing services, and primary healthcare services.

In summary, the data used is based on electronic records that contain information on the billing claim, related diagnoses, and procedures performed, spread over eight health care services categories over a 14 year period (2009 until 2023). It serves as the basis to construct all the key outcomes of this study (apart from prescriptions data, which are described next). The definition of the outcome variables used in this study is provided in Table A3, while the summary of the key outcomes, grouped by treatment arms, is shown in Table 1.

### A5.2 EHIF prescriptions data

In addition, EHIF provides reimbursement for prescriptions. The relevant 'prescriptions' data set is not linked to a specific bill number, but rather records each prescription issued to a given patient, including the doctor issuing it, prescription status, medicines and dosage prescribed, as well as over-the-counter price and the amount covered by EHIF. Prescribed medicines are identified both by their name and by WHO-managed Anatomical Therapeutic Chemical (ATC) Classification codes, which facilitates identifying the course of treatment for each patient.

### A5.3 EHIF Mini Information System Portal

In addition to the data sources described above, EHIF also maintains an online system called 'Mini Information System Portal' (MISP). It is used by EHIF to store, among others,

information on each patient served. For the purposes of this study, EHIF helped us to use MISP to construct a list of chronically-ill patients. The list also included additional information such as the patient's family doctor, the date they were categorized as at risk, and the number of co-morbidities. This information was used to identify the starting, 'ECM eligible' population for this study (see top-right cell in Figure A1.

Table A3: Codebook for the outcome variables

| Variable | Source | Codes | Description |
|---|---|---|---|
| **Demographics** | | | |
| Age | EHIF billing claims | - | patient's age in June 2021 |
| Male | EHIF billing claims | - | patient's sex |
| Mild risk | EHIF billing claims | - | patient's health risk class 'mild/moderate' as opposed to 'severe' |
| **Primary care (assigned clinic)** | | | |
| ECM inclusion | EHIF procedures billing | 9092 | consultation with a doctor about being included into ECM programme (procedure code ending in '9092') at the assigned clinic |
| ECM care plan | EHIF procedures billing | 9095 | consultation with a doctor about developing or renewing a care plan (procedure code ending in '9095') at the assigned clinic |
| ECM inclusion refuse | EHIF procedures billing | 9589 | consultation with a doctor about being included into ECM programme (procedure code ending in '9589') at the assigned clinic |
| Doctor in-person chronic care | EHIF procedures billing | 9044 | consultation with a doctor in-person (procedure code ending in '9044') at the assigned clinic |
| Doctor phone | EHIF procedures billing | 9018 | consultation with a doctor over phone (procedure code ending in '9018') at the assigned clinic |
| Nurse in-person | EHIF procedures billing | 9061 | consultation with a nurse in-person (procedure code ending in '9061') at the assigned clinic |
| Nurse phone | EHIF procedures billing | 9064 | consultation with a nurse over phone (procedure code ending in '9064') at the assigned clinic |
| Any consultation | EHIF procedures billing | 9044, 9018, 9061, 9064 | row pools together all types of consultations with doctors and nurses at the assigned clinic |
| Primary | EHIF procedures billing | - | patient receiving primary healthcare treatment for any reason or diagnosis, excluding the doctor and nurse consultations, at the assigned clinic |
| Outpatient | EHIF procedures billing | - | patient receiving outpatient treatment for any reason and diagnosis,excluding the doctor and nurse consultations, at the assigned clinic |
| **Primary care (not assigned clinic)** | | | |
| Primary | EHIF procedures billing | - | patient receiving primary healthcare treatment for any reason or diagnosis, not at the assigned clinic |
| Outpatient | EHIF procedures billing | - | patient receiving outpatient treatment for any reason and diagnosis, not at the assigned clinic |
| **Other care** | | | |
| Inpatient | EHIF procedures billing | - | patient receiving inpatient treatment (hospitalised) for any reason and diagnosis |
| Inpatient (via referral) | EHIF billing claims | E-T0011 | patient hospitalised with admission by doctor referral (admission code: E-T0011) |
| Inpatient (via ambulance) | EHIF billing claims | E-T0001 | patient hospitalised with admission by ambulance (admission code: E-T0001) |
| Treat. time (total days) | EHIF billing claims | - | total treatment duration (difference between start and end of all treatment bills) |
| Inpatient time (total days) | EHIF billing claims | - | total treatment duration (difference between start and end of inpatient (hospitalization) treatment bills) |
| Treat. time (average days) | EHIF billing claims | - | average treatment duration (difference between start and end of all treatment bills) |
| Inpatient time (average days) | EHIF billing claims | - | average treatment duration (difference between start and end of inpatient (hospitalization) treatment bills) |
| Inpatient re-admission (30) | EHIF billing claims | - | patient re-hospitalized within 30 days of the start of previous hospitalisation, regardless of the diagnosis |
| Inpatient re-admission (90) | EHIF billing claims | - | patient re-hospitalized within 90 days of the start of previous hospitalisation, regardless of the diagnosis |
| Inpatient re-admission (30, severe) | EHIF billing claims | - | patient re-hospitalized for any of the severe conditions within 30 days of the start of previous hospitalisation for any of the severe conditions |
| Inpatient re-admission (90, severe) | EHIF billing claims | - | patient re-hospitalized for any of the severe conditions within 90 days of the start of previous hospitalisation for any of the severe conditions |
| Daycare healthcare | EHIF procedures billing | - | patient receiving daycare healthcare treatment for any reason or diagnosis |
| Inpatient nursing/rehabilitation | EHIF procedures billing | - | patient receiving inpatient nursing or rehabilitation treatment for any reason or diagnosis |
| Outpatient nursing/rehabilitation | EHIF procedures billing | - | patient receiving outpatient nursing or rehabilitation treatment for any reason or diagnosis |
| No of diagnoses (total) | EHIF diagnoses billing | - | number of diagnosed conditions (total in the period) |
| No of diagnoses (average) | EHIF diagnoses billing | - | number of diagnosed conditions (average per healthcare interaction) |
| No of procedures (total) | EHIF procedures billing | - | number of procedures underwent by a patient (total in the period) |
| No of procedures (average) | EHIF procedures billing | - | number of procedures underwent by a patient (average per healthcare interaction) |

| Variable | Source | Codes | Description |
|---|---|---|---|
| Covid incidence | EHIF diagnoses billing (ICD-10) | 9092 | patient diagnosed with SARS-CoV-2 (Covid-19) (ICD-10 code: U07.1); (procedure code ending in '9092') |
| Covid test | EHIF procedures billing | 3183, 66634,66645,9519 | patient underwent any of testing procedures for SARS-CoV-2 (procedure code ending in '3183', '66634','66645','9519') |
| Covid vaccine | EHIF procedures billing | 3197, 3199, 9595, 9590, 9591, 9592, 9593, 9594, 9595, 9596, 9597, 9598, 9599 | patient underwent any of vaccination procedures for SARS-CoV-2 (procedure code ending in '3197', '3199', '9595', '9590', '9591', '9592', '9593', '9594', '9595', '9596', '9597', '9598', '9599') |
| Covid vaccine refuse | EHIF procedures billing | 9589 | patient refusing vaccine for SARS-CoV-2 (procedure code ending in '9589') |
| **Severe hospitalization** | | | |
| Intensive care (i) | EHIF procedures billing | 2044, 2070 | patient time in intensive care of I degree (procedure code ending in '2044' or '2070') |
| Intensive care (ii) | EHIF procedures billing | 2045, 2071 | patient time in intensive care of II degree (procedure code ending in '2045' or '2071') |
| Intensive care (iii) | EHIF procedures billing | 2046, 2072 | patient time in intensive care of III degree (procedure code ending in '2045' or '2072') |
| Intensive care (iiia) | EHIF procedures billing | 2059, 2073 | patient time in intensive care of IIIA degree (procedure code ending in '2059' or '2073') |
| Pneumonia (h) | EHIF diagnoses billing (ICD-10) | J12.0, J12.1, J12.2, J12.81, J12.82, J12.89, J12.3, J12.9, J18.1, J13, J15.0, J15.1, J14, J15.4, J15.3, J15.20, J15.211, J15.212, J15.29, J15.8, J15.5, J15.6, A48.1, J15.9, J15.7, J16.0, J16.8, J18.0, J18.9, J18.8, J11.08, J11.00, J10.08, J10.01, J10.00 | patient diagnosed with pneumonia during hospitalisation (EHIF diagnoses billing (ICD-10) codes: J12.0, J12.1, J12.2, J12.81, J12.82, J12.89, J12.3, J12.9, J18.1, J13, J15.0, J15.1, J14, J15.4, J15.3, J15.20, J15.211, J15.212, J15.29, J15.8, J15.5, J15.6, A48.1, J15.9, J15.7, J16.0, J16.8, J18.0, J18.9, J18.8, J11.08, J11.00, J10.08, J10.01, J10.00) |
| **Screening** | | | |
| Glycohemoglobin | EHIF procedures billing | 66118 | patient underwent any of the glycohemoglobin monitoring procedures for diabetes II, as defined by EHIF (procedure code ending in 66118) |
| Glycohemoglobin (all) | EHIF procedures billing | 66118, 6506A, 9118, 9050 | patient underwent any of the glycohemoglobin monitoring procedures (procedure code ending in 66118) |
| Creatinine | EHIF procedures billing | 66102 | patient underwent any of the creatine monitoring procedures for diabetes II and hypertensive disease, as defined by EHIF (procedure code ending in 66118) |
| Creatinine (all) | EHIF procedures billing | 66102, 9102, 6500D | patient underwent any of the creatine monitoring procedures (procedure code ending in 66118) |
| Cholesterol | EHIF procedures billing | 66104 | patient underwent any of the cholesterol or triglycerides monitoring procedures for diabetes II, hypertensive disease and myocardial infarction as defined by EHIF (procedure code ending in 66118) |
| Cholesterol (all) | EHIF procedures billing | 66104, 6503F, 6501F, 6501G, 66105, 9106, 6303G, 9104, 9040, 9042, 6502L | patient underwent any of the cholesterol or triglycerides monitoring procedures (procedure code ending in 66118) |
| Glucose | EHIF procedures billing | 66101 | patient underwent any of the glucose monitoring procedures for hypertensive disease and myocardial infarction as defined by EHIF (procedure code ending in 66118) |
| Glucose (all) | EHIF procedures billing | 66101, 9050, 9101, 9131, 9118, 9011, 6500B, 9067Z | patient underwent any of the glucose monitoring procedures (procedure code ending in 66118) |
| ECG | EHIF procedures billing | 6320, 6322, 6323 | patient underwent ECG monitoring procedure for hypertensive disease as defined by EHIF (procedure code ending in 6320, 6322, 6323) |
| TSH | EHIF procedures billing | 66706 | patient underwent any of the screening, hormone testing, immunoassays for pathogens monitoring procedures for hypothyroidism as defined by EHIF (procedure code ending in 66706) |
| Any monitoring | EHIF procedures billing | 66118, 66102, 66104, 66101, 6320, 6322, 6323, 66706 | patient underwent any of the monitoring procedures for chronically ill patients as defined by EHIF (procedure code ending in 66118, 66102, 66104, 66101, 6320, 6322, 6323, 66706) |
| **Diagnosed conditions** | | | |

| Variable | Source | Codes | Description |
|---|---|---|---|
| Pneumonia | EHIF diagnoses billing (ICD-10) | J12.0, J12.1, J12.2, J12.81, J12.82, J12.89, J12.3, J12.9, J18.1, J13, J15.0, J15.1, J14, J15.4, J15.3, J15.20, J15.211, J15.212, J15.29, J15.8, J15.5, J15.6, A48.1, J15.9, J15.7, J16.0, J16.8, J18.0, J18.9, J18.8, J11.08, J11.00, J10.08, J10.01, J10.00 | patient diagnosed with pneumonia during any healthcare interaction (EHIF diagnoses billing (ICD-10) codes: J12.0, J12.1, J12.2, J12.81, J12.82, J12.89, J12.3, J12.9, J18.1, J13, J15.0, J15.1, J14, J15.4, J15.3, J15.20, J15.211, J15.212, J15.29, J15.8, J15.5, J15.6, A48.1, J15.9, J15.7, J16.0, J16.8, J18.0, J18.9, J18.8, J11.08, J11.00, J10.08, J10.01, J10.00) |
| Heart failure | EHIF diagnoses billing (ICD-10) | I11.0, I13.0, I13.2, I50.9, I50.814, I50.43, I50.42, I50.41, I50.40, I50.33, I50.32, I50.31, I50.30, I50.23, I50.22, I50.21, I50.20, I50.1, I50.810, I50.811, I50.812, I50.813, I50.82, I50.83, I50.84, I50.89 | patient diagnosed with heart failure during any healthcare interaction (EHIF diagnoses billing (ICD-10) codes: I11.0, I13.0, I13.2, I50.9, I50.814, I50.43, I50.42, I50.41, I50.40, I50.33, I50.32, I50.31, I50.30, I50.23, I50.22, I50.21, I50.20, I50.1, I50.810, I50.811, I50.812, I50.813, I50.82, I50.83, I50.84, I50.89) |
| Stroke | EHIF diagnoses billing (ICD-10) | I63.02, I63.12, I63.22, I63.239, I63.240, I63.241, I63.242, I63.243, I63.244, I63.245, I63.246, I63.039, I63.033, I63.032, I63.031, I63.219, I63.119, I63.019, I63.213, I63.212, I63.211, I63.113, I63.112, I63.111, I63.013, I63.012, I63.011, I63.59, I63.19, I63.09, I63.00, I63.10, I63.29, I63.20, I63.311, I63.312, I63.313, I63.319, I63.321, I63.322, I63.323, I63.329, I63.331, I63.332, I63.333, I63.339, I63.341, I63.342, I63.343, I63.349, I63.39, I63.6, I63.30, I63.411, I63.412, I63.413, I63.419, I63.421, I63.422, I63.423, I63.429, I63.431, I63.432, I63.433, I63.439, I63.441, I63.442, I63.443, I63.449, I63.49, I63.40, I63.511, I63.512, I63.513, I63.519, I63.521, I63.522, I63.523, I63.529, I63.531, I63.532, I63.533, I63.539, I63.541, I63.542, I63.543, I63.549, I63.81, I63.89, I63.9, I63.50 | patient diagnosed with stroke during any healthcare interaction (EHIF diagnoses billing (ICD-10) codes: I63.02, I63.12, I63.22, I63.239, I63.240, I63.241, I63.242, I63.243, I63.244, I63.245, I63.246, I63.039, I63.033, I63.032, I63.031, I63.219, I63.119, I63.019, I63.213, I63.212, I63.211, I63.113, I63.112, I63.111, I63.013, I63.012, I63.011, I63.59, I63.19, I63.09, I63.00, I63.10, I63.29, I63.20, I63.311, I63.312, I63.313, I63.319, I63.321, I63.322, I63.323, I63.329, I63.331, I63.332, I63.333, I63.339, I63.341, I63.342, I63.343, I63.349, I63.39, I63.6, I63.30, I63.411, I63.412, I63.413, I63.419, I63.421, I63.422, I63.423, I63.429, I63.431, I63.432, I63.433, I63.439, I63.441, I63.442, I63.443, I63.449, I63.49, I63.40, I63.511, I63.512, I63.513, I63.519, I63.521, I63.522, I63.523, I63.529, I63.531, I63.532, I63.533, I63.539, I63.541, I63.542, I63.543, I63.549, I63.81, I63.89, I63.9, I63.50) |
| Myocardial infarction | EHIF diagnoses billing (ICD-10) | I21.09, I22.0, I21.01, I21.02, I21.19, I22.1, I21.11, I21.29, I22.8, I21.4, I22.2, I21.21, I21.3, I21.A9, I21.A1, I21.9, I22.9 | patient diagnosed with myocardial infarction during any healthcare interaction (EHIF diagnoses billing (ICD-10) codes: I21.09, I22.0, I21.01, I21.02, I21.19, I22.1, I21.11, I21.29, I22.8, I21.4, I22.2, I21.21, I21.3, I21.A9, I21.A1, I21.9, I22.9) |
| No. of severe diag. (total) | EHIF diagnoses billing (ICD-10) | - | number of any healthcare interactions due to any of the severe conditions (total in the period; conditions include acute myocardial infarction, COPD, heart failure, pneumonia, and stroke; EHIF diagnoses billing (ICD-10) codes: as specified in notes for individual conditions) |
| COPD | EHIF diagnoses billing (ICD-10) | J44.1, J44.0, J41.8, J42, J43.9, J43.8, J43.2, J43.1, J43.0, J44.9 | patient diagnosed with a chronic obstructive pulmonary disease (COPD) during any healthcare interaction (ICD-10 code: J44.1, J44.0, J41.8, J42, J43.9, J43.8, J43.2, J43.1, J43.0, J44.9) |
| Asthma | EHIF diagnoses billing (ICD-10) | J45 | patient diagnosed with asthma during hospitalisation (ICD-10 code: J45) |
| Diabetes | EHIF diagnoses billing (ICD-10) | E11 | patient diagnosed with diabetes during hospitalisation (ICD-10 code: E11) |
| Hypertension | EHIF diagnoses billing (ICD-10) | I10, I11, I12, I13, I15 | patient diagnosed with hypertension during hospitalisation (EHIF diagnoses billing (ICD-10) codes: I10, I11, I12, I13, I15) |

| Variable | Source | Codes | Description |
|---|---|---|---|
| Any avoidable hospitalization | EHIF diagnoses billing (ICD-10) | J45, J44, E11, I50.9, I10, I11, I12, I13, I15 | number of hospitalisations for any of the avoidable conditions (total in the period; conditions include acute asthma, diabeted II, COPD, hypertension, heart failure; EHIF diagnoses billing (ICD-10) codes: as specified in notes for individual conditions) |
| Alcohol abuse | EHIF diagnoses billing (ICD-10) | F10, Z71.4 | patient receiving healthcare services of any type due to diagnosis of alcohol abuse (EHIF diagnoses billing (ICD-10) codes: F10 and Z71.4) |
| Arthritis | EHIF diagnoses billing (ICD-10) | M05, M06, M15, M16, M17, M18, M19 | patient receiving healthcare services of any type due to diagnosis of arthritis (EHIF diagnoses billing (ICD-10) codes: M05, M06, M15, M16, M17, M18, M19) |
| Atrial fibrillation | EHIF diagnoses billing (ICD-10) | I48 | patient receiving healthcare services of any type due to diagnosis of atrial fibrillation abuse (ICD-10 code: I48) |
| Chronic kidney disease | EHIF diagnoses billing (ICD-10) | N18 | patient receiving healthcare services of any type due to diagnosis of atrial fibrillation abuse (ICD-10 code: N18) |
| Cancer | EHIF diagnoses billing (ICD-10) | C18, C34, C50, C61 | patient receiving healthcare services of any type due to diagnosis of cancer (EHIF diagnoses billing (ICD-10) codes: C18, C34, C50, C61) |
| Depression | EHIF diagnoses billing (ICD-10) | F32 | patient receiving healthcare services of any type due to diagnosis of depression (ICD-10 code: F32) |
| Substance use | EHIF diagnoses billing (ICD-10) | F11, F12, F13, F14, F15, F16, F17, F18, F19 | patient receiving healthcare services of any type due to diagnosis of substance use (EHIF diagnoses billing (ICD-10) codes: F11, F12, F13, F14, F15, F16, F17, F18, F19) |
| Hyperlipidemia | EHIF diagnoses billing (ICD-10) | E78 | patient receiving healthcare services of any type due to diagnosis of hyperlipidemia (ICD-10 code: E78) |
| Hypertensive heart | EHIF diagnoses billing (ICD-10) | I11 | patient receiving healthcare services of any type due to diagnosis of hypertensive heart (ICD-10 code: I11) |
| Ischemic heart disease | EHIF diagnoses billing (ICD-10) | I21, I22, I23, I24, I25 | patient receiving healthcare services of any type due to diagnosis of ischemic heart disease (ICD-10 code: I21, I22, I23, I24, I25) |
| Osteoporosis | EHIF diagnoses billing (ICD-10) | M80, M81 | patient receiving healthcare services of any type due to diagnosis of osteoporosis (EHIF diagnoses billing (ICD-10) codes: M80, M81) |
| Underweight | EHIF diagnoses billing (ICD-10) | E66, R63.5 | patient receiving healthcare services of any type due to diagnosis related to deficient body mass (EHIF diagnoses billing (ICD-10) codes: E66, R63.5) |
| Overweight/obese | EHIF diagnoses billing (ICD-10) | R63.4, R63.6, T75.82, X52 | patient receiving healthcare services of any type due to diagnosis related to excessive body mass (EHIF diagnoses billing (ICD-10) codes: R63.4, R63.6, T75.82, X52) |
| **Prescriptions** | | | |
| N(total) | EHIF prescriptions billing | - | total number of prescriptions issued to a patient |
| N (realized) | EHIF prescriptions billing | - | total share of prescriptions realized by a patient |
| Cost (total) | EHIF prescriptions billing | - | total price of prescriptions realized by a patient |
| Cost (EHIF) | EHIF prescriptions billing | - | total price of prescriptions realized by a patient that was paid by EHIF |
| Cost (EHIF per.) | EHIF prescriptions billing | - | total share of price of prescriptions realized by a patient that was paid by EHIF |
| Time av. (days) | EHIF prescriptions billing | - | average time, in days, between prescription being issued and being realized by a patient |
| Diabetes | EHIF prescriptions billing (ATC) | A10 | patient issued a prescription (Rx) for diabetes medication (ATCC codes starting with A10) |
| Diabetes (realized) | EHIF prescriptions billing (ATC) | A10 | patient realized a prescription (Rx) for diabetes medication (ATCC codes starting with A10) |
| Diabetes (assigned) | EHIF prescriptions billing (ATC) | A10 | patient issued a prescription (Rx) for diabetes medication (ATCC codes starting with A10) at the assigned clinic |
| Anti-thrombotic | EHIF prescriptions billing (ATC) | B01 | patient issued a prescription (Rx) for anti-thrombotic medication (ATCC codes starting with B01) |
| Anti-thrombotic (realized) | EHIF prescriptions billing (ATC) | B01 | patient realized a prescription (Rx) for anti-thrombotic medication (ATCC codes starting with B01) |
| Anti-morrhagic | EHIF prescriptions billing (ATC) | B02 | patient issued a prescription (Rx) for anti-morrhagic medication (ATCC codes starting with BO2) |
| Anti-morrhagic (realized) | EHIF prescriptions billing (ATC) | B02 | patient realized a prescription (Rx) for anti-morrhagic medication (ATCC codes starting with B02) |
| Anti-anemic | EHIF prescriptions billing (ATC) | B03 | patient issued a prescription (Rx) for anti-anemic medication (ATCC codes starting with B03) |
| Anti-anemic (realized) | EHIF prescriptions billing (ATC) | B03 | patient realized a prescription (Rx) for anti-anemic medication (ATCC codes starting with B03) |
| Cardiac | EHIF prescriptions billing (ATC) | C01 | patient issued a prescription (Rx) for cardiac therapy medication (ATCC codes starting with C01) |
| Cardiac (realized) | EHIF prescriptions billing (ATC) | C01 | patient realized a prescription (Rx) for cardiac therapy medication (ATCC codes starting with C01) |
| Anti-hypertensive | EHIF prescriptions billing (ATC) | C02 | patient issued a prescription (Rx) for anti-hypertensive medication (ATCC codes starting with C02) |
| Anti-hypertensive (realized) | EHIF prescriptions billing (ATC) | C02 | patient realized a prescription (Rx) for anti-hypertensive medication (ATCC codes starting with C02) |

| Variable | Source | Codes | Description |
|---|---|---|---|
| Anti-hypertensive (assigned) | EHIF prescriptions billing (ATC) | C02 | patient realized a prescription (Rx) for anti-hypertensive medication (ATCC codes starting with C02) at assigned clinic |
| Diuretics | EHIF prescriptions billing (ATC) | C03 | patient issued a prescription (Rx) for duretics medication (ATCC codes starting with C03) |
| Diuretics (realized) | EHIF prescriptions billing (ATC) | C03 | patient realized a prescription (Rx) for duretics medication (ATCC codes starting with C03) |
| Beta-blockers | EHIF prescriptions billing (ATC) | C07 | patient issued a prescription (Rx) for beta blocking medication (ATCC codes starting with C07) |
| Beta-blockers (realized) | EHIF prescriptions billing (ATC) | C07 | patient realized a prescription (Rx) for beta blocking medication (ATCC codes starting with C07) |
| Beta-blockers (assigned) | EHIF prescriptions billing (ATC) | C07 | patient issued a prescription (Rx) for beta blocking medication (ATCC codes starting with C07) at the assigned clinic |
| Ca-bloc. | EHIF prescriptions billing (ATC) | C08 | patient issued a prescription (Rx) for calcium channel blocker medication (ATCC codes starting with C08) |
| Ca-bloc. (realized) | EHIF prescriptions billing (ATC) | C08 | patient realized a prescription (Rx) for calcium channel blocker medication (ATCC codes starting with C08) |
| Statins | EHIF prescriptions billing (ATC) | C10 | patient issued a prescription (Rx) for statins medication (ATCC codes starting with C10) |
| Statins (realized) | EHIF prescriptions billing (ATC) | C10 | patient realized a prescription (Rx) for statins medication (ATCC codes starting with C19) |
| Statins (assigned) | EHIF prescriptions billing (ATC) | C10 | patient issued a prescription (Rx) for statins medication (ATCC codes starting with C10) at the assigned clinic |
| Antibiotic | EHIF prescriptions billing (ATC) | J01 | patient issued a prescription (Rx) for bacterial antibiotics medication (ATCC codes starting with J01) |
| Antibiotic (realized) | EHIF prescriptions billing (ATC) | J01 | patient realized a prescription (Rx) for bacterial antibiotics medication (ATCC codes starting with J01) |
| Vaccines | EHIF prescriptions billing (ATC) | J07 | patient issued a prescription (Rx) for a vacine (ATCC codes starting with J07) |
| Vaccines (realized) | EHIF prescriptions billing (ATC) | J07 | patient realized a prescription (Rx) for a vaccine (ATCC codes starting with J07) |
| Anti-histamine | EHIF prescriptions billing (ATC) | R06 | patient issued a prescription (Rx) for anti-histamineamine medication (ATCC codes starting with R06) |
| Anti-histamine (realized) | EHIF prescriptions billing (ATC) | R06 | patient realized a prescription (Rx) for anti-histamineamine medication (ATCC codes starting with R06) |
| Any key | EHIF prescriptions billing (ATC) | C02, C07, A10, C10 | patient issued any of the key prescriptions (Rx) - anti-hypertensives, beta-blockers, diabetes medication, statins - in managing chronically ill patients (ATCC codes starting with C02, C07, A10, C10) |
| Any key (realized) | EHIF prescriptions billing (ATC) | C02, C07, A10, C10 | patient realized any of the key prescriptions (Rx) - anti-hypertensives, beta-blockers, diabetes medication, statins - in managing chronically ill patients (ATCC codes starting with C02, C07, A10, C10) |
| Any key (assigned) | EHIF prescriptions billing (ATC) | C02, C07, A10, C10 | patient issued any of the key prescriptions (Rx) - anti-hypertensives, beta-blockers, diabetes medication, statins - in managing chronically ill patients (ATCC codes starting with C02, C07, A10, C10) at the assigned clinic |
| Any other | EHIF prescriptions billing (ATC) | - | patient issued a prescription (Rx) for any other medication than anti-hypertensives, beta-blockers, diabetes medication, or statins - in managing chronically ill patients (ATCC codes starting with C02, C07, A10, C10) |
| Any other (realized) | EHIF prescriptions billing (ATC) | - | patient realized a prescription (Rx) for any other medication than anti-hypertensives, beta-blockers, diabetes medication, or statins - in managing chronically ill patients (ATCC codes starting with C02, C07, A10, C10) |

### A5.4 Survey of doctors

At the start of the ECM program, we undertook an online survey of all family doctors in Estonia (covering both treatment and control groups) using EHIF's existing survey infrastructure. This survey aimed to measure details of how doctors conduct consultations with chronic patients, their operational capacity and levels of satisfaction with their practice. [39] Specifically, the topics covered in the survey were:

- **Doctor's overall clinical approach**:
  - Frequency of contact and coordination with chronic patients provided by the doctor.
  - Preparedness levels of doctor/clinical staff to manage patients with or developing chronic conditions.
  - Details on type of care provided to patients with chronic conditions.
  - Details on nature of coordination between patients and community services; between doctor and hospitals.
- **Practice profile**:
  - Number of full-time personnel working in the practice, hours/shifts worked by the personnel.
  - Average time spent with every patient in a routine visit by the doctor.
  - Any extra duties undertaken by the staff in preceding months.
- **Satisfaction and stress**:
  - Satisfaction levels with being a doctor.
  - Satisfaction levels with specific aspects of doctor's practice.

The response rate was broadly similar across geographic regions. The descriptive statistics reported in the paper are raw averages of the responses received.

[39] All surveying and other contact with doctors was conducted in Estonian, unless otherwise specified.

### A5.5 Care plan assessments

In order to better understand how ECM was implemented in practice, our intervention involved 4 external consultants, who were tasked with conducting training and coaching of the enrolled doctors, running regular feedback sessions with them, as well as performing an evaluation of a random set of care plans prepared for the ECM patients.

Evaluation of the care plans was a part of one of the visits to the doctor and his/her team. It was aimed to coincide with the completion of most if not all of the care plans. While on site, the evaluator assessed care plans from five patients, randomly selected from the full set of ECM treatment patients assigned to the visited doctor. The randomization process relied on random sorting of numbers 1 through 25 (max. number of ECM treatment patients per doctor) and selecting patients corresponding to the first five numbers. All the care plans selected were printed out, assessed using an online survey form, and then returned to the clinics to destroy or add to the patient records. In total, 72 care plans were evaluated.[40] The survey evaluation comprised 8 questions. Their text is listed below, along with the response options in the square brackets.

- Is this care plan X available? [0 - No; 1 - Yes]
- Overall, are all mandatory fields of the care plan filled with relevant information? [1 - Excellent; 2 - Good; 3 - Satisfactory; 4 - Unsatisfactory; 5 - Absent]
- Does the care plan provide a series of non-medical activities that promote holistic health? [1 - Excellent; 2 - Good; 3 - Satisfactory; 4 - Unsatisfactory; 5 - Absent]
- Does the care plan seem to be specific to the needs of the individual patient? [1 - Excellent; 2 - Good; 3 - Satisfactory; 4 - Unsatisfactory; 5 - Absent]
- Are patient goals measurable and timebound in care plan? [1 - Excellent; 2 - Good; 3 - Satisfactory; 4 - Unsatisfactory; 5 - Absent]
- Is there an action plan to achieve those patient goals in care plan? [0 - Not included; 1 - Yes, action plans are completely tailored to the goals set; 2 - Yes, patient goals are included in the action plans, among other plans to promote health]

[40] Examples of the care plans are shown in Section A2 of the Appendix.

- Is all the information easy to grasp and understandable from the patient's point of view i.e., not too medical in care plan? [1 - Excellent; 2 - Good; 3 - Satisfactory; 4 - Unsatisfactory; 5 - Absent]
- Any comments for this care plan? [Open-ended]

## A6 Further results

This section presents ECM results using a series of alternative group comparisons and model specifications.

### A6.1 Heterogeneity by patient risk classification

Tables A4 and A5 replicate the ANCOVA models presented in the main text in Table 2, sub-dividing the sample into mild-risk and severe-risk patients respectively. This parallels to sample splitting applied for survival analysis between Tables 3 and 4 and therefore allows us to determine whether the overall effects found in the main text are driven by only a sub-group of patients in a given risk class. For both mild-risk and severe-risk patients the full-sample effects uncovered in Table 2 persist, with a reduction in sample size causing only small increases in the associated standard errors. The mild-risk sub-group of patients boosts a better health profile - with fewer consultations, hospitalizations, healthcare interactions due to diagnosis of severe conditions, and key prescriptions issued.

Table A4 shows that in particular for the mild-risk patients the effects of ECM intervention uncovered in the full sample remain mostly unchanged. The effects on primary healthcare utilization, as well as on screening procedures, persist, both in terms of effect size and significance, strengthening noticeably only for doctor phone consultations. The positive ECM effects on the number of interactions due to severe diagnosed conditions persist, but for heart failure and obesity they are reduced by about 40%. A contrary pattern is seen in the effects on prescriptions, where the effects increase by about 30% for statins, all key prescriptions, and all other prescriptions. Table A5 also shows few deviations from the full-sample results of Table 2.

Table A4: **ECM Impact:** On patient's care (ANCOVA, mild-risk)

| Variable | Means (control) | | ECM treatment vs. control | |
|---|---|---|---|---|
| | *Any* | *Count* | *Any* | *Count* |
| | (1) | (2) | (3) | (4) |
| **Primary care (assigned clinic)** | | | | |
| ECM inclusion | 0.051 | 0.028 | 0.771*** (0.032) | 0.466*** (0.026) |
| ECM care plan | 0.048 | 0.06 | 0.793*** (0.032) | 0.942*** (0.075) |
| Doctor in-person chronic care | 0.467 | 0.381 | 0.097*** (0.030) | 0.144*** (0.039) |
| Doctor phone | 0.91 | 3.819 | 0.009 (0.009) | 0.211*** (0.081) |
| Nurse in-person | 0.768 | 1.044 | 0.070*** (0.019) | 0.216*** (0.067) |
| Nurse phone | 0.727 | 1.799 | 0.093*** (0.022) | 0.351*** (0.095) |
| Any consultation | 0.973 | 7.065 | 0.004 (0.003) | 0.894*** (0.184) |
| Primary | 0.882 | 1.487 | 0.025** (0.011) | 0.071* (0.037) |
| Outpatient | 0.556 | 0.62 | 0.138*** (0.022) | 0.219*** (0.039) |
| **Primary care (not assigned clinic)** | | | | |
| Primary | 0.087 | 0.11 | 0.010 (0.010) | 0.019 (0.016) |
| Outpatient | 0.842 | 3.155 | 0.019 (0.014) | 0.046 (0.123) |
| **Other care** | | | | |
| Inpatient | 0.219 | 0.186 | -0.014 (0.016) | -0.007 (0.016) |
| Inpatient (via ambulance) | 0.09 | 0.061 | -0.013 (0.010) | -0.010 (0.007) |
| Inpatient re-admission (30) | 0.027 | 0.022 | 0.006 (0.006) | -0.000 (0.006) |
| Inpatient re-admission (90) | 0.046 | 0.042 | 0.005 (0.009) | -0.004 (0.008) |
| Daycare healthcare | 0.102 | 0.083 | 0.020 (0.015) | 0.028 (0.017) |
| Inpatient nursing/rehabilitation | 0.033 | 0.03 | -0.002 (0.009) | -0.003 (0.011) |
| Outpatient nursing/rehabilitation | 0.146 | 0.178 | -0.017 (0.013) | -0.024 (0.027) |
| Covid incidence | 0.214 | 0.136 | 0.023 (0.016) | 0.017 (0.013) |
| Covid vaccine | 0.722 | 0.824 | -0.003 (0.013) | -0.031 (0.019) |
| **Screening** | | | | |
| Glycohemoglobin | 0.651 | 0.681 | 0.053*** (0.020) | 0.109*** (0.027) |
| Creatinine | 0.916 | 2.278 | 0.048*** (0.010) | 0.204 (0.145) |
| Cholesterol | 0.874 | 1.073 | 0.067*** (0.012) | 0.153*** (0.034) |
| Glucose | 0.83 | 1.656 | 0.046*** (0.014) | 0.179 (0.135) |
| TSH | 0.628 | 0.857 | 0.051** (0.020) | 0.130*** (0.048) |
| **Diagnosed conditions** | | | | |
| Heart failure | 0.25 | 0.558 | 0.004 (0.014) | 0.093* (0.053) |
| Stroke | 0.005 | 0.004 | 0.003 (0.004) | -0.000 (0.003) |
| Myocardial infarction | 0.017 | 0.019 | 0.002 (0.005) | 0.005 (0.008) |
| Hyperlipidemia | 0.438 | 0.64 | 0.093*** (0.021) | 0.292*** (0.048) |
| Overweight/obese | 0.126 | 0.173 | 0.042*** (0.014) | 0.086*** (0.025) |
| **Prescriptions** | | | | |
| Diabetes | 0.206 | 1.318 | 0.001 (0.008) | 0.105 (0.076) |
| Anti-hypertensive | 0.027 | 0.052 | 0.001 (0.009) | 0.009 (0.011) |
| Beta-blockers | 0.567 | 2.242 | -0.005 (0.016) | 0.040 (0.060) |
| Statins | 0.566 | 2.13 | 0.028* (0.016) | 0.170** (0.069) |
| Any key | 0.809 | 5.746 | -0.000 (0.015) | 0.335** (0.137) |
| Any other | 0.984 | 15.713 | 0.001 (0.005) | 1.07*** (0.282) |
| **FE** | - | - | Strata | Strata |
| **Controls** | - | - | Age, sex, $DV_{18-21}$ | Age, sex, $DV_{18-21}$ |
| **N** | 1,966 | 1,966 | 3,086 | 3,086 |

*** $< 1\%$; ** $< 5\%$; * $< 10\%$.

**Notes:** The table measures patient-level health outcomes in the post-treatment period (28/05/2021 - 31/03/2023). Only mild-risk patients are included in the analyses. Outcome variables in 'Count' columns (2,4,6) are measured as annualized and winsorized (at 99.9th percentile) sums of a given outcome (diagnosis, procedure, or consultation) per patient and period. 'Any' columns (1, 3,5) measure the same variables converted to 0/1 dummy values, meaning they take values of 1 if a patient had a particular diagnosis, procedure, or consultation at any point during the treatment period, and 0 otherwise.

All regression models are estimated controlling for patients' values age and sex, as well as the value of a given outcome

variable in pre-treatment period (01/01/2018 - 27/05/2021). The only exception is 'ECM inclusion' and 'ECM care plan', which are estimated as WLS, i.e. without pre-treatment values as controls, as those procedures are introduced as a part of the intervention. The pre-treatment values are recorded in parallel with their post-treatment equivalents as either counts or dummies in the respective columns. All models include fixed effects as specified in the bottom panel, where strata refers to doctor interacted with patient risk classification level and block to clinic-level randomization block. Fully empty rows code variables that after winsorizing resulted in all values being 0. Models in columns 3-4 are also weighted by strata-level inverse probabilities of treatment assignment, whereas those in columns 5-6 are unweighted due to lack of equivalent weights for the 'Pure control' group. Standard errors of the coefficients are clustered by doctor and provided in parentheses.
The treatment groups are defined as follows: **Pure Control** - all patients classified by EHIF as eligible for ECM, but at clinics not assigned to ECM intervention (see 'Pure control' group in the randomization chart in Figure A1); **ECM Control** - patients selected to be in the ECM control at participating doctor, irrespective of their actual treatment status; **ECM Treatment** - patients selected to receive ECM treatment at participating doctors, irrespective of their actual treatment status. The exact **coding definition** of each of the variables is provided in Table A3.

Table A5: **ECM Impact:** On patient's care (ANCOVA, severe-risk)

| Variable | Means (control) | | ECM treatment vs. control | |
|---|---|---|---|---|
| | *Any* | *Count* | *Any* | *Count* |
| | (1) | (2) | (3) | (4) |
| **Primary care (assigned clinic)** | | | | |
| ECM inclusion | 0.046 | 0.026 | 0.755*** (0.044) | 0.432*** (0.026) |
| ECM care plan | 0.048 | 0.055 | 0.771*** (0.044) | 0.894*** (0.089) |
| Doctor in-person chronic care | 0.476 | 0.389 | 0.131*** (0.033) | 0.154*** (0.035) |
| Doctor phone | 0.916 | 4.467 | 0.002 (0.009) | -0.039 (0.141) |
| Nurse in-person | 0.767 | 1.097 | -0.004 (0.020) | 0.117 (0.088) |
| Nurse phone | 0.729 | 2.079 | 0.094*** (0.028) | 0.169* (0.088) |
| Any consultation | 0.961 | 8.118 | 0.002 (0.006) | 0.402** (0.177) |
| Primary | 0.845 | 1.449 | 0.033** (0.013) | 0.146** (0.063) |
| Outpatient | 0.509 | 0.563 | 0.107*** (0.031) | 0.247*** (0.044) |
| **Primary care (not assigned clinic)** | | | | |
| Primary | 0.134 | 0.205 | -0.015 (0.011) | -0.016 (0.019) |
| Outpatient | 0.85 | 3.858 | 0.011 (0.017) | -0.076 (0.117) |
| **Other care** | | | | |
| Inpatient | 0.309 | 0.273 | -0.031 (0.024) | -0.035 (0.026) |
| Inpatient (via ambulance) | 0.133 | 0.091 | -0.003 (0.016) | -0.006 (0.012) |
| Inpatient re-admission (30) | 0.056 | 0.045 | -0.020** (0.010) | -0.023*** (0.009) |
| Inpatient re-admission (90) | 0.079 | 0.071 | -0.011 (0.013) | -0.016 (0.013) |
| Daycare healthcare | 0.139 | 0.117 | -0.024 (0.017) | -0.031* (0.018) |
| Inpatient nursing/rehabilitation | 0.052 | 0.046 | 0.014 (0.013) | 0.004 (0.012) |
| Outpatient nursing/rehabilitation | 0.135 | 0.185 | 0.011 (0.017) | -0.006 (0.039) |
| Covid incidence | 0.183 | 0.123 | 0.008 (0.023) | 0.024 (0.019) |
| Covid vaccine | 0.725 | 0.827 | -0.008 (0.023) | -0.036 (0.041) |
| **Screening** | | | | |
| Glycohemoglobin | 0.731 | 0.89 | 0.042** (0.018) | 0.116*** (0.041) |
| Creatinine | 0.949 | 2.946 | 0.022** (0.009) | -0.044 (0.171) |
| Cholesterol | 0.895 | 1.135 | 0.027* (0.014) | 0.145*** (0.046) |
| Glucose | 0.865 | 2.678 | 0.016 (0.014) | -0.167 (0.254) |
| TSH | 0.648 | 0.961 | 0.046*** (0.016) | 0.147** (0.060) |
| **Diagnosed conditions** | | | | |
| Heart failure | 0.38 | 0.97 | 0.077*** (0.020) | 0.270*** (0.069) |
| Stroke | 0.006 | 0.007 | 0.002 (0.004) | 0.002 (0.005) |
| Myocardial infarction | 0.02 | 0.031 | -0.005 (0.007) | -0.006 (0.011) |
| Hyperlipidemia | 0.413 | 0.618 | 0.101*** (0.021) | 0.252*** (0.049) |
| Overweight/obese | 0.15 | 0.181 | 0.081*** (0.021) | 0.247*** (0.054) |
| **Prescriptions** | | | | |
| Diabetes | 0.357 | 2.769 | 0.042*** (0.011) | 0.069 (0.137) |
| Anti-hypertensive | 0.048 | 0.125 | -0.011 (0.010) | -0.015 (0.024) |
| Beta-blockers | 0.697 | 2.972 | 0.011 (0.019) | 0.047 (0.097) |
| Statins | 0.642 | 2.655 | 0.024 (0.015) | 0.038 (0.088) |
| Any key | 0.896 | 8.537 | 0.026** (0.010) | 0.118 (0.240) |
| Any other | 0.986 | 21.004 | 0.006 (0.005) | 0.102 (0.339) |
| **FE** | - | - | Strata | Strata |
| **Controls** | - | - | Age, sex, $DV_{18-21}$ | Age, sex, $DV_{18-21}$ |
| **N** | 1,309 | 1,309 | 1,970 | 1,970 |

*** $< 1\%$; ** $< 5\%$; * $< 10\%$.

**Notes:** The table measures patient-level health outcomes in the post-treatment period (28/05/2021 - 31/03/2023). Only severe-risk patients are included in the analyses. Outcome variables in 'Count' columns (2,4,6) are measured as annualized and winsorized (at 99.9th percentile) sums of a given outcome (diagnosis, procedure, or consultation) per patient and period. 'Any' columns (1, 3,5) measure the same variables converted to 0/1 dummy values, meaning they take values of 1 if a patient had a particular diagnosis, procedure, or consultation at any point during the treatment period, and 0 otherwise.

All regression models are estimated controlling for patients' values age and sex, as well as the value of a given outcome

variable in pre-treatment period (01/01/2018 - 27/05/2021). The only exception is 'ECM inclusion' and 'ECM care plan', which are estimated as WLS, i.e. without pre-treatment values as controls, as those procedures are introduced as a part of the intervention. The pre-treatment values are recorded in parallel with their post-treatment equivalents as either counts or dummies in the respective columns. All models include fixed effects as specified in the bottom panel, where strata refers to doctor interacted with patient risk classification level and block to clinic-level randomization block. Fully empty rows code variables that after winsorizing resulted in all values being 0. Models in columns 3-4 are also weighted by strata-level inverse probabilities of treatment assignment, whereas those in columns 5-6 are unweighted due to lack of equivalent weights for the 'Pure control' group. Standard errors of the coefficients are clustered by doctor and provided in parentheses.
The treatment groups are defined as follows: **Pure Control** - all patients classified by EHIF as eligible for ECM, but at clinics not assigned to ECM intervention (see 'Pure control' group in the randomization chart in Figure A1); **ECM Control** - patients selected to be in the ECM control at participating doctor, irrespective of their actual treatment status; **ECM Treatment** - patients selected to receive ECM treatment at participating doctors, irrespective of their actual treatment status. The exact **coding definition** of each of the variables is provided in Table A3.

### A6.2 Interaction effects

In order to further check if the ECM treatment had differential outcomes for certain subgroups of patients, in Table A6 we also present the results of several models, where the ECM treatment dummy is interacted with a series of other variables. Those include clinic-level service level (as measured by QBS scores, columns 3-4) and management quality (columns 5-6), which aim to check if ECM was more effective in better-run clinics. ECM treatment is also interacted with the provider-level assessment of the care plans developed (columns 7-8). Those were assessed by consultants as described in section A5.5. The variable measuring the plan quality is constructed by extracting the values of the first principal component of the 6 survey questions intended to evaluate different facets of each care plan. Finally, ECM treatment is also interacted with the annualized count of each outcome in the pre-treatment period (columns 9-10).

Overall, we find no evidence of heterogeneous treatment effects across different levels of healthcare and care plan quality. Patients suffering from certain pre-existing conditions did see a differential ECM impact on some of the outcomes measured. Those significant interaction effects between pre-existing health problems and ECM treatment assignment are mostly seen for chronic conditions, including heart problems, high cholesterol, obesity, and insulin-level management. It suggests that ECM might have allowed the patients with known long-term health issues to more frequently consult those with their health providers.

Table A6: **ECM Impact:** On patient's care (interactions; counts)

| Variable | Means (control) | | QBS | | Mng. Q. | | Plan Q. | | Pre-18 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Any* | *Count* | $\beta_{treat}$ | $\beta_{interact}$ | $\beta_{treat}$ | $\beta_{interact}$ | $\beta_{treat}$ | $\beta_{interact}$ | $\beta_{treat}$ | $\beta_{interact}$ |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| **Primary care (assigned clinic)** | | | | | | | | | | |
| ECM inclusion | 0.049 | 0.027 | 0.529*** | -0.000 | 0.478*** | -0.002 | 0.457*** | -0.008 | - | - |
| | | | (0.103) | (0.000) | (0.057) | (0.004) | (0.022) | (0.013) | | |
| ECM care plan | 0.048 | 0.058 | 1.30*** | -0.001 | 0.801*** | 0.011 | 0.949*** | 0.021 | - | - |
| | | | (0.427) | (0.001) | (0.162) | (0.012) | (0.072) | (0.040) | | |
| Doctor in-person chronic care | 0.471 | 0.384 | 0.174 | -0.000 | 0.171** | -0.001 | 0.157*** | -0.005 | 0.151*** | -0.005 |
| | | | (0.236) | (0.001) | (0.076) | (0.005) | (0.032) | (0.018) | (0.040) | (0.054) |
| Doctor phone | 0.912 | 4.078 | 0.642 | -0.002 | 0.023 | 0.005 | 0.082 | -0.029 | 0.144 | -0.007 |
| | | | (0.915) | (0.002) | (0.196) | (0.016) | (0.101) | (0.046) | (0.126) | (0.041) |
| Nurse in-person | 0.767 | 1.066 | 0.725** | -0.001* | 0.373*** | -0.018** | 0.184*** | -0.027 | 0.194** | -0.019 |
| | | | (0.325) | (0.001) | (0.137) | (0.009) | (0.055) | (0.028) | (0.079) | (0.082) |
| Nurse phone | 0.728 | 1.911 | 1.05*** | -0.002* | 0.356*** | -0.007 | 0.285*** | -0.062* | 0.163* | 0.082* |
| | | | (0.402) | (0.001) | (0.138) | (0.013) | (0.072) | (0.033) | (0.090) | (0.050) |
| Any consultation | 0.968 | 7.485 | 2.60** | -0.005 | 0.936*** | -0.024 | 0.660*** | -0.123 | 0.269 | 0.069* |
| | | | (1.32) | (0.003) | (0.328) | (0.025) | (0.162) | (0.076) | (0.287) | (0.040) |
| Primary | 0.867 | 1.472 | 0.175 | -0.000 | 0.164* | -0.005 | 0.113*** | -0.006 | 0.155*** | -0.026 |
| | | | (0.306) | (0.001) | (0.095) | (0.006) | (0.038) | (0.020) | (0.058) | (0.030) |
| Outpatient | 0.537 | 0.597 | -0.151 | 0.001** | 0.120** | 0.009* | 0.219*** | -0.001 | 0.278*** | -0.163 |
| | | | (0.150) | (0.000) | (0.057) | (0.005) | (0.033) | (0.017) | (0.044) | (0.126) |
| **Primary care (not assigned clinic)** | | | | | | | | | | |
| Primary | 0.106 | 0.148 | -0.098 | 0.000 | -0.012 | 0.001 | 0.003 | 0.003 | 0.003 | 0.006 |
| | | | (0.098) | (0.000) | (0.019) | (0.001) | (0.010) | (0.006) | (0.010) | (0.022) |
| Outpatient | 0.845 | 3.436 | 0.086 | -0.000 | 0.121 | -0.004 | 0.091 | -0.023 | -0.124 | 0.041 |
| | | | (0.717) | (0.002) | (0.205) | (0.015) | (0.098) | (0.050) | (0.150) | (0.040) |
| **Other care** | | | | | | | | | | |
| Inpatient | 0.255 | 0.221 | -0.043 | 0.000 | 0.007 | -0.002 | -0.012 | -0.002 | -0.050*** | 0.194** |
| | | | (0.072) | (0.000) | (0.029) | (0.002) | (0.012) | (0.006) | (0.018) | (0.094) |
| Inpatient (via ambulance) | 0.107 | 0.073 | -0.040 | 0.000 | -0.012 | 0.000 | -0.006 | 0.003 | -0.008 | -0.016 |
| | | | (0.067) | (0.000) | (0.013) | (0.001) | (0.007) | (0.003) | (0.007) | (0.094) |
| Inpatient re-admission (30) | 0.038 | 0.032 | -0.004 | -0.000 | -0.011 | 0.000 | -0.007 | 0.004* | -0.009* | -0.023 |
| | | | (0.026) | (0.000) | (0.010) | (0.001) | (0.005) | (0.002) | (0.005) | (0.083) |
| Inpatient re-admission (90) | 0.059 | 0.054 | -0.043 | 0.000 | -0.003 | -0.000 | -0.005 | 0.003 | -0.016* | 0.286 |
| | | | (0.034) | (0.000) | (0.014) | (0.001) | (0.007) | (0.003) | (0.008) | (0.223) |
| Daycare healthcare | 0.117 | 0.097 | 0.042 | -0.000 | -0.008 | 0.001 | 0.007 | -0.012** | -0.001 | 0.076 |
| | | | (0.092) | (0.000) | (0.032) | (0.002) | (0.012) | (0.005) | (0.018) | (0.206) |
| Inpatient nursing/rehabilitation | 0.04 | 0.036 | 0.061* | -0.000* | 0.012 | -0.001 | -0.002 | -0.005 | 0.007 | -0.475** |
| | | | (0.034) | (0.000) | (0.020) | (0.001) | (0.008) | (0.005) | (0.008) | (0.209) |
| Outpatient nursing/rehabilitation | 0.142 | 0.181 | 0.142 | -0.000 | 0.078 | -0.008* | -0.008 | 0.007 | -0.039 | 0.159 |
| | | | (0.154) | (0.000) | (0.050) | (0.004) | (0.031) | (0.013) | (0.026) | (0.171) |
| Covid incidence | 0.202 | 0.131 | -0.020 | 0.000 | 0.015 | 0.000 | 0.020* | -0.010* | 0.018 | 0.044 |
| | | | (0.076) | (0.000) | (0.027) | (0.002) | (0.011) | (0.006) | (0.012) | (0.146) |
| Covid vaccine | 0.723 | 0.825 | 0.114 | -0.000 | -0.046 | 0.001 | -0.039* | -0.006 | -0.083** | 0.090** |
| | | | (0.161) | (0.000) | (0.045) | (0.004) | (0.023) | (0.010) | (0.041) | (0.046) |
| **Screening** | | | | | | | | | | |
| Glycohemoglobin | 0.683 | 0.765 | 0.118 | -0.000 | 0.160** | -0.004 | 0.120*** | 0.006 | 0.116*** | -0.004 |
| | | | (0.192) | (0.001) | (0.068) | (0.005) | (0.030) | (0.016) | (0.030) | (0.045) |
| Creatinine | 0.929 | 2.545 | 0.077 | 0.000 | 0.268 | -0.015 | 0.106 | -0.060 | 0.195 | -0.043 |
| | | | (0.900) | (0.002) | (0.262) | (0.018) | (0.114) | (0.057) | (0.198) | (0.108) |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Cholesterol | 0.882 | 1.098 | 0.436* | -0.001 | 0.173*** | -0.002 | 0.158*** | -0.009 | 0.297*** | -0.130** |
| | | | (0.225) | (0.001) | (0.065) | (0.005) | (0.033) | (0.016) | (0.065) | (0.061) |
| Glucose | 0.844 | 2.065 | -0.559 | 0.002 | 0.398 | -0.033* | 0.043 | -0.075 | 0.083 | -0.022 |
| | | | (0.524) | (0.002) | (0.261) | (0.019) | (0.135) | (0.067) | (0.306) | (0.199) |
| TSH | 0.636 | 0.898 | 0.391 | -0.001 | 0.285*** | -0.013** | 0.142*** | -0.024 | 0.068 | 0.085* |
| | | | (0.294) | (0.001) | (0.096) | (0.007) | (0.044) | (0.022) | (0.051) | (0.045) |
| **Diagnosed conditions** | | | | | | | | | | |
| Heart failure | 0.302 | 0.723 | 0.107 | 0.000 | 0.096 | 0.004 | 0.153*** | 0.005 | 0.050 | 0.176*** |
| | | | (0.379) | (0.001) | (0.095) | (0.007) | (0.051) | (0.027) | (0.035) | (0.062) |
| Stroke | 0.005 | 0.005 | -0.016 | 0.000 | -0.005 | 0.001 | 0.003 | 0.000 | 0.000 | 0.165 |
| | | | (0.010) | (0.000) | (0.006) | (0.000) | (0.003) | (0.001) | (0.002) | (0.421) |
| Myocardial infarction | 0.018 | 0.024 | 0.044 | -0.000 | -0.015 | 0.001 | -0.002 | 0.001 | 0.002 | -0.062 |
| | | | (0.031) | (0.000) | (0.016) | (0.001) | (0.007) | (0.003) | (0.005) | (0.122) |
| Hyperlipidemia | 0.428 | 0.631 | 0.266 | 0.000 | 0.248*** | 0.003 | 0.282*** | -0.019 | 0.208*** | 0.118** |
| | | | (0.363) | (0.001) | (0.093) | (0.007) | (0.043) | (0.024) | (0.041) | (0.047) |
| Overweight/obese | 0.136 | 0.176 | 0.316 | -0.000 | 0.100** | 0.004 | 0.145*** | 0.012 | 0.097*** | 0.342*** |
| | | | (0.245) | (0.001) | (0.045) | (0.004) | (0.027) | (0.013) | (0.023) | (0.121) |
| **Prescriptions** | | | | | | | | | | |
| Diabetes | 0.266 | 1.898 | -0.167 | 0.001 | 0.285 | -0.013 | 0.176 | -0.025 | 0.107** | -0.005 |
| | | | (0.953) | (0.003) | (0.318) | (0.025) | (0.162) | (0.082) | (0.049) | (0.037) |
| Anti-hypertensive | 0.036 | 0.081 | -0.038 | 0.000 | -0.045 | 0.004 | -0.005 | 0.031*** | -0.006 | 0.065 |
| | | | (0.131) | (0.000) | (0.042) | (0.003) | (0.016) | (0.010) | (0.007) | (0.115) |
| Beta-blockers | 0.619 | 2.534 | 0.100 | -0.000 | -0.040 | 0.008 | 0.091 | 0.036 | 0.046 | -0.001 |
| | | | (0.317) | (0.001) | (0.142) | (0.012) | (0.077) | (0.039) | (0.064) | (0.020) |
| Statins | 0.597 | 2.34 | 0.460 | -0.001 | 0.253 | -0.009 | 0.175** | 0.015 | 0.197*** | -0.033 |
| | | | (0.560) | (0.001) | (0.158) | (0.012) | (0.075) | (0.040) | (0.063) | (0.021) |
| Any key | 0.844 | 6.862 | 0.306 | 0.000 | 0.466 | -0.011 | 0.438* | 0.058 | 0.427*** | -0.024 |
| | | | (1.35) | (0.004) | (0.485) | (0.038) | (0.233) | (0.123) | (0.141) | (0.024) |
| Any other | 0.985 | 17.828 | 1.92 | -0.003 | 1.40** | -0.047 | 0.856** | -0.290 | 0.839* | -0.008 |
| | | | (2.31) | (0.006) | (0.687) | (0.053) | (0.349) | (0.178) | (0.503) | (0.027) |
| **FE** | - | | Bloc x Risk | | Bloc x Risk | | Bloc x Risk | | Strata | |
| **Controls** | - | | Age, sex | | Age, sex | | Age, sex | | Age, sex | |
| **N** | 3,275 | | 5,056 | | 5,056 | | 4,843 | | 5,056 | |

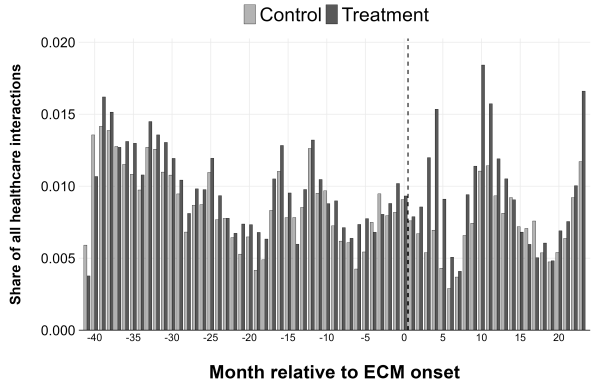
*** $< 1\%$; ** $< 5\%$; * $< 10\%$.

**Notes**: The table measures patient-level health outcomes in the post-treatment period (28/05/2021 - 31/03/2023) for patients assigned to either control or treatment condition. Outcome variables in the 'Count' columns (2) are measured as annualized and winsorized (at 99.9th percentile) sums of a given outcome (diagnosis, procedure, or consultation) per patient and period. 'Any' columns (1) measure the same variables converted to 0/1 dummy values, meaning they take values of 1 if a patient had a particular diagnosis, procedure, or consultation at any point during the treatment period, and 0 otherwise
All regression models in columns 3-10 use measure the outcome variable specified in each row as counts. All models include a dummy for ECM treatment groups. In each model that dummy is interacted with the variable specified in the column heading. Treatment group and interaction coefficient are listed under $\beta_{treat}$ and $\beta_{interact}$ respectively. The interaction variables are: **QBS** - variable measuring doctor-level Quality Bonus Scheme score; **Mng. Q.** - doctor-level management quality scores; **Plan Q.** - doctor-level evaluations of ECM care plan quality, prepared by external consultants and based on the first principal component of 6 care plan evaluation survey questions (see details in Section A5.5);**Pre-18** - pre-treatment value of a given condition/diagnosis/procedures between 2018 and the onset of ECM in June 2021 (also measured as counts). All models contain controls for patients' age and sex and are weighted by strata-level inverse probabilities of treatment assignment. The models further include fixed effects as specified in the bottom panel, where strata refers to doctor interacted with patient risk classification level and block to clinic-level randomization block.
The treatment groups are defined as follows: **ECM Control** - patients selected to be in the ECM control at participating doctor, irrespective of their actual treatment status; **ECM Treatment** - patients selected to receive ECM treatment at participating doctors, irrespective of their actual treatment status. The exact **coding definition** of each of the variables is provided in Table A3.

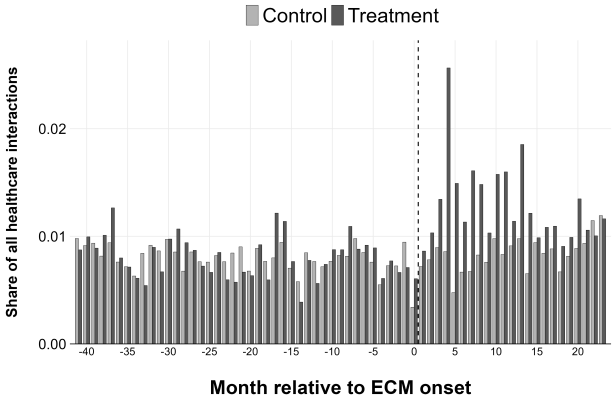
## A6.3 Dynamics of ECM

Figure A3: Dynamics of ECM effects

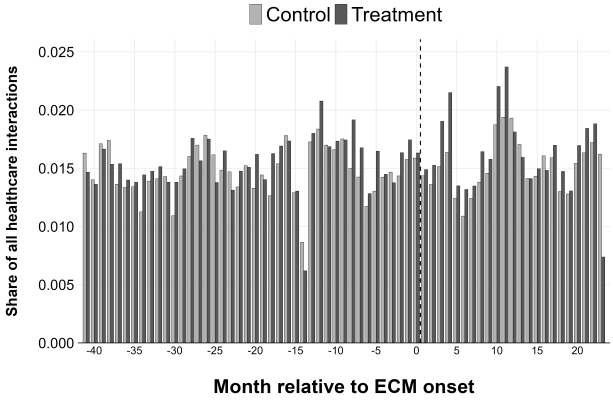
(a) **Consultations**: Doctor in-person chronic



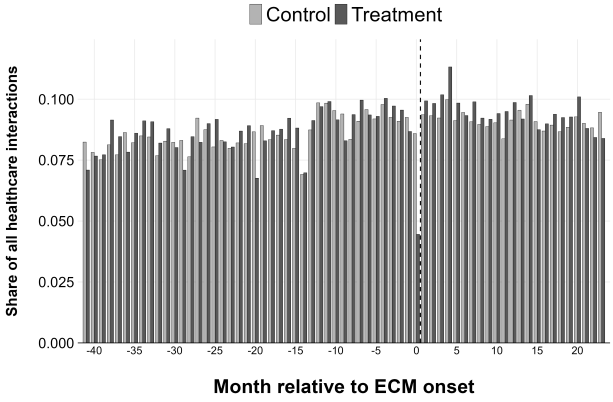

(b) **Diagnoses**: Overweight/obese




(c) **Prescriptions**: Statins




(d) **Screening**: Glycohemoglobin




**Notes**: The figures show monthly counts of the outcomes of interest for ECM treatment and control groups, relative to all reported healthcare interactions in a given month. The time is calculated in months relative to ECM onset on 28/05/2021 (marked in the figures by a dashed vertical line). The numbers shown are **unweighted**.
The treatment groups are defined as follows: **ECM Control** - patients selected to be in the ECM control at participating doctors, irrespective of their actual treatment status; **ECM Treatment** - patients selected to receive ECM treatment at participating doctors, irrespective of their actual treatment status. The exact **coding definition** of each outcome variable is provided in Table A3.

### A6.4 Mediation analysis

One of the key effects of ECM was the decreased risk of death during the treatment period among mild-risk patients. This effect is likely to be a compound of many different factors, of which our data allows us to measure only a restricted subset. In order to gauge the degree to which observable actions undertaken within ECM help to explain the mortality differences, this sub-section turns to mediation analysis as outlined in Rijnhart et al. (2021).

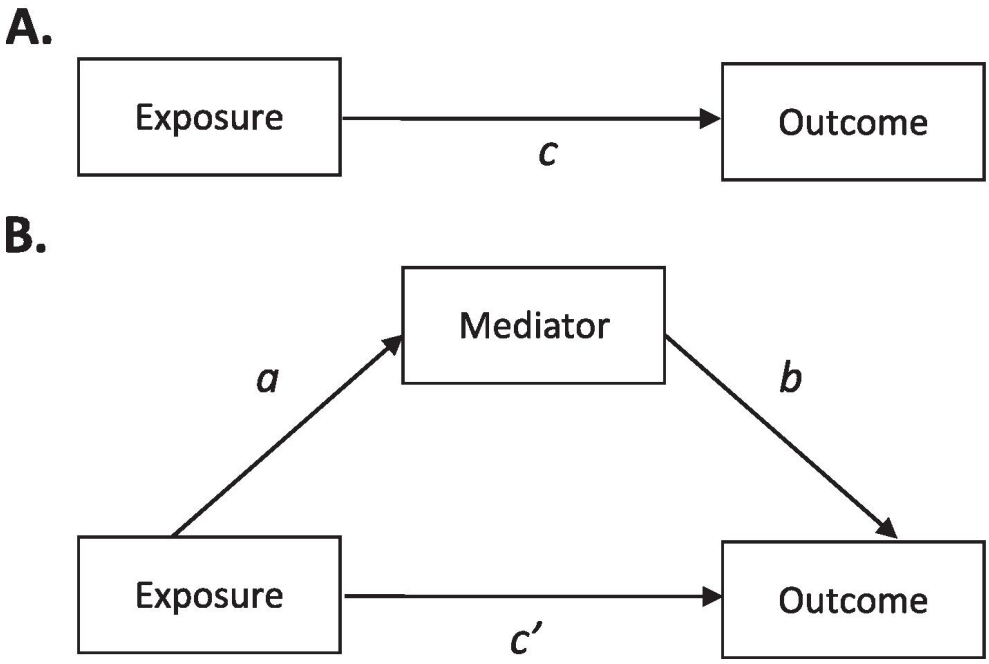
Mediation analysis recognizes that the effects of an explanatory factor X (ECM treatment in this case) on the outcome of interest Y (mortality) might not be direct, but mediated through a third variable. For ECM the direct effect is most likely minuscule, as the creation of the care plan alone has no effects on a patient's health and therefore their probability of dying. The uncovered effects on mortality are most likely the results of a series of changes in a patient's life, including dietary adjustments, increases levels of physical activity, more careful monitoring of one's health etc. Those changes unfortunately cannot be measured using the billing micro-data. Rather, our data allows us to assess the impact of ECM-induced behaviors on the decreased risk of dying. For instance, statin prescriptions might be one of such mediating factors. Figure A4, based on (Rijnhart et al., 2021), presents a graphical decomposition of mediation process into total exposure effect (panel A) and exposure-mediator effect (panel B). The extent to which the direct effect of exposure is working only through the mediator can be calculated by subtracting $c'$ coefficient from $c$. Alternatively, the quotient $\frac{c-c'}{c}$ can be obtained, to get the ratio of the direct effect that is working via mediator alone.

In the causal inference setting, like an RCT analysed here, mediation analysis strives to determine the difference between two counterfactual outcomes $Y_i(x, M_i(x))$, where $Y_i$ is individual's $i$ outcome of interest, $x$ indicates the treatment condition of an individual (0 for control and 1 for treatment), and $M_o(x)$ the value of mediator variable for individual $i$ under treatment condition $x$ (Rijnhart et al., 2021). This leads to the following notation for total unit treatment effect $\tau_i$, as discussed by (Tingley et al., 2014), who also introduce $R$ package that is used below to implement the analyses:

$$\tau_i = Y_i(1, M_i(1)) - Y_i(0, M_i(0))$$

Alternatively, this can be written down as a sum of "causal mediation effects" $\delta_i(x)$ and "direct effects" $\zeta_i(x)$:

Figure A4: Mediation analysis flowchart (based on Rijnhart et al. 2021)




$$\tau_i = \delta_i(x) + \zeta_i(x)$$

The causal mediation effects are obtained by calculating the difference in the outcome that would be obtained if the treatment status was kept constant at $x$, but mediator value was adjusted to the values expected under treatment and control conditions. In other, words, this is the change in the outcome that would be expected if mediator changed its values as if under different treatment condition, but everything else stayed the same:

$$\delta_i(x) = Y_i(x, M_i(1)) - Y_i(x, M_i(0))$$

The direct effect is in turn obtained by keeping the mediator at the same level, depending on the treatment condition, but allowing the treatment status itself to vary:

$$\zeta_i(x) = Y_i(1, M_i(x)) - Y_i(0, M_i(x))$$

Table A7: **Mediation analysis:** ECM effect on mortality

| **Mediating variable** | Causal mediation effects $\delta_i(x)$ (1) | Direct effects $\zeta_i(x)$ (2) | Ratio mediated $\frac{\delta_i(x)}{\delta_i(x)+\zeta_i(x)}$ (3) |
|---|---|---|---|
| **Primary care (assigned clinic)** | | | |
| Doctor in-person chronic care | -0.005*** (-0.001) | -0.009 (-0.006) | 0.367** (0.106) |
| Doctor phone | -0.001 (-0.001) | -0.013** (-0.005) | 0.040 (0.006) |
| Nurse in-person | -0.003*** (-0.001) | -0.010* (-0.005) | 0.240** (0.072) |
| Nurse phone | -0.002*** (-0.001) | -0.012** (-0.006) | 0.126** (0.044) |
| Any consultation | -0.004*** (-0.001) | -0.010* (-0.006) | 0.265** (0.076) |
| Primary | -0.001** (-0.001) | -0.012** (-0.005) | 0.102** (0.047) |
| Outpatient | -0.002*** (-0.001) | -0.012** (-0.005) | 0.133** (0.052) |
| **Primary care (not assigned clinic)** | | | |
| Primary | 0.000 (0.000) | -0.014** (-0.006) | 0.001 (0.020) |
| Outpatient | 0.000 (0.000) | -0.013** (-0.005) | 0.011 (0.014) |
| **Other care** | | | |
| Inpatient | -0.001 (-0.001) | -0.013** (-0.005) | 0.061 (0.065) |
| Inpatient (via ambulance) | -0.002 (-0.002) | -0.011** (-0.005) | 0.167 (0.008) |
| Inpatient re-admission (30) | 0.000 (-0.001) | -0.013** (-0.005) | 0.026 (0.049) |
| Inpatient re-admission (90) | -0.001 (-0.001) | -0.013** (-0.005) | 0.046 (0.045) |
| Daycare healthcare | 0.000 (0.000) | -0.014** (-0.005) | 0.007 (0.039) |
| Inpatient nursing/rehabilitation | 0.000 (-0.001) | -0.013** (-0.005) | 0.020 (0.039) |
| Outpatient nursing/rehabilitation | 0.000 (0.000) | -0.014** (-0.005) | 0.001 (0.026) |
| Covid incidence | 0.001* (0.000) | -0.014** (-0.005) | 0.045 (0.094) |
| Covid vaccine | 0.000 (0.000) | -0.014** (-0.005) | 0.031 (0.075) |
| **Screening** | | | |
| Glycohemoglobin | 0.000 (0.000) | -0.014** (-0.005) | 0.008 (0.067) |
| Creatinine | 0.002* (0.001) | -0.015*** (-0.005) | 0.119* (0.236) |
| Cholesterol | 0.000 (0.000) | -0.014** (-0.005) | 0.029 (0.106) |
| Glucose | 0.001 (0.000) | -0.015** (-0.005) | 0.091 (0.257) |
| TSH | 0.000 (0.000) | -0.014** (-0.005) | 0.004 (0.047) |
| **Diagnosed conditions** | | | |
| Heart failure | 0.000 (0.000) | -0.013** (-0.005) | 0.003 (0.011) |
| Stroke | 0.000 (0.000) | -0.014** (-0.005) | 0.000 (0.014) |
| Myocardial infarction | 0.000 (0.000) | -0.014** (-0.005) | 0.001 (0.020) |
| Hyperlipidemia | -0.002*** (-0.001) | -0.011* (-0.006) | 0.173** (0.066) |
| Overweight/obese | 0.000 (0.000) | -0.013** (-0.005) | 0.005 (0.033) |
| **Prescriptions** | | | |
| Diabetes | 0.000 (0.000) | -0.013** (-0.005) | 0.006 (0.009) |
| Anti-hypertensive | 0.000 (0.000) | -0.014** (-0.005) | 0.000 (0.017) |
| Beta-blockers | 0.000 (0.000) | -0.013** (-0.005) | 0.016 (0.019) |
| Statins | -0.001** (-0.001) | -0.013** (-0.006) | 0.074** (0.036) |
| Any key | -0.001** (-0.001) | -0.013** (-0.005) | 0.066** (0.031) |
| Any other | -0.001*** (-0.001) | -0.012** (-0.005) | 0.078** (0.031) |

*** $< 1\%$; ** $< 5\%$; * $< 10\%$.

**Notes:** The table shows the results of mediation analysis for mild-risk patients, implemented using the approach of (Tingley et al., 2014). The definitions of the causal and direct effects are discussed in detail in the text above, as well as, in much greater detail, in the cited paper.

The mediation analysis is implemented by estimating two OLS models. The first model evaluates the effect ECM treatment assignment on the value of mediating variable of interest. Second, the outcome of interest, in this case dummy variable for whether a patient died during the observation period (1) or not (0), is modelled using both the ECM treatment assignment and the mediating variables. Both models also include the standard set of controls - patient age, sex, as well as strata-level fixed effects.

Standard errors are obtained by re-running the analysis using quasi-Bayesian Monte Carlo method based on normal approximation (Tingley et al., 2014), with 1,000 simulations. Only patients assigned to ECM control and treatment groups are included in the analyses.

The treatment groups are defined as follows: **ECM Control** - patients selected to be in the ECM control at participating doctor, irrespective of their actual treatment status; **ECM Treatment** - patients selected to receive ECM treatment at

participating doctors, irrespective of their actual treatment status. The exact **coding definition** of each of the variables is provided in Table A3.

Applying this approach to assess the scope of ECM activities impacting mortality for mild-risk patients, as done in Table A7, it can be seen that no single variable mediates the majority of the uncovered mortality effects. More frequent interactions with the primary healthcare system appear to be driving between 10% and 36.7% of the direct effect (column 3). Another effect of this size is only seen for hyperlipidemia diagnoses and creatinine monitoring. Around 6-8% of the direct effects are also mediated by more frequent prescriptions, in particular statins. We also undertake a combined assessment of the key features of ECM: more regular interactions with the primary healthcare system and regular uptake of appropriate prescriptions, and find that together these account for roughly half of the experimental variation we see in mortality rates.

### A6.5 Treatment-on-the-treated estimates

In order to estimate the effect of ECM uptake, rather than only ECM assignment, instrumental variables (2SLS) version of all the models in Table 2 were also estimated and are presented in Table A8. The statistical significance of the effects remains almost perfectly consistent with the ones discussed in the main text. The absolute effect size is increased by approximately 27%, consistent with the treatment uptake rate.

Table A8: **ECM Impact:** On patient's care (IV/TOT)

| Variable | Means (control) | | ECM treatment vs. control | |
|---|---|---|---|---|
| | *Any* | *Count* | *Any* | *Count* |
| | (1) | (2) | (3) | (4) |
| **Primary care (assigned clinic)** | | | | |
| Doctor in-person chronic care | 0.471 | 0.384 | 0.139*** (0.033) | 0.189*** (0.040) |
| Doctor phone | 0.912 | 4.078 | 0.010 (0.008) | 0.150 (0.098) |
| Nurse in-person | 0.767 | 1.066 | 0.056*** (0.020) | 0.223*** (0.071) |
| Nurse phone | 0.728 | 1.911 | 0.121*** (0.027) | 0.364*** (0.085) |
| Any consultation | 0.968 | 7.485 | 0.004 (0.004) | 0.914*** (0.163) |
| Primary | 0.867 | 1.472 | 0.037*** (0.010) | 0.130*** (0.041) |
| Outpatient | 0.537 | 0.597 | 0.161*** (0.026) | 0.292*** (0.039) |
| **Primary care (not assigned clinic)** | | | | |
| Primary | 0.106 | 0.148 | -0.000 (0.010) | 0.006 (0.013) |
| Outpatient | 0.845 | 3.436 | 0.012 (0.017) | 0.003 (0.103) |
| **Other care** | | | | |
| Inpatient | 0.255 | 0.221 | -0.025 (0.015) | -0.021 (0.017) |
| Inpatient (via ambulance) | 0.107 | 0.073 | -0.012 (0.012) | -0.011 (0.008) |
| Inpatient re-admission (30) | 0.038 | 0.032 | -0.006 (0.007) | -0.012* (0.006) |
| Inpatient re-admission (90) | 0.059 | 0.054 | -0.001 (0.009) | -0.009 (0.009) |
| Daycare healthcare | 0.117 | 0.097 | 0.004 (0.014) | 0.008 (0.016) |
| Inpatient nursing/rehabilitation | 0.04 | 0.036 | 0.006 (0.009) | -0.000 (0.011) |
| Outpatient nursing/rehabilitation | 0.142 | 0.181 | -0.008 (0.014) | -0.020 (0.031) |
| Covid incidence | 0.202 | 0.131 | 0.022 (0.018) | 0.025* (0.014) |
| Covid vaccine | 0.723 | 0.825 | -0.013 (0.017) | -0.042 (0.028) |
| **Screening** | | | | |
| Glycohemoglobin | 0.683 | 0.765 | 0.063*** (0.017) | 0.144*** (0.032) |
| Creatinine | 0.929 | 2.545 | 0.051*** (0.009) | 0.142 (0.148) |
| Cholesterol | 0.882 | 1.098 | 0.065*** (0.011) | 0.194*** (0.041) |
| Glucose | 0.844 | 2.065 | 0.047*** (0.014) | 0.063 (0.161) |
| TSH | 0.636 | 0.898 | 0.069*** (0.015) | 0.177*** (0.056) |
| **Diagnosed conditions** | | | | |
| Heart failure | 0.302 | 0.723 | 0.045*** (0.015) | 0.205*** (0.052) |
| Stroke | 0.005 | 0.005 | 0.003 (0.003) | 0.001 (0.003) |
| Myocardial infarction | 0.018 | 0.024 | 0.001 (0.005) | 0.001 (0.008) |
| Hyperlipidemia | 0.428 | 0.631 | 0.115*** (0.022) | 0.356*** (0.044) |
| Overweight/obese | 0.136 | 0.176 | 0.075*** (0.018) | 0.191*** (0.034) |
| **Prescriptions** | | | | |
| Diabetes | 0.266 | 1.898 | 0.026* (0.014) | 0.126 (0.090) |
| Anti-hypertensive | 0.036 | 0.081 | -0.002 (0.007) | -0.001 (0.015) |
| Beta-blockers | 0.619 | 2.534 | 0.016 (0.013) | 0.055 (0.064) |
| Statins | 0.597 | 2.34 | 0.042*** (0.015) | 0.158** (0.069) |
| Any key | 0.844 | 6.862 | 0.025* (0.013) | 0.333** (0.158) |
| Any other | 0.985 | 17.828 | 0.004 (0.004) | 0.900*** (0.301) |
| **FE** | - | - | Strata | Strata |
| **Controls** | - | - | Age, sex | Age, sex |
| **N** | 3,275 | 3,275 | 5,056 | 5,056 |

*** < 1%; ** < 5%; * < 10%.

**Notes**: The table measures patient-level health outcomes in the post-treatment period (28/05/2021 - 31/03/2023) for patients assigned to either control or treatment condition. Outcome variables in the 'Count' columns (2,4) are measured as annualized and winsorized (at 99.9th percentile) sums of a given outcome (diagnosis, procedure, or consultation) per patient and period. 'Any' columns (1, 3) measures the same variables converted to 0/1 dummy values, meaning they take values of 1 if a patient had a particular diagnosis, procedure, or consultation at any point during the treatment period, and

0 otherwise.

All regression models in columns 3-4 refer to instrumental regression coefficients, where the treatment assignment is random assignment to ECM Control or ECM Treatment, and the treatment uptake is defined as a patient developing an ECM healthcare plan with their doctor. All regression models are estimated controlling for patients' values age and sex, as well as the value of a given outcome variable in pre-treatment period (01/01/2018 - 27/05/2021) The only exception is 'ECM inclusion' and 'ECM care plan', which are estimated as WLS, i.e. without pre-treatment values as controls, as those procedures are introduced as a part of the intervention. The pre-treatment values are recorded in parallel with their post-treatment equivalents as either counts or dummies in the respective columns. All models include fixed effects as specified in the bottom panel, where strata refers to doctor interacted with patient risk classification level and block to clinic-level randomization block. Fully empty rows code variables that after winsorizing resulted in all values being 0. Models in columns 3-4 are also weighted by strata-level inverse probabilities of treatment assignment. Standard errors of the coefficients are clustered by doctor and provided in parentheses.

The treatment groups are defined as follows: **ECM Control** - patients selected to be in the ECM control at participating doctor, irrespective of their actual treatment status; **ECM Treatment** - patients selected to receive ECM treatment at participating doctors, irrespective of their actual treatment status. The exact **coding definition** of each of the variables is provided in Table A3.

### A6.6 Multiple hypothesis adjustments

The values of statistical significance of model coefficient from Table 2 were also adjusted for multiple hypothesis testing using Benjamini-Hochberg and Romano-Wolf procedures. This approach is taken to ensure the treatment effects found don't simply stem from the number of tests carried out.

Benjamini-Hochberg procedure adjust each p-value by multiplying it by $\frac{m}{i}$ - the ratio of the number of hypotheses being tested ($m$) and the rank of a given p-value in an ascending distribution of all p-values tested ($i$). It therefore increases the testing rigour the higher the number of hypotheses tested, but relaxes it for comparatively higher p-values.

In turn, Romano-Wolf procedure is a more stringent test, controlling for the family-wise error rate (FWER), which accounts for the possibility of outcomes, and therefore also the associated p-values, not being (fully) independent of each other. In this procedure, bootstrapped resampling (with 10,000 iterations here) is used to re-estimate the test statistic of interest and compare them to the original estimate, as documented in (Clarke, 2019).

The results of those tests are shown below in Table A9. In all but few instances they confirm that the results uncovered are unlikely to be due to chance. Apart from the results originally significant only at 10% level, the only challenges to that interpretation come from p-values for nurse in-person consultations and the prescriptions results as re-estimated using Romano-Wolf procedures (columns 7-8).

### A6.7 Randomization inference

Finally, the p-values for both the ANCOVA results (Table 2) and survival analyses (Figures 2 and 3) are also re-calculated using randomization inference. By re-randomizing treatment assignment 10,000 times, using the original randomization procedure, we can test how likely it was to recover the effects of at least the same magnitude by a random chance. The p-values in columns 9-10 of Table 2 confirm that the effects found in the ANCOVA models are extremely unlikely to be spurious. Similarly, Figure A5, suggests that the effect on mortality among the mild-risk patients is unlikely to be due to chance, with randomization p-value standing at 0.021. On the other hand, both the effects on mortality and first hospitalization in the severe-risk group, as well as in aggregate, are found to yield randomization p-values above 0.05, corresponding to the non-significant results in main text.

Table A9: **ECM Impact:** Robustness checks

| Variable | $\beta_{\text{treatment}}$ | | P-values | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | ANCOVA | | Benjamini-Hochberg | | Romano-Wolf | | Randomization inference | |
| | *Any* (1) | *Count* (2) | *Any* (3) | *Count* (4) | *Any* (5) | *Count* (6) | *Any* (7) | *Count* (8) | *Any* (9) | *Count* (10) |
| **Primary care (assigned clinic)** | | | | | | | | | | |
| ECM inclusion | 0.764 | 0.466 | <0.001*** | <0.001*** | <0.001*** | <0.001*** | <0.001*** | <0.001*** | <0.001*** | <0.001*** |
| ECM care plan | 0.784 | 0.935 | <0.001*** | <0.001*** | <0.001*** | <0.001*** | <0.001*** | <0.001*** | <0.001*** | <0.001*** |
| Doctor in-person chronic care | 0.111 | 0.151 | <0.001*** | <0.001*** | <0.001*** | <0.001*** | 0.001*** | <0.001*** | <0.001*** | <0.001*** |
| Doctor phone | 0.007 | 0.051 | 0.27 | 0.597 | 0.417 | 0.713 | 0.985 | 0.999 | 0.299 | 0.596 |
| Nurse in-person | 0.044 | 0.170 | 0.008*** | 0.006*** | 0.022** | 0.016** | 0.172 | 0.101 | <0.001*** | <0.001*** |
| Nurse phone | 0.095 | 0.285 | <0.001*** | <0.001*** | <0.001*** | 0.001*** | <0.001*** | 0.004*** | <0.001*** | <0.001*** |
| Any consultation | 0.003 | 0.645 | 0.308 | <0.001*** | 0.438 | 0.001*** | 0.989 | 0.004*** | 0.291 | <0.001*** |
| Primary | 0.029 | 0.107 | <0.001*** | 0.013** | 0.001*** | 0.035** | 0.01** | 0.229 | 0.002*** | 0.002*** |
| Outpatient | 0.124 | 0.218 | <0.001*** | <0.001*** | <0.001*** | <0.001*** | <0.001*** | <0.001*** | <0.001*** | <0.001*** |
| **Primary care (not assigned clinic)** | | | | | | | | | | |
| Primary | -0.002 | 0.002 | 0.842 | 0.827 | 0.865 | 0.827 | 0.998 | 0.999 | 0.832 | 0.844 |
| Outpatient | 0.013 | 0.073 | 0.358 | 0.448 | 0.473 | 0.587 | 0.989 | 0.998 | 0.259 | 0.525 |
| **Other care** | | | | | | | | | | |
| Inpatient | -0.020 | -0.017 | 0.087* | 0.186 | 0.179 | 0.313 | 0.818 | 0.947 | 0.139 | 0.261 |
| Inpatient (via ambulance) | -0.009 | -0.009 | 0.303 | 0.208 | 0.438 | 0.335 | 0.989 | 0.96 | 0.316 | 0.241 |
| Inpatient re-admission (30) | -0.004 | -0.008 | 0.437 | 0.075* | 0.539 | 0.155 | 0.995 | 0.728 | 0.455 | 0.102 |
| Inpatient re-admission (90) | -0.001 | -0.007 | 0.908 | 0.266 | 0.908 | 0.41 | 0.998 | 0.979 | 0.909 | 0.368 |
| Daycare healthcare | 0.004 | 0.012 | 0.719 | 0.46 | 0.782 | 0.587 | 0.998 | 0.998 | 0.672 | 0.32 |
| Inpatient nursing/rehabilitation | 0.004 | -0.002 | 0.597 | 0.793 | 0.713 | 0.815 | 0.998 | 0.999 | 0.536 | 0.753 |
| Outpatient nursing/rehabilitation | -0.005 | -0.010 | 0.65 | 0.71 | 0.751 | 0.776 | 0.998 | 0.999 | 0.653 | 0.669 |
| Covid incidence | 0.017 | 0.019 | 0.225 | 0.094* | 0.362 | 0.183 | 0.974 | 0.798 | 0.178 | 0.035** |
| Covid vaccine | -0.019 | -0.035 | 0.208 | 0.125 | 0.35 | 0.23 | 0.972 | 0.874 | 0.157 | 0.1 |
| **Screening** | | | | | | | | | | |
| Glycohemoglobin | 0.049 | 0.113 | 0.001*** | <0.001*** | 0.003*** | 0.001*** | 0.022** | 0.006*** | <0.001*** | <0.001*** |
| Creatinine | 0.039 | 0.103 | <0.001*** | 0.387 | <0.001*** | 0.53 | <0.001*** | 0.993 | <0.001*** | 0.316 |
| Cholesterol | 0.052 | 0.154 | <0.001*** | <0.001*** | <0.001*** | <0.001*** | <0.001*** | <0.001*** | <0.001*** | <0.001*** |
| Glucose | 0.036 | 0.055 | 0.002*** | 0.713 | 0.006*** | 0.776 | 0.046** | 0.999 | <0.001*** | 0.73 |
| TSH | 0.052 | 0.139 | <0.001*** | 0.005*** | 0.001*** | 0.014** | 0.004*** | 0.089* | <0.001*** | <0.001*** |
| **Diagnosed conditions** | | | | | | | | | | |
| Heart failure | 0.033 | 0.147 | 0.015** | 0.004*** | 0.035** | 0.012** | 0.266 | 0.071* | 0.017** | 0.002*** |
| Stroke | 0.004 | 0.002 | 0.164 | 0.354 | 0.29 | 0.524 | 0.943 | 0.993 | 0.147 | 0.392 |
| Myocardial infarction | -0.001 | -0.003 | 0.758 | 0.672 | 0.802 | 0.776 | 0.998 | 0.999 | 0.724 | 0.635 |
| Hyperlipidemia | 0.094 | 0.287 | <0.001*** | <0.001*** | <0.001*** | <0.001*** | <0.001*** | <0.001*** | <0.001*** | <0.001*** |
| Overweight/obese | 0.057 | 0.146 | <0.001*** | <0.001*** | 0.001*** | <0.001*** | 0.007*** | <0.001*** | <0.001*** | <0.001*** |
| **Prescriptions** | | | | | | | | | | |
| Diabetes | 0.023 | 0.142 | 0.102 | 0.372 | 0.198 | 0.529 | 0.85 | 0.993 | 0.097* | 0.295 |
| Anti-hypertensive | -0.002 | -0.006 | 0.706 | 0.75 | 0.782 | 0.793 | 0.998 | 0.999 | 0.685 | 0.766 |
| Beta-blockers | 0.013 | 0.046 | 0.43 | 0.551 | 0.539 | 0.679 | 0.995 | 0.999 | 0.417 | 0.573 |
| Statins | 0.038 | 0.158 | 0.015** | 0.037** | 0.035** | 0.08* | 0.265 | 0.484 | 0.011** | 0.04** |
| Any key | 0.022 | 0.341 | 0.053* | 0.131 | 0.116 | 0.23 | 0.65 | 0.874 | 0.056* | 0.098* |
| Any other | 0.003 | 0.848 | 0.323 | 0.016** | 0.442 | 0.039** | 0.989 | 0.259 | 0.387 | 0.029** |
| **Iterations** | - | - | - | - | - | - | 10,000 | 10,000 | 10,000 | 10,000 |
| **FE** | Strata | | | | | | | | | |
| **Controls** | Age, sex | | | | | | | | | |
| **N** | 5,056 | | | | | | | | | |

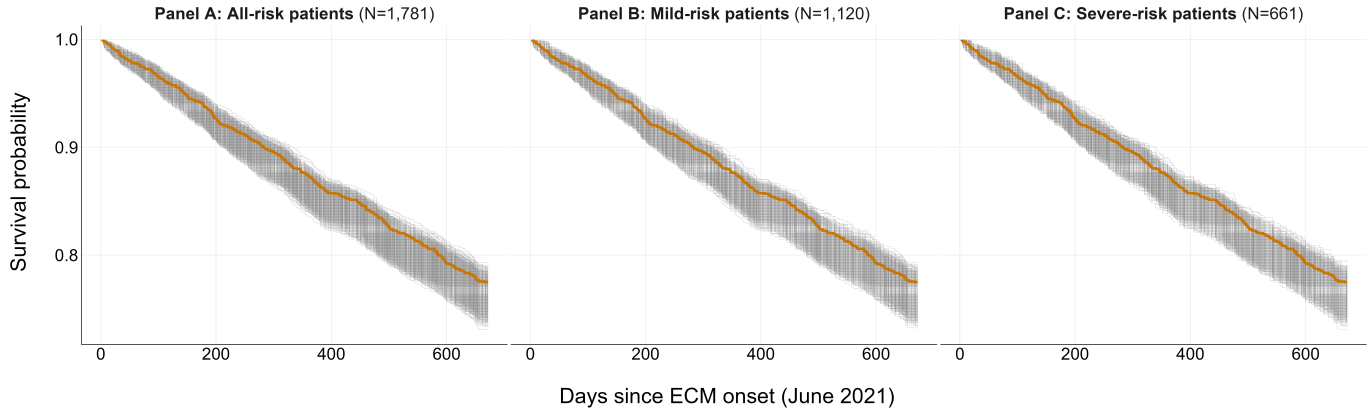
*** < 1%; ** < 5%; * < 10%.

**Notes:** The table measures patient-level health outcomes in the post-treatment period (28/05/2021 - 31/03/2023) for patients assigned to either control or treatment condition. The first two columns (1 and 2) copy the values of regression coefficients from ANCOVA models presented in columns 3 and 4 of Table 2 for greater transparency. All model specifications remain unchanged compared to their description in the notes under that table, unless otherwise indicated.

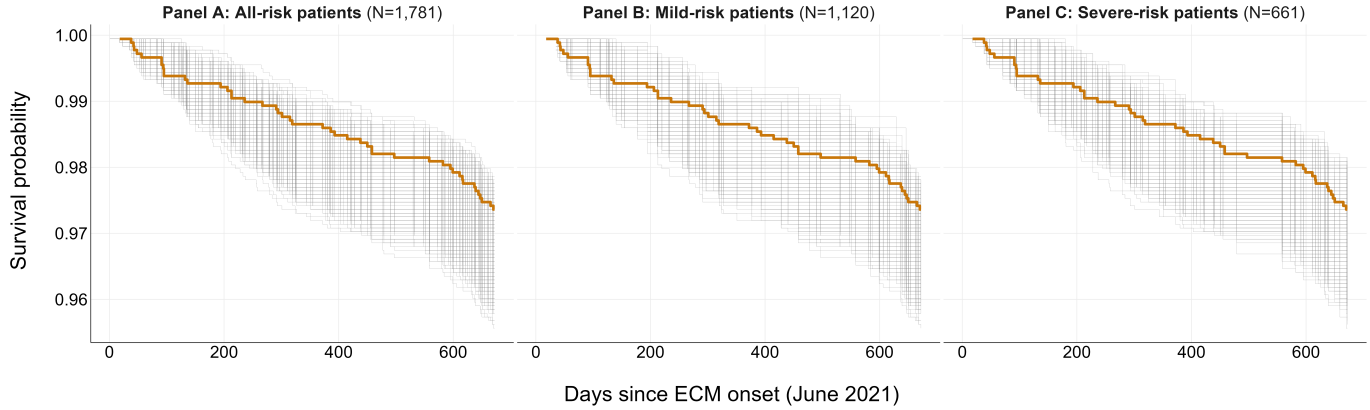
The remaining columns (3-10) indicate the p-values associated with each coefficient, depending on the estimation technique. Columns 3 and 4 replicate the p-values from the ANCOVA models in Table 2, again for easier comparison. Columns 5 and 6 adjust the p-values using Benjamini-Hochberg procedure. Columns 7 and 8 estimate the p-values using randomized inference method, based on 10,000 iterations. Finally, columns 9 and 10 estimate the p-values using Romano-Wolf correction, controlling for the familywise error rate (FWER).
The treatment groups are defined as follows: **ECM Control** - patients selected to be in the ECM control at participating doctors, irrespective of their actual treatment status; **ECM Treatment** - patients selected to receive ECM treatment at participating doctors, irrespective of their actual treatment status. The exact **coding definition** of each variable is provided in Table A3.

Figure A5: Survival curves (randomization inference)

(a) Hospitalization




(b) Mortality




**Notes**: The plot shows survival probability curves, which measure patient's survival probability from ECM onset on 28/05/2021 until the first hospitalization (top panel) and death (bottom panel). All observations are right-censored at the end of the observation period (31/03/2023). For survival until hospitalization they are additionally right-censored at the time of death for patients who died without being hospitalized before 31/03/2023. The survival probabilities are shown for the group of patients assigned to receive ECM treatment - both regardless of their risk class code (Panel A) and divided into mild-risk (Panel B) and severe-risk patients (Panel C), with N specifying the sample size for each group. The dark-orange lines show the survival curves under the original ECM treatment assignment, while the grey lines show survival curves under each of 10,000 re-randomized placebo treatment assignments following the original randomization approach.
**Randomization inference p-values** for subfigure (a) are equal to **0.199** for all-risk patients, **0.382** for mild-risk patients and **0.293** for severe-risk patients. For subfigure (b) they are equal to **0.234** for all-risk patients, **0.021** for mild-risk patients and **0.760** for severe-risk patients.