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Stayin' alive: The introduction of municipal in-patient acute care units was associated with reduced mortality and fewer hospital readmissions

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A R T I C L E I N F O

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A B S T R A C T

Background: Integrated care is seen as integral in combating the current and projected resource scarcity in the healthcare systems of developed economies. Previous research finds positive effects from implementing intermediate care but there is a lack of research on how this shift towards care integration has affected traditional quality indicators within healthcare, indicators such as mortality rates and hospital readmissions. We seek to contribute to the discourse by studying how the introduction of intermediate care in the form of municipal acute units (MAUs) in Norway has affected age adjusted mortality rates and hospital readmissions.
Data and methods: In this retrospective cohort study we utilize yearly population-based registry data from 2010 to 2016, analysed with fixed-effects regressions. Data on the implementation, characteristics and localization of the MAUs were gathered by telephone during the implementation period. Data on mortality rates and hospital readmissions were collected from Statistics Norway and the Norwegian patient registry.
Results: Our analyses finds that the introduction of MAU was associated with a statistically significant reduction in both aggregated mortality rates and hospital readmission rates. In depth analyses finds that our results are contingent upon the age of the patients treated at the MAUs and the clinical characteristics of the medical units themselves.
Conclusion: Our findings indicate that the shift towards intermediate care through the introduction of MAUs has increased performance within the public healthcare sector in Norway. Our findings indicate that the introduction of MAU have had a positive public health impact by lowering the mortality and readmission rates for the oldest population cohort in Norway. Our findings suggests that countries with comparatively similar healthcare systems as Norway could achieve similar benefits from implementing intermediate care in the form of somatic medical institutions in the local communities.

1. Introduction

One of the major healthcare trends within OECD countries for over a decade has been a shift towards various forms of integrated care (OECD, 2017). Integrated care is a multifaceted concept covering various forms of organisational models within healthcare that aim to increase coordination, alignment and connectivity between and within the various organisational entities (Goodwin, 2016; Kodner and Kyriacou, 2000; Dahl et al., 2015; Singer et al., 2011). In essence, integrated care aims to overcome care fragmentation that have the potential to increase the likelihood of adverse patient outcomes by decreasing the quality of provided care (Goodwin, 2016). Integrated care is therefore viewed as an antidote to the fragmentation within and between service levels in modern health systems.

A central component of integrated care is various forms of intermediate care. The main purpose of intermediate care, as with other forms of integrated care, is to decrease fragmentation between services and thus reduce the likelihood of poor patient outcomes (Melis and Rikkert, 2004). Especially important for intermediate care is the focus on bridging the gap between primary and secondary healthcare by offering continuous treatment paths for patients in need of frequent healthcare, primarily elderly people, at a level between primary and secondary healthcare. Intermediate care is therefore mainly targeted at this demographic group (Boston et al., 2001; Erler et al., 2011; Kodner and

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Kyriacou, 2000; Van Kempen et al., 2013).

The concept of intermediate care gained international attention in 2014, when the head of the British NHS stated that intermediate community hospitals would be a central tool to combat the challenges posed by demographic shifts and resource scarcity (Kmietowicz, 2014). The NHS's commitment to this shift of care from hospitals to the community has proven steadfast, as it is a central component in the NHS' "long-term plan" (Alderwick and Dixon, 2019). In addition to the British NHS, countries like Portugal, Netherlands, Italy, and Norway have turned to various forms of intermediate care as community hospitals, to enhance care integration (Bertnum et al., 2018; Erler et al., 2011).

Several studies have found that the introduction of community hospitals and other forms of intermediate care units have resulted in a reduction of unnecessary hospital admissions among elderly patients (Dahl et al., 2015; Millar et al., 2014; Pearson et al., 2015; Szczepura, 2011; Nancarrow, 2004; Martin et al., 2004; Roe and Beech, 2005; Philp et al., 2013). Studies also found that this form of intermediate care is associated with a reduction in prolonged hospital stays and delayed discharges from the hospitals (Bertnum et al., 2018; Steiner, 1997, 2001; Martin et al., 2007). Furthermore, previous research documented that intermediate care units is associated with increased support of independent living (Roe and Beech, 2005), increased continuity of care (Dahl et al., 2015) and reduction of travel distance in transition between levels of care (Pearson et al., 2015; Roe and Beech, 2005).

Even though previous research finds positive impact from intermediate care, very few studies have investigated how its introduction have affected outcomes more directly associated with healthcare quality, both on the individual patient- and system level. Consequently, little is known about the association between intermediate care and traditional quality indicators such as mortality and hospital readmission rates. According to the OECD report "Healthcare at a glance" (2021), quality indicators such as mortality rates and hospital readmission "provide valuable insight into the quality of integration between hospital and community care" (OECD, 2021). Therefore, we wanted to study the effects of intermediate care, a central part of the broader integrated care perspective, on outcomes that are commonly utilized as quality indicators, namely mortality rates and hospital readmissions.

We do this through the case of the so-called 'Municipal in-patient Acute Care Unit' (MAU), sometimes also referred to as 'municipal acute bed units', that was gradually implemented in all Norwegian municipalities following a healthcare decentralisation and coordination reform in 2012 (Vatnøy et al., 2020; Swanson and Hagen, 2016; Skinner, 2015). Many of the few earlier studies of the effects of intermediate care have been studies on small samples and/or studies that were not able to utilize a control group when assessing the effect on outcome variables. In our case the sequential implementation of the MAUs across different municipalities from 2012 to 2016 allows for interpreting the reform as a natural experiment with controls. The natural experiment in combination with register-based data makes it possible to come closer to causal effects of the introduction of the MAUs.

1.1. *Intermediate care in Norwegian municipalities pre- and post- MAU*

A MAU is defined as a municipal or inter-municipal in-patient assistance service that provides 24/7 accommodation to people in urgent need of help and for whom the municipality is able to provide care for (Forsetlund et al., 2014). The main goal of introducing MAUs was to relieve the specialized health services of somatic treatment and hospital admissions for users that can be treated by the primary health services. According to the Norwegian Directorate of Health (DoH), MAU was mainly launched to reduce the number of unnecessary hospital admissions at the somatic hospitals, both directly through an alternative and decentralised treatment option, and as a preventive measure by lowering the threshold for early treatment of elderly with chronic diseases (The Norwegian directory of healthIS-2836, 2018).

Patients admitted to a MAU are those needing close follow-up by nurses or primary physicians, after having been assessed by a GP, typically in a GP's office or at a local emergency care service. The specific organisation of the MAU varies, but they are all organized as part of the municipal health services together with GPs, local emergency services, long-term care services and other social care services (Vatnøy et al., 2020). The most common way of organizing a MAU is within nursing homes, where 59% of the units are localised (The Norwegian directory of healthIS-2836, 2018). The fact that the majority of the MAUs in Norway are organized at nursing homes reflect how this form of intermediate care targets the elderly. Also, this is how intermediate care have been organized in, for instance, the UK and the Netherlands (Hakkaart-vanRoijen et al., 2004; Melis and Rikkert, 2004; Greene et al., 2005).

Part of the rationale for introducing MAUs was results from previous research on intermediate care in the form of community hospitals. A study of a Norwegian community hospital by Lappegard and Hjortdal (2013; 2014) showed that patients admitted to a local community hospital were more satisfied with care than those admitted to a general hospital. A study by Garåsen et al. (2007), Based on the results of a randomized controlled trial, the study concluded that intermediate care in the form of a local community hospital was an equal or better alternative to general hospital admittance. Interestingly, they also found that fewer patients admitted to the community hospitals died, compared to those admitted to general hospitals.

Another Norwegian study compared health care utilisation by elderly patients in a municipality with an intermediate care hospital to that of a municipality without an intermediate care hospital (Dahl et al., 2015). They found that the introduction of an intermediate care hospital reduced the length of hospital stay for people aged above 60 years of age, without exposing patients to increased health risks. Furthermore, a study by Lappegard and Hjortdal (2013) looked at how patients admitted at a local community hospital fared compared to patients admitted at a general hospital. The results showed very small differences in patient outcomes, but they trended towards positive outcomes.

Overall, studies of the effects of intermediate care in the form of community hospitals or similar institutions in Norway find positive effects, which lay a scientific basis for expecting positive results of the introduction of MAU from 2012 and onwards. However, much of the evidence stems from studies of community hospitals that were already in operation years before MAUs were introduced in 2012, not of effects from the newly invented MAUs themselves. Furthermore, the studies of the actual MAUs are mainly small-n studies of larger well-staffed and equipped community hospitals, or qualitative studies, which makes it hard to conclude on the effects of MAU outside the studied context (cf. Leonardsen et al., 2016: Leonardsen, 2017; Johannessen & Steihaug, 2020).

A noteworthy exception is a Norwegian study on the effects of MAUs by Swanson and Hagen (2016). Their study analysed whether implementation of MAUs had any effect on hospitalisations, using some of the same data and methods as employed in this study. The results showed that the introduction of MAUs was associated with a statistically significant reduction in acute hospital admissions at internal medicine s, with a slightly stronger effect for those aged 80 years and above. Furthermore, the analysis revealed that the statistical significance and size of the effects were affected by the institutional characteristics of the MAU. The effect size was larger if the MAU had physicians on duty 24/7, while there was no statistically significant effect on hospital admissions if the MAU lacked access to physicians, or if the MAU was not coordinated with a local emergency service, indicating that access to physicians is a key factor (Swanson and Hagen, 2016).

Islam and Egil (2019) also analysed the effect of MAU (or 'emergency bed capacity', which is how they label MAU) and found that MAU is associated with a reduction in hospital emergency admissions. They arrived at their conclusions through quasi-experimental difference-in-difference analysis of various sources of registry data, which is a similar approach to that of Swanson and Hagen (2016). Therefore, we believe a similar study that utilize the opportunity for a quasi-experimental design to analyse the effects of MAUs on central quality indicators for the health care system is both viable and needed.

The findings from previous research led us to expect positive aggregate effects in a large study of the impact of MAUs on the quality of healthcare. We therefore hypothesise that MAUs will lead to reduced readmissions and mortality for elderly patients. Furthermore, previous research shows that the organization of the community hospital is of importance for achieving positive outcomes. Therefore, we should expect that the effects from introducing MAUs may vary based on the organization of the MAU, operationalized in our study as the location of the MAU and the level of access to doctors within a given unit.

Our hypothesis that MAUs will lead to a reduction in readmission rates is based on two mechanisms. First, patients formerly discharged to home or nursing homes can now be discharged to the MAUs, where they in many cases receive more specialized healthcare in the form of access to physicians and medical equipment. Compared to the previously available alternatives, the MAUs offer the patients more intensive care due to the competence standard set for the MAUs. This may lead to fewer readmissions. However, admitting patients discharged from somatic hospitals would be against the intentions of the MAU's design and is something that the individual municipalities seek to avoid. Nevertheless, this is a possible mechanism that could in theory affect readmission rates. Second, for patients discharged to home, the MAUs represents an alternative to hospital readmissions in cases with worsening conditions, which will be registered as reduced hospital readmission rates in or data.

The mechanisms for a reduction in age-adjusted mortality rates are slightly different. First, mortality will be reduced since the MAUs support the patients discharged from hospitals with more intensive treatment than the patients discharged to municipalities without these intermediate services will. Secondly, admissions to MAUs may occur at an earlier stage than to a hospital. This follows because the MAU is designed to have a lower bar for admission for cases that are not clear-cut, were the patient need supervision, but might not obviously need hospital admission. This could have a preventive effect on adverse outcomes, which on aggregate could lead to a reduction in mortality rates. Before we present our results, we introduce the data and methodology in greater detail in the next section.

2. Data and methods

2.1. Data and study population

This study is designed as a retrospective cohort-study that utilizes aggregated yearly patient, population, and mortality data on a municipal level. The reason for choosing this approach, as opposed to analysing more recent cross-sectional data, is that the sequential implementation of the MAUs in the various municipalities allows for a quasi-experimental design. MAUs were established within the municipalities at different points in time during the implementation period from 2012 to 2016, effectively forming a quasi-treatment and control group within each municipality. A few municipal amalgamations during our study period were handled by using the municipality structure of 2018 (n = 423). Table 4 contains a complete overview of how each of the variables included in the models are defined as well as information of valid data.

The analyses are based on a panel data set constructed from various sources; 1) Statistics Norway's KOSTRA database (all control variables and the population data utilized in the creation of the age adjusted mortality rates), 2) publicly available aggregated patient data from The Norwegian Patient Register (hospital readmission data) collected from the DoH and 3) data on MAUs collected from the municipalities by Hagen and colleagues at the University of Oslo (see Table 1). KOSTRA is a database containing aggregated municipal level data (e.g., economic, demographic, socio economic and health care data). The Norwegian Patient Registry is a database that contains information about all patients that have received in-hospital treatment, treatment in outpatients' clinics or from contract specialists. NPRs individual level data are restricted due to ethical considerations, but for our purposes, we were interested in aggregated, yearly data, which are publicly available through the DoH. Therefore, no permissions or ethical grants were needed (Law of official statistics and Statistics Norway, §7). Data from both KOSTRA and NPR were accessed through the respective websites of the SSB and the DoH. The descriptive statistics for all the variables in the analyses are presented in Table 2 whereas we separate the descriptive statistics pre- and post-reform in Table 3.

2.2. Dependent variables: readmissions and mortality

Both hospital readmissions among the elderly and age-adjusted mortality rate are commonly employed as indicators that reflect the quality of cooperation between primary and specialized health services, the quality of the received treatment in the health services, and as indications of the general health condition in the municipalities (Quentin et al., 2019: Ngantcha et al., 2017). A literature review by Fischer et al. (2014) on the validity of readmission rates as a quality indicator stated that mortality and readmission rates should be viewed in relation to each other, if the goal is to assess the performance of, for instance, a hospital (Mamidanna et al., 2012; Krumholz et al., 2013). We therefore include both outcomes in our study to capture the different quality dimensions of each aggregate.

Data on *hospital readmissions* are collected from the Norwegian DoH's 'National quality indicators' (The Norwegian directorate of health, 2020) which are publicly available at their website. A readmission is defined as an acute admission, independently of the cause of admission and the hospital admitted to, and which occurs between 8 hours and 30 days after discharge from any previous in-hospital stay (The Norwegian directorate of health, 2020; Skyrud et al., 2020). Readmission are operationalized as a probability rate constructed through a statistical generalized linear model (GLM) by the DoH. It is a continuous variable that includes readmission rates for 11 of the most common diagnosis groups, with COPD, pneumonia, fractures, gastroenteritis, heart failure and anaemia topping the frequency list (The Norwegian directorate of health, 2020). We only have data for people aged 67 year or older in our study and, unfortunately, this variable contains missing data for approximately 38 municipalities (10%) in our period of study. Furthermore, we only have data from 2013 to 2016 for hospital readmissions, as opposed to 2010–2016 for mortality rates. We checked if there was systematic under-reporting of readmissions data for specific regions but could not see any specific pattern. However, due to data protection regulation the DoH do not report data from municipalities with less than 1200 inhabitants. As this restriction includes 29 municipalities, the total number of included municipalities for the readmission analyses are 394 (out of 423).

Table 1
Descriptive statistics for the period. All data except household income, is presented as rates per *1000 inhabitants. Household income is in thousands (NOK).*

	Mean	SD	Min	Max
Mortality rate 80+ years	0.106	0.031	.001	0.454
Readmission rate 67+ years	14.625	1.731	6.778	22.919
80 years +	53.789	14.777	20.258	99.290
80+ years in nursing homes	9.396	4.156	.883	24.574
Number of GPs*	3.228	4.092	.015	28.427
Household income in thousands	306.113	35.290	204	446
Welfare recipients	25.209	8.725	5.038	54.175
Population	12.091	36.893	.207	666.757
MAU	.596	.490	0	1
Year	2014.443	.725	2010	2016
MAU by GP*	.897	.829	0	2
N	423			

MAU by GP = MAU by access to general practitioners 24/7.
Number of GPs* = Employed general practitioners in the municipalities.

Table 2
Descriptive statistics pre- and post the Coordination reform of 2012. All data is presented as rates per 1000 inhabitants and household income is provided in thousands (NOK).

	2010			2016		
	Mean	Min	Max	Mean	Min	Max
Mortality rate 80+ years	0.104	.003	0.224	0.103	.003	0.454
Readmission rate 67+ years				14.523	6.733	22.931
80 years +	55.335	20.359	98.661	52.764	20.836	93.974
80+ years in nursing homes	11.142	.975	33.621	9.828	.978	30.401
Number of GPs*	4.859	.016	38.671	5.110	.014	54.569
Household income	527.474	388	726	708.865	431	966
Welfare recipients	25.416	4.674	64.581	26.172	6.272	79.155
Population	11.645	.499	599.230	12.559	.201	666.757
GP 24/7		0	1		0	1
MAU		0	1		0	1
MAU by GP*		0	2		0	2

MAU by GP = MAU by access to GP.

Table 3
Definition of variables and overview of missing data.

Variable notation in the models	Definition	Missing data
Readmission rates >67 years old	The probability of hospital readmissions 30 days after discharge for people older than 67 years of age	N = 394/423
Mortality rates >80 years old	Age and gender adjusted mortality rates for people older than 80 years of age	N = 404/423
MAU	Municipal in-patient acute care units	N = 423
MAU without access to a doctor	Municipal in-patient acute care units without dedicated access to physicians	N = 423
MAU with access to a doctor*	Municipal in-patient acute care units with access to a physician during daytime	N = 423
Doctor present at MAU 24/7	Municipal in-patient acute care units with dedicated physicians that provide 24/7 coverage	N = 423
Individual income	Mean individual income, in thousand NOK	N = 423
Welfare recipients	Number of people within the municipalities on welfare services, per 1000 inhabitants	N = 423
Number of people >80 years	Number of people above 80 years of age as rates per 1000 inhabitants	N = 423
Number of people >80 years in nursing homes	Number of people above 80 years of age in nursing homes, as rates per 1000 inhabitants	N = 423
Number of GPs	Number of general practitioners divided by the total population, as rates per 1000 inhabitants	N = 423
Time	Time as year-dummies	T = 6 years

Mortality rate is a much-used indicator to reflect the general population health within a country (Goodacre et al., 2015; Crede and Hierholzer, 1988). Aggregated age-adjusted mortality rates are commonly used as outcome-quality indicators in studies of the healthcare systems of other countries, especially within the United States and the United Kingdom. It is a frequently used indicator for analysing broader healthcare trends within a unit (e.g., within the healthcare system of a country, a hospital, or a clinic (Benjamins et al., 2021; Axon and Williams, 2011). In this study, age-adjusted mortality rate is operationalized as a continuous variable constructed by the authors, using population data collected from Statistics Norway's KOSTRA-database, which is publicly available.

We do not operationalize mortality as a crude death rate, since this could lead to skewed results based upon population characteristics, such as age and gender, within the various municipalities. Instead, we operationalized the outcome as age-adjusted mortality by calculating the mean mortality rate for each municipality for each year, adjusted for age structure and gender composition within each municipality (direct standardization). We did this for two age cohorts: 18–79 years and 80 years and older, to test our hypothesis based on the findings of previous studies that MAUs would primarily affect the oldest age cohort. We lacked detailed population data from 19 municipalities (n = 404/423 municipalities), partly because of a county amalgamation in Mid-Norway (Trondelag) in addition to randomly distributed missing data in terms of region and municipality size.

Table 4
Model 1. The effect of MAU on age adjusted mortality rates (>80 years) and rates of readmission to hospital within 30 days (>67 years). MAU operationalized by as a composite measure. Elasticities (std.error) in parentheses. Fixed effects for municipalities included.

	(1)	(2)
	Log readmission rates >67 years old	Log mortality rates >80 years old
MAU	−0.0142 (0.00952)	−0.0205 (0.0126)
Household income	−0.00136** (0.000429)	0.000552 (0.000350)
Number of >80-years	0.000105 (0.00271)	−0.0229*** (0.00309)
Welfare recipients	−0.000622 (0.00446)	−0.00638 (0.00365)
Number of GPs*	−0.000134 (0.00337)	0.00428 (0.00395)
Number of >80 year in nursing homes	0.0000536 (0.00485)	−0.00552 (0.00446)
Year 2011		−0.0244** (0.00875)
Year 2012		−0.0134 (0.0127)
Year 2013		−0.0669*** (0.0159)
Year 2014	0.0378*** (0.0102)	−0.101*** (0.0185)
Year 2015	0.0564*** (0.0123)	−0.0905*** (0.0206)
Year 2016	0.0821*** (0.0145)	−0.115*** (0.0252)
Constant	3.156*** (0.184)	−1.399*** (0.155)
N	1483	2813
adj. R^2	0.790	0.794
Within R^2	0.1065	0.1093

Standard errors in parentheses.
$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.
GPs = general practitioner.
MAU = Municipal acute unit.

2.3. Main explanatory variable: MAU

The empirical models test both the general effect of MAUs, as well as the separate effects of different organisational forms of the MAU. The data on MAUs was gathered by phone by Hagen and colleagues in the period 2013–2017 and included the location, organisation, and clinical characteristics of the MAUs for all the Norwegian municipalities (n = 426 in 2016),as well as the location, organisation and clinical characteristics of the MAU. In our initial analysis, we treated the MAU variable as dichotomous, with the value of 1 from the year that the first patient was treated, indicating that a MAU was in effect within a municipality.

2.4. Control variables

In order to account for demographic and structural aspects that may influence readmissions and mortality rates for the elderly, municipality-specific control variables were included in our analyses. The selection and inclusion of control variables are based upon a traditional supply and demand framework, specifically adapted to suit analyses of the public sector (Rattso, 1989; Inman, 1979; Rubinfeld, 1987). This approach has also been utilized in previous quantitative analyses of the effects of MAU (Swanson and Hagen, 2016). Hospital-specific aspects may also be of relevance for the two outcomes and are accounted for through the fixed effects analyses, as the municipalities will be clustered within a specific hospital sector. Also, following Swanson and Hagen (2016), variables reflecting the existing demand for municipal health services were included in the empirical model: *population share above 80 years*, *population share above 80 years in institutions*, *household income* and *the number of welfare recipients* per *1000 inhabitants.*

Geographical factors, such as the distance from a given municipality to a local hospital, are also captured by the municipality-specific characteristics in the fixed effects analyses. Structural factors, such as the existing supply of municipal health care services, are captured by including the variable *number of GPs per capita (within a municipality)*. The model is also weighted by the *population size* of the municipality. Our models therefore account for the effect of large and populous municipalities with short distances to the health services (through a combination of utilizing fixed effects and population weights), allowing us to generalise the results independently of municipality size and geographic location. Finally, we included a control for *years* in the model as dummy variables (time fixed effects) to account for external changes in the dependent variables that could be ascribed to the other aspects of the cooperation reform.

2.5. Statistical analyses

One of the strengths of this study is that the gradual implementation of MAUs allows for a natural experiment where we have data for the dependent variables in the pre- and post-treatment periods. Furthermore, our data has a panel structure, with repeated observations of the same units across time (Wooldridge, 2009). The data can be denoted as follows: (X_{it}, Y_{it}), $i = 1, \ldots, n$ and $t = 1, \ldots, T)$, where the index i represents units and t the time periods.

We are interested in eliminating sources of municipality-specific heterogeneity, as this will reduce the risk of skewed results due to selection bias. Fixed effects models may be estimated using various techniques depending on the data set at hand. In our case, we have a rather short panel (t = 6) that involves a large number of dummy variables, thereby reducing the degrees of freedom and returning less efficient estimators. Therefore, we utilized within effect-estimations, which uses deviations from the group average instead of a dummy variable for each unit (Park, 2011). The fixed effects model, with both individual and time fixed effects, can be formulated as the following equation:

$$Y_{it} = \beta_0 + \alpha_i + \gamma_t + \beta_1 x_1 \ldots \beta_2 x_2 + t + (B_X X_{ti}) + \beta_x Z_i + \varepsilon_{it}$$

Our empirical model, exemplified in this section using the outcome of mortality rates, can thus be described by the following equation (exemplified with mortality rates):

$$(Log)\ MortalityRate_{it} = \beta 1 MAU_{it} + ControlVariables_i + \beta 1 MAU_{it} Doctor 24/7_{it} + MunicipalFixedEffects_{\alpha i} +_t + TimeFixedEffects + u_{it}$$

The term $(\text{Log})Y_{it}$ represents the value of the different models' dependent variables, where i = unit and t = time. $\beta_1 \ldots \beta_2$ is the coefficient for the MAU variable and the control variables, which are represented by ^{X}it. We log-transform the dependent variables in order to achieve a better model fit and to ease interpretation of the results. The term α_i ($i = 1 \ldots n$) captures the municipal fixed effects (i), and *yt* represents the time-fixed effects, while u_{it} represents the error term. The control variables capturing supply and demand of health services are denoted $B_X X_{thi}$ in the equation. The term is included as a vector of the β coefficients to the X control variables. Using fixed effects and within-estimation isolates the effect of the MAU measure, controlling for time-variant variables included in the model that may influence the value of $^{Y}1$ and $Y2$. We also include an interaction term between MAU and level of access to physicians. Z_i denotes the interaction term, where the effect of coefficients $\beta_x Z_i$ for Y, regressed on X at particular values of the moderator Z_i. In addition, the model controls for time-constant factors that are unique for every analytical unit, without including these factors in the model, thereby controlling for selection effects related to early adoption of MAU due to high demand for MAU services. Therefore, we control for inherent municipal characteristics that could skew the distribution of units in our treatment and control groups. Following the robustness tests for heteroscedasticity and autocorrelation the models were estimated with Huber-White robust standard errors (Wooldridge, 2009).

Following Swanson and Hagen (2016), we also tested if the organization of the MAU affected our outcomes. However, we expanded upon their analyses and recreated their data to capture in greater detail how the MAUs were implemented. Our dataset included a detailed description of where the MAU was localized (e.g., at a nursing home or at a hospice) and of the level of access to physicians. We analysed the effect of organizing MAU at five different locations, relative to having no MAU at all. We categorized the organisational MAU variable based upon the type of health institution where the MAU is located. This allowed us to test the effect of MAUs organized at 1) a nursing home, 2) a local hospital, 3) a local emergency service) a district medical center and 5) a hospice relative to not having MAU at these locations. Furthermore, we categorized MAU by 24/7 coverage and estimated the effect of access to physicians as an interaction term with MAU localization, in order to test the effect of the level of access to physicians at the five different locations.

3. Results

In Models 1 and 2 (Table 4), we analysed the effects of MAU by a composite dichotomous measure, with no adjustments for location or other characterizations. The results indicate that the MAUs have a negative effect on mortality rates by −2% for the 80+ age cohort. However, the findings are just shy of being statistically significant ($p = 0.10$) at the 10% level. When testing the effect of MAUs on mortality stratified by age groups below 80, our analyses yield no statistically significant findings neither (not reported in tables). The result from Model 1 is the same for readmission rates 30 days after hospital discharge for people above 67 years of age; we find that MAU is associated with a reduction in readmission rates, but the statistical significance of the findings disappears when we introduce control variables in our model ($p = 0.13$), as shown in Table 4.

Expanding upon model 1 and 2, we introduced variables that specifies the localizations of the MAUs. In Models 3 and 4 (Table 5), we find

Table 5
Model 2. The effect of MAU on age adjusted mortality rates (>80 years) and rates of readmission to hospital within 30 days (>67 years). MAU operationalized by location of MAU. Elasticities (std.error) in parentheses. Fixed effects for municipalities included.

	(3) Log readmission rates >67 years old	(4) Log mortality rates >80 years old
MAU: Nursing homes	−0.0235 (0.0122)	−0.00254 (0.0139)
MAU: Local hospital	−0.0161 (0.0211)	−0.0886*** (0.0167)
MAU: LES*	−0.0122 (0.0184)	−0.00445 (0.0167)
MAU: District medical Center	−0.0213 (0.0139)	0.00529 (0.0154)
MAU: Hospice	−0.00152 (0.0137)	−0.0157 (0.0137)
Household income	−0.00140** (0.000425)	0.000829 (0.000359)
Number of >80-years	0.000267 (0.00270)	−0.0257*** (0.00195)
Welfare recipients	−0.000597 (0.00448)	−0.00757* (0.00352)
Number of GPs*	0.000445 (0.00340)	0.00167 (0.00302)
Number of >80 year in nursing homes	0.000165 (0.000455)	−0.00482 (0.00345)
2011.year		−0.0286** (0.00943)
2012.year		−0.0232 (0.0128)
2013.year		−0.0751*** (0.0174)
2014.year	0.0385*** (0.0103)	−0.116*** (0.0219)
2015.year	0.0578*** (0.0126)	−0.110*** (0.0224)
2016.year	0.0826*** (0.0147)	−0.135*** (0.0267)
Constant	3.156*** (0.181)	−1.330*** (0.141)
N	1476	2802
adj. R^2	0.790	0.797
Within R^2	0.1102	0.1228

p-values in parentheses.
$^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.00$.
GP: General practitioner.
MAU: Municipal acute in-patient units.
LES: Local emergency service.

that if the MAUs are located at a local hospital, the introduction of MAU has an effect of −8.8% (p = 0.000) on the age-adjusted mortality rates for the 80+ age cohort. For the other ways of organizing MAUs, which make up the majority, we find no effects on mortality. Neither is there a statistically significant effects of the different ways of localizing the MAUs on readmissions.

In models 5 and 6 we analyse the effect of maximum access to doctors (24/7 all days a week), relative to less or no access to doctors at the same MAU locations (Table 6). For readmission rates (model 3), we find no statistically significant effect of having access to doctors 24/7 at the MAUs. In fact, we find that the MAUs located at nursing homes with access to doctors during daytime, or on nights and on weekends, that is associated with a −2.5% (p = 0.039) reduction in readmission rates for the 67+ age cohort. We find no effect from MAU organized in any other locations in model 5, nor do we find an effect from the interaction term with 24/7 access to physicians. The main effect from 24/7 access to doctors is also statistically insignificant in model 5. For mortality rates (model 6), we find that MAU located at local hospitals with 24/7 access to physicians is associated with a −11% (p = 0.002) reduction in age adjusted mortality rates for the 80+ cohort. We find no effect from MAU organized in any other locations in model 6, nor do we find an effect from the interaction term with access to 24/7 access to physicians. The main effect from 24/7 access to doctors is also statistically insignificant in model 6.

4. Discussion

The main take aways from this study is that the introduction of MAU was not associated with increased mortality rates for the 80+ age cohort, nor was it associated with increased readmission rates for the 67+ age cohort. In fact, the results of our analyses indicate that it is possible to achieve a reduction in these outcomes, but only if the MAUs are organized in a certain way and importantly, the findings are opposite

Table 6
Models 3–6. The effect of MAU on age adjusted mortality rates (>80 years) and rates of readmission to hospital within 30 days (>67 years). Complete model, including organization of MAU by access to physicians. Elasticities (std.error) in parentheses. Fixed effects for municipalities included.

	(5) Log readmission rates >67 years old	(6) Log mortality rate >80 years old
MAU: Nursing homes	−0.0258* (0.0124)	−0.00148 (0.0146)
MAU: Local hospital	−0.0146 (0.0256)	−0.0172 (0.0336)
MAU: Local emergency services	−0.0197 (0.0242)	−0.0291 (0.0163)
MAU: District medical Center	−0.0224 (0.0142)	0.00272 (0.0162)
MAU: Hospice	0.00296 (0.0147)	−0.0222 (0.0164)
MAU with 24/7 doctors	−0.0114 (0.0326)	0.0264 (0.0185)
MAU at nursing home with 24/7 doctors	0.0646 (0.0461)	−0.0466 (0.0335)
MAU at local hospital with 24/7 doctor	0.00362 (0.0495)	−0.117** (0.0374)
MAU at local emergency services with 24/7 doctor	0.0345 (0.0500)	0.0623 (0.0356)
MAU at DMS with 24/7 doctors	0.0330 (0.0459)	0.0140 (0.0346)
MAU at hospice with 24/7 doctors	0	0
Household income	−0.00142** (0.000431)	−0.000797* (0.000369)
Number of >80-years	0.000321 (0.00268)	−0.0264*** (0.00183)
Welfare recipients	−0.000455 (0.00440)	−0.00797* (0.00351)
Number of GPs*	0.000462 (0.00346)	0.00104 (0.00298)
Number of >80 year in nursing homes	0.0000953 (0.00490)	−0.00480 (0.00438)
Year 2011		−0.0286** (0.00954)
Year 2012		−0.0224 (0.0131)
Year 2013		−0.0729*** (0.0177)
Year 2014	0.0387*** (0.0105)	−0.114*** (0.0224)
Year 2015	0.0582*** (0.0127)	−0.108*** (0.0230)
Year 2016	0.0836*** (0.0149)	−0.135*** (0.0273)
Constant	3.160*** (0.182)	−1.279*** (0.138)
N	1474	2801
adj. R^2	0.790	0.798
Within R^2	0.1136	0.1288

p-values in parentheses.
$^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.00$.
GP: General practitioner.
MAU: Municipal acute in-patient units.
LES: Local emergency service.

between the two outcomes. The association between MAU and reduction in mortality rates and readmission rates are only statistically significant if the MAUs is organized as larger medical units, with 24/7 physician access to physicians. On the other hand, the reduction in readmission rates is contingent upon MAU being organized as smaller units, as we only find statistically significant effects from MAU located at nursing homes without 24/7 physician access. There are several possible explanations for our findings, and they differ depending on the outcome.

The reduction in readmission rates could be caused by the fact that the implementation of MAUs resulted in there being an additional alternative to hospital admissions, which naturally leads to a reduction in readmissions to hospitals. Therefore, it is likely that some of the reduction in readmissions after MAU implementation is a consequence of patients simply being readmitted to the MAU, of which 59% of the beds are located at nursing homes, instead of the regional hospital, not because fewer patients need to be readmitted due to MAU. The fact that we do not find any effect from the level of access to physicians strengthens this explanation, as there is no theoretical reason to expect that lower levels of medical care would yield comparatively positive effects on readmission rates. However, it is possible that the reduction in readmissions is at least in part due to MAU reducing the number of people requiring readmissions through the intended mechanism of prevention, improved coordination between services and strengthening of local healthcare and that these effects are more prevalent in remote municipalities with smaller MAUs. Another possible and more quality of care rooted explanation for our findings on readmission rates is related to the reduced burden of transportation. Previous research has shown that distance in and of itself is a barrier to adequate healthcare (Giambruno et al., 1997; Nemet and Bailey, 1982; Kruzich et al., 2003). The introduction of MAU at local nursing homes reduces travel distance and increases healthcare access for fragile patient, which in turn could have an effect of quality indicators such as readmission rates.

For mortality rates, one explanation is that MAUs work as intended and are providing comparatively better healthcare within the municipalities after its implementation. This could mean that providing specialized healthcare as intermediate care at a local level enables adaptability and efficiency, resulting in preventive effects from early treatment, which could reduce both mortality and readmission rates. Furthermore, the implementation of MAUs enables an intermediate care alternative to being discharged to their home from a hospital, thus providing a better option for patients that were previously discharged to their home due to capacity strains at the various hospitals. However, this could also lead to hospitals discharging patients to a MAU that would strictly benefit from staying longer at a hospital, which could, on an aggregate level, negatively affect mortality rates. Another caveat related to this proposed mechanism is the fact that MAU is not intended for step-down patients. While this mechanism could theoretically explain some of the proven association, this makes it less likely.

This could explain why we find that it is only the large MAUs located at local hospitals with dedicated 24/7 physician coverage that is associated with a reduction in mortality, as they can provide high levels of specialized care. This is also in line with previous research on the effect of community hospitals pre-MAU introduction, which finds similar benefits of integrated care that shares clinical characteristics with an actual hospital (Lappegard and Hjortdal 2013; Garåsen et al., 2007). Our analyses of the relative effect of access to physicians on mortality rates strengthens this explanation, as we find that the association between MAU and reduction in mortality rates is contingent upon having 24/7 access to physicians. This association could both reflect an effect from to the direct benefits of having dedicated access to physicians, but also that the level of access to physicians serves as a proxy for large and well-equipped MAUs.

In addition, these MAUs themselves might also serve as a proxy for a certain municipal service profile both in terms of staffing and clinical characteristics within a municipality, that are not captured by our models. The overall transfer of responsibilities from specialized healthcare to the municipalities was described by Sogstad et al. (2020) as leading to "a continuum of care service models from a generalist approach to highly specialized care services". This transfer entailed an overall increase in specialized staff within the municipalities, including nurses and other healthcare personnel in addition to physicians. As these factors are not time-invariant baseline characteristics within the municipalities, they will not be captured by our fixed effects, nor will our control variables completely capture these exogenous effects from the Coordination reform as a whole, even though we include time-fixed effects in our models. Municipalities that already had a comprehensive service profile were likely to be the ones to implement MAUs as large and well-equipped units. These municipalities would also be better rigged to benefit from other components of the Coordination reform as well, which in addition to the MAUs themselves could affect mortality rates within the municipality. Thus, the MAUs with 24/7 access to physicians might also serve as a proxy for a comprehensive service profile within the municipalities that implemented such MAUs, as opposed to small MAUs located at, for instance, nursing homes.

5. Limitations

One strength of this study is the access to data on the exact starting date of the MAUs, which made it possible to utilize the sequential implementation to isolate the effects on readmissions and mortality. P Steps to ensure internal validity have been taken and the analyses account for municipal heterogeneity and external shocks trough unit/entity and time fixed effects. The results in this study are not limited to specific municipal characteristics such as municipal size or structural factors that are specific for a given municipality since this is a large-n study that utilized weighted fixed effects regression.

However, our study also has some limitations, primarily related to data access. In terms of missing data, we do not have readmission data from the smallest municipalities in Norway (n=<1200 inhabitants), which is a limitation in terms of generalizations of the effects of MAUs in the smallest municipalities. On a more general level related to data quality, it would be a strength if we were able to utilize individual level data from the various public registries where the same individuals were coupled and matched across databases.

When we analyse the effect of MAU with aggregated municipal data as opposed to individual level registry data, we are limited to obtaining statistical associations between MAU and our outcomes, we are not proving causal effects. Therefore, it is likely that some of the effect of MAU in our analyses can be explained by factors not directly linked to MAU but rather to the broader changes in the healthcare system stemming from the coordination reform as a whole; factors that are not captured by our fixed effects. For instance, the number of nurses and staff/services in the municipalities was substantially increased as part of the broader transfer of responsibilities from specialized health care to municipal healthcare, which could result in improvements (i.e., reductions) in both mortality rates and hospital readmission rates (Sogstad et al., 2020). Furthermore, when modelling the effect of MAU on aggregated municipal data, as opposed to individual level registry data, the size of the coefficients should be interpreted as directional rather than substantive quantifications of real-world effects.

Another limitation is the quite short time period under study, especially for readmission rates, which could bias our results. Furthermore, the fact that the various municipalities self-selected time of MAU implementation raises endogeneity concerns, which we believe is proper to mention even though we have taken the suitable methodological steps to reduce this risk of bias by including municipal specific effects. Also, even though we find that MAUs are associated with positive effects within the Norwegian context, it is, of course, hard to argue that these effects are *automatically* transferable to an international context regardless of the characteristics of a given healthcare system.

If one is to expect the positive results of intermediate care such as community hospitals, or some form of MAUs, it is very likely that the health system in which these policies are to be implemented must share some key characteristics. Previous research on the effects of intermediate care, operationalized as various forms of decentralised community hospitals, are from public health systems within the OECD (mainly within the NHS) that were primarily centralised before introducing various forms of intermediate care at a municipal level. Therefore, we believe that the findings of this study are limited to health systems within countries that are comparatively similar to that of Norway.

6. Conclusion

Our findings indicate that integrated care in Norway through MAUs are working as intended and are alleviating pressure of specialized healthcare while at the same time improving the health and well-being for elderly patients within the various municipalities, possibly through the mechanisms discussed in this paper. Nevertheless, it is important to underline that the associations between introducing MAU and reductions in mortality rates are conditioned upon organizing MAU as comparatively large medical units that are staffed and equipped accordingly. For readmission rates, our analyses indicates that it is the smaller MAUs that is associated with reductions in readmission rates.

We believe that the findings of this study are also relevant to the ongoing international discourse on the effects of decentralisation trough integrated care, as our findings indicate that intermediate care in the form of MAUs targeting the elderly could be an important tool for dealing with the great demographic shifts in the coming years. However, our findings are limited to countries that are comparatively similar to Norway in terms of, especially, health system characteristics. Even though we find that implementing MAUs is associated with a reduction in both mortality and readmission rates in this study, more research is needed in order to strengthen the body of evidence, both on MAUs directly and on similar forms of integrated care outside the Norwegian context.

Credit author statement

Geir Haakon Hilland: Conceptualization, Methodology / Study design, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration, Funding acquisition, Terje P. Hagen: Conceptualization, Methodology / Study design, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Supervision, Pål E. Martinussen: Conceptualization, Validation, Investigation, Resources, Writing – original draft, Writing – review & editing, Supervision, Project administration, Funding acquisition

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Parts of the data can be made available upon request, but not all due to property rights

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