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Is greater integration associated with larger reductions in unplanned hospital admissions? An analysis of new care models in England

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Abstract

Background: Health systems around the world are aiming to improve the integration of health and social care services to deliver better care for patients. The evidence base is weak, however, and it is unclear if integrated care programmes actually lead to better integration of services and indeed whether greater integration is associated with improved outcomes.

Objective: To examine whether the integrated primary and acute care systems (PACS) model in the English National Health Service lead to greater integration of care and whether integration is causally associated with improved outcomes.

Data: English outpatient and inpatient Hospital Episode Statistics (HES) data for the period 2014/15-2016/17 merged with publicly available data on population and general practice (GP) characteristics in for 399 practices in three intervention sites and three comparison sites in England.

Methods: We applied causal mediation analysis using a linear structural equation model to assess whether greater integration of primary and secondary care was causally associated with reduced emergency admissions for ambulatory care sensitive conditions (ACSAs) for older adults. First, we estimated a difference-in-differences (DiD) model to test whether PACS improved the integration of primary and secondary care. We measured integration as the change in the concentration of outpatient referrals at the GP practice level. Secondly, we included the integration measure in a DiD model to assess the impact of PACS on ACSAs. We conducted the analysis both for the aggregated number of intervention and comparison GPs across the three PACS and for each PACS separately.

Results: PACS was associated with greater integration in one of the three sites. Integration had an ambiguous impact on ACSAs. In two sites, greater integration was associated with more ACSAs. In one PACS, greater integration was associated with fewer ACSAs.

Conclusion: The analysis emphasises the need to focus future evaluations of integrated care programmes on the extent to which integrated care does indeed lead to better integration, and to better understand the hypothesised causal impact of integration on health outcomes.

Keywords: ambulatory care sensitive admissions, concentration index, integrated care, mediation analysis, NHS vanguards.

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1 Introduction

In many developed countries, changing population demographics has led policy makers to suspect that existing care models are not well suited for an aging population that increasingly lives longer with one or more chronic conditions **[1, 2].** Consequently, health systems have embarked on a move towards care delivery models aiming to integrate care across primary, secondary and sometimes social care **[3, 4].** In England, a range of new care models thus aims to provide less fragmented care and greater integration between health care providers catering for local populations **[5, 6].** To date, the majority of the evaluations of these initiatives have focused on whether integrated care programmes have achieved their objectives such as reducing emergency admissions and costs for the populations; the results so far are mixed **[7, 8].** However, causal mechanisms exploring the reason behind the success or failure of these programmes have received little attention in the health policy evaluation literature. Therefore, in an effort to better understand the potential pathways through which these initiatives affect their promised outcomes, this study proposes a mediation framework to estimate the mediated effect of the integration of primary and secondary care on the relationship between integrated care programmes and unplanned hospital admissions.

In England, evaluations of the effect of integrated care programmes on unplanned hospital utilisation have found, for example, a 9% increase following the implementation of 16 integrated care pilots and a slight increase as a result of a multidisciplinary team management intervention in Manchester **[9, 10].** On the contrary, evaluations of different integrated care programmes in London and in the North East of the country did not found a statistical effect on emergency admissions **[11-13].** The story of mixed results is not different in the international experience **[7, 14].**

The mixed results has led to a discussion in the literature about whether reduced emergency admissions is an appropriate evaluation criteria for these programmes, and a suggestion that other outcomes might be more likely to be affected **[14].** However, this debate fails to address a crucial point, namely to which extent the integrated care programmes were indeed successful in integrating care. A plausible explanation for a lack of effect is that providers simply did not coordinate their action after the programmes were introduced.

This paper proposes that, as a first step in understanding whether integrated care programmes are successful, it is critical to examine whether and to which extent the integrated care programmes have indeed lead to greater integration of care. In other words, we propose to examine the mechanism through which new care models are hypothesised to work: the integration of care from across the spectrum of care. To this end, we suggest a mediation analysis approach to explore the causal pathway between integrated care programmes and the use of emergency hospital care.

In 2015, vanguards were launched across England as part of the NHS New Care Models programme aiming to break down the traditional barriers between health and care organisations to establish more personalised and coordinated health services for patients **[15, 16]**. By September 2016 there were a total of 50 vanguards classified in five types of models: integrated primary and acute care systems (PACS), multispecialty community providers, enhanced health in care homes, urgent and emergency care, and acute care collaborations **[15]**. The PACS model is a population-based care model based on the general practice (GP) registered list that brings together a group of providers taking responsibility for delivering a full range of primary, community, mental health and hospital services for their local population **[17, 18].** Its aim is to join up services to allow better decision making and more sustainable use of resources with a greater focus on prevention and integrated community-based care and less reliance on hospital care **[18].** National funding for vanguards ended in March 2018 and some of the core components of the PACS model are now being widely introduced across England **[17]**. The analysis presented here focuses on three PACS: Northumberland Accountable Care Organisation (ACO), Salford Together and South Somerset Symphony Programme serving a population of 320K, 230K and 200K, respectively. In each case, the PACS partners include one county council, one acute trust and one clinical commissioning group (CCG). In addition, the Northumberland PACS has one ambulance trust working together with local GPs and the Salford PACS has one mental health trust **[15]**.

General Practices (GPs) play a crucial role in the integration of primary and secondary care. From their referral patterns, we can infer whether GPs changed behaviour after the introduction of PACS. Tighter integration is expected to lead to a greater concentration in referrals to the PACS partner hospital. We, therefore, posit that integration of care could be measured using the concentration of general practice referrals to specialist outpatient care.

Our mediation analysis approach begins by estimating whether PACS increased integration of primary and secondary care. To that end, we calculate Herfindahl-Hirschman (HHI) style concentration indexes for each practice in the PACS areas and a set of comparison areas. An increase in the HHI suggests that integration increased following the introduction of the PACS. In a second step, we examine the impact of the PACS on the rate of ambulatory care sensitive emergency admissions (ACSAs) at practice level and, by conditioning on the variation in the measure of integration of care, we are able to distinguish between the indirect effect (through a change in integration) and the direct effect (all other routes) **[19, 20]**.

We find evidence that suggests a mediated effect of the integration of primary and secondary care on the relationship between the Salford PACS and unplanned hospital admissions although in the opposite direction as hypothesised: an increase in integration led to an increase in the rate of ACSAs.

Our paper contributes to the literature on integrated care in two ways. First, by suggesting a mediation analysis approach in the evaluation of integrated care initiative. Second, by using the concentration of outpatient referrals to measure integration of care.

2 Methods

2.1 Outpatient referrals and unplanned hospital admissions

We use outpatient Hospital Episode Statistics (HES) data between March 2014 and September 2016 to identify outpatient referral flows from GP practices located in three English National Health Service (NHS) CCGs: Northumberland, Salford, and Somerset, and, as detailed below, in their respective comparison areas. We also use HES admitted patient care data to identify unplanned hospital care measured using emergency admissions for chronic ambulatory care sensitive conditions (ACSAs) amongst adults aged 65 or older registered in any of the GPs studied **[21]**. Chronic ACSAs are those hospitalisations that might be prevented by effective care and case management. We identify them using the International Classification of Disease (ICD -10) codes of their primary diagnosis and include some infections, diseases of the blood, neurological disorders, mental and behavioural disorders as well as cardiovascular and respiratory diseases **[22]**.

2.2 Practice and population characteristics

We merged the HES data with a number of additional variables publicly available from NHS Digital, namely, the age and sex composition of the population registered in each GP and the health care workforce available in these **[23, 24]**. Hypertension, Diabetes, Heart Failure and Obesity prevalence rates were taken from the Quality Outcome Framework indicators **[25].** Finally, GPs deprivation scores were taken from Public Health England **[26].**

No providers merged or changed provider codes during the respective study periods for which they were included; therefore, no recoding of providers was required. However, data on registered population, disease prevalence rates, workforce and deprivation score were not available for all the observed GPs and, thus, the GPs with missing information are excluded in the models that include these variables.

2.3 Measuring integration

To capture changes in the level of integration between primary and secondary care, we focus on the concentration of each GP's referrals of patients to secondary outpatient care. In England, each year, more than 10m outpatient referrals are made and they arguable can be considered the interface between primary and secondary care. If primary care providers' work start to integrate care more closely, we expect to be able to see a greater concentration in the number of hospitals to which they are referring patients. This is in line with the literature on referral networks which has demonstrated that referral patterns can be used to identify professional relationships between physicians **[27-29]**

First, for each of the three PACS studied, we identify all GPs located within the CCG of implementation (intervention practices) and all GPs practices outside of the CCG, but located within a defined distance from the geographic boundary of the CCG (comparison practices). The distance threshold, defined separately for each PACS, is the one that produces balance between the number of practices within and outside the CCG of implementation: 5km for Salford, 10km for Northumberland and 12 km for Somerset. Next, we use HES to identify all outpatient presentations by adult patients aged 65 years or older and registered to 'intervention' and 'comparison' practices to acute hospital trusts in the 12 months before the implementation of the intervention (baseline), and 12 months after the implementation date (endline). Then, for each GP, we compute the Herfindahl-Hirshmann Index (HHI):

$$HHI = \sum_{j=1}^{N} s_{ij}^2 \qquad (1)$$

where s_{ij} is the proportion of patients referred from GP practice *i* to Hospital *j* and N is the total number of hospitals referred to by the GP practice *i*. The HHI is a measure of concentration which means that if a given GP increases the proportion of its referrals to a specific hospital, its HHI will increase as the hospital's share of the total patients that are referred to outpatient from the GP in question is increasing. The HHI can be converted into a numbers equivalent index by taking its reciprocal **[30].** The index (1/HHI) is interpreted as the number of equal-sized acute hospitals to which the GP practice refers patients that would yield the same HHI.[1] In this sense, GPs with higher HHI (and thus lower 1/HHI) concentrate their outpatient referrals to fewer hospitals than GPs with lower HHI. We propose that this concentration index can be interpreted as a measure of integration of primary and secondary care as it captures information of the level of interaction between GPs and acute hospitals: a higher share of the referrals of a GP might reflect better coordination and exchange of information between hospitals and GPs.

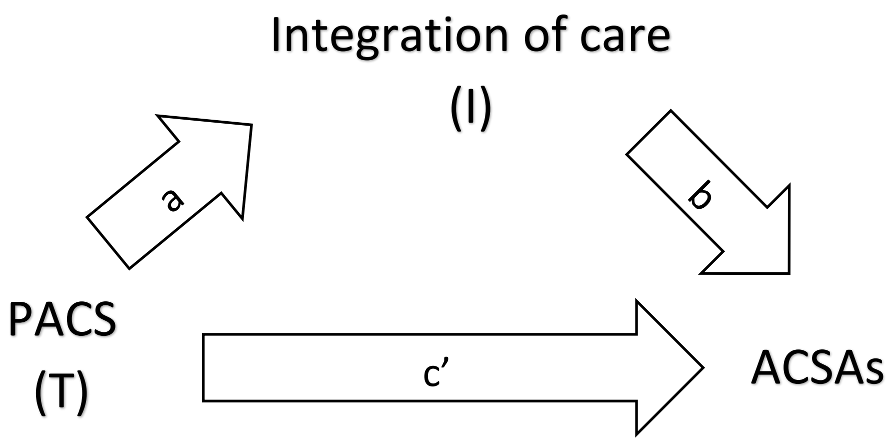
2.4 Analysis

The identification of a causal mechanism requires the specification of an intermediate variable or a mediator that lies on the causal pathway between the treatment and outcome variables **[31]**. Hence, the investigation of causal mechanisms is based on the estimation of causal mediation effects. An earlier review showed that mediation studies are generally of two types **[20].** One type consists of investigating how a particular effect occurs, usually after finding evidence of a causal relationship between two variables: X and Y. In this framework, a mediator variable is added to the analysis to improve the understanding of the relation or to determine if the relation is spurious. The second type of these studies focuses on the mediational processes; in this type of research an intervention is designed to change mediating variables that are hypothesised to be causally related to a dependent variable. If the hypothesised relations are correct a policy that substantially changes the mediating variables will in turn change the outcome **[20]**. The present paper lies in the second type of mediation analysis.

[1] Here equal size means having the same proportion of patients referred by the same GP.

The rationale of the PACS design is that integrating health care services will allow better decision-making and more sustainable use of resources with a greater focus on prevention and less reliance on emergency or unplanned hospital care **[18].** We illustrate this hypothesised causal mechanism in **Figure 1** as a single mediator model in which a PACS (T) causally affects unplanned hospital care through the integration of care.

Figure 1. Single Mediator Model



The goal of this approach is to decompose the causal effect of a treatment into the indirect effect, which represents the hypothesised causal mechanism (the combination of arrow "a" and arrow "b"), and the direct effect, which represents all the other mechanisms (arrow "c'").

Following Anselmi et al. (2017) that applied the linear structural equation model within a difference-in-differences (DiD) analysis, our approach to assess mediation comprises three steps **[19, 20, 32].**

First, we estimate the impact of the PACS in Northumberland, Salford and Somerset on integration of care using the following difference-in differences (DiD) regression model

$$I_{it} = \beta_0^1 + a(T_i * \delta_t) + \beta_1^1 \delta_t + \beta_2^1 T_i + \varepsilon_{it}^1 \qquad (2)$$

where I_{it} is the integration of care measure (1/HHI) of GP *i* in time *t*. T_i is a variable indicating if the GP is an intervention (1) or a comparison practice (0). δ_t is a dummy variable taking the value of 0 at baseline and 1 at endline and ε_{it} is the residual. The effect of the PACS on integration of care is captured by the estimation of a. If PACS have indeed contributed to a higher integration of care in their local health systems, we would expect a significantly negative *a* (i.e. outpatient referrals from GPs would concentrate in fewer hospitals). Model (2) is first estimated aggregating the GP practices in the intervention and comparison groups from the three PACS and clustering at the PACS level with bootstrapped standard errors **[33]**. Additionally, Model (2) is estimated for each PACS. It is important to note that while an increase in the integration measure suggested here reflects a higher concentration of outpatient referrals, this concentration might not necessarily be directed towards the hospital trust participating in the vanguard. Therefore, to assess the extent to which a change in the concentration of referrals is indeed related to a change in the share of patients referred to the participating hospital trust from intervention GPs, we use a difference-in-difference-in-differences (DDD) models to estimate the effect of each PACS on the proportions of patients referred from intervention and control GPs to the participating hospital trust **[34]**.

In a second step, we estimate the impact of PACS on ACSAs using a DiD model

$$Y_{it} = \beta_0^2 + c(T_i * \delta_t) + \beta_1^2\delta_t + \beta_2^2 T_i + \varepsilon_{it}^2 \quad (3)$$

where Y_{it} is the ACSAs per 1000 adults aged 65 or older registered in GP *i* in time *t.* If PACS have indeed been successful in reducing unplanned and preventable hospital care, we would expect a significantly negative *c* (i.e. PACS have reduced ACSAs). Model (3) was estimated first using all observations and then analysing each PACS separately.

Finally, we identify the direct and indirect causal effects by adding I_{it} as covariate in (2):

$$Y_{it} = \beta_0^3 + c'(T_i * \delta_t) + bI_{it} + \beta_1^3\delta_t + \beta_2^3 T_i + \varepsilon_{it}^3 \quad (4)$$

If *b* is significant and |c'| < |c| we can infer that the effect of PACS (T_i) on ACSAs (Y_{it}) is mediated through integrated care I_{it}. c' measures the direct effect of T_i on Y_{it} and the indirect or mediated effect is calculated as the product between *a* and *b*. The assessment of the statistical significance of the indirect effect is performed using bootstrapped standard errors **[20, 32].** Like Models (2) and (3), Model (4) was estimated for the aggregated case and separately for each of the three PACS.

In sum, the following conditions are required to support the causal mechanism hypothesis depicted in Figure 1

1. Significantly negative *a* in Model (2), suggesting that PACS has increased integration of care.
2. A significantly positive *b* in Model (4), i.e. the higher the spread of providers (1/HHI) – the lower the integration – the higher the ACSA rate.
3. A significantly negative indirect effect of the policy (*a* * *b*)
4. A negative direct effect, but smaller in absolute terms than the total effect.

It is worth mentioning that due to the potential presence of opposing mediated effects, overall relations between the treatment (PACS) and the outcome (ACSA rate) may not be statistically significant yet mediation still exist **[20]**.

Table 1. Descriptive Statistics

	Before				After			
	PACS Mean (SD)	**Comparison Mean (SD)**	**Combined Mean (SD)**	**Diff - T-stat$^{\Phi}$ (p-value)**	**PACS Mean (SD)**	**Comparison Mean (SD)**	**Combined Mean (SD)**	**Diff - T-stat$^{\Phi}$ (p-value)**
GP practices	164	235	399	[redacted]	164	233	397	[redacted]
ACSC emergency admissions per 1000 population	8.74 (3.5)	8.93 (3.23)	8.85 (3.33)	0.55 (0.58)	9.20 (3.15)	8.88 (3.29)	9.01 (3.24)	-0.98 0.33
ACSC emergency admissions per 1000 old adults	28.66 (12.93)	35.26 (17.58)	32.55 (16.14)	4.10 (0.001)	29.84 (13.14)	33.88 (16.68)	32.21 (15.43)	2.58 (0.01)
Emergency admissions per 1000 population	101.66 (22.49)	98.70 (23.39)	99.91 (24.25)	1.2 (0.23)	106.48 (21.18)	97.96 (21.56)	101.48 (21.78)	-3.91 (0.00)
Number of hospitals to which practice referred patients for outpatient care	14.31 (6.75)	11.22 (6.00)	12.49 (6.49)	-4.81 (0.00)	15.03 (7.31)	11.63 (6.35)	13.03 (6.96)	-4.94 (0.00)
Equivalent number of equal size hospitals referred (1/HHI)	1.94 (0.67)	1.94 (0.59)	1.94 (0.64)	-0.08 (0.94)	1.86 (0.60)	2.03 (0.66)	1.96 (0.64)	2.70 (0.01)
Outpatient referrals per registered patient	0.57 (0.18)	0.58 (0.25)	0.57 (0.22)	0.38 (0.70)	0.62 (0.18)	0.59 (0.25)	0.60 (0.23)	-1.32 0.19
GP list size	6,911.7 (4289.2)	6,670 (3644)	6,769.3 (3918.6)	-0.61 (0.55)	7,001.3 (4311.8)	6,876.8 (3795.6)	6,928.3 (4012.1)	-0.30 (0.76)
Proportion of patients aged 65 or older	0.20 (0.07)	0.16 (0.07)	0.18 (0.07)	-6.84 (0.00)	0.21 (0.07)	0.16 (0.07)	0.18 (0.07)	-6.86 (0.00)
Proportion of male patients	0.50 (0.02)	0.51 (0.03)	0.50 (0.02)	3.09 (0.00)	0.50 (0.02)	0.051 (0.03)	0.50 (0.02)	2.95 (0.00)
FTE GPs	4.34 (2.93)	3.61 (2.30)	3.92 (2.61)	-2.83 (0.00)	4.21 (2.50)	3.65 (2.34)	3.88 (2.41)	-2.20 (0.03)
Proportion of male FTE GPs	0.52 (0.26)	0.54 (0.27)	0.53 (0.26)	0.69 (0.49)	0.53 (0.24)	0.54 (0.28)	0.54 (0.26)	0.40 (0.69)
Patients per FTE GPs	1,854 (1326)	2,230 (1650.6)	2,071 (1531.3)	2.37 (0.02)	1,978.9 (2075.1)	2,214.5 (1357.1)	2,119 (1686.8)	1.29 (0.20)
Deprivation score	22.80 (10.20)	28.44 (13.32)	26.08 (12.41)	4.44 (0.00)	22.80 (10.20)	28.44 (13.32)	26.08 (12.41)	4.44 (0.00)
Prevalence hypertension	15.59 (3.67)	13.65 (3.67)	14.45 (3.79)	-5.18 (0.00)	15.68 (3.92)	13.70 (3.67)	14.51 (3.90)	-5.14 (0.00)
Prevalence diabetes	6.53 (1.19)	6.78 (1.80)	6.68 (1.58)	1.54 (0.12)	6.78 (1.30)	7.03 (1.84)	6.92 (1.64)	1.50 (0.13)
Prevalence heart failure	0.88 (0.36)	0.76 (0.35)	0.81 (0.36)	-3.15 (0.00)	0.92 (0.37)	0.82 (0.38)	0.86 (0.38)	-2.62 (0.01)
Prevalence obesity	9.86 (3.38)	9.94 (3.29)	9.91 (3.33)	0.24 (0.81)	10.29 (3.98)	10.47 (3.60)	10.39 (3.76)	0.48 (0.63)

This analysis was recently extended to the longitudinal case for the period 2013/14-2017/18 and now includes all the nine PACS in England. Section 5 –Next Steps– describes the longitudinal approach and highlights its main challenges.

3 Results

3.1 Descriptive statistics

The present analysis is based on data from 44 GPs in the Northumberland CCG, 45 in Salford CCG, 75 in Somerset CCG and from 235 in their respective comparison areas. **Table 1** shows that at baseline the rate of ACSAs per 1000 registered adults aged 65 or older was higher in the GPs located in comparison areas; the deprivation score in comparison practices as well as the patients to full time equivalent (FTE) GPs ratio was also higher. On the other hand, the average number of hospitals to which the practice referred patients for outpatient care (but not the concentration of referrals), the proportion of patients aged 65 or older, the number of FTE GPs and the prevalence rates of hypertension and heart failure were higher in intervention GPs. For presentation purposes, descriptive statistics tables for each PACS separately are not shown, but available from the authors upon request.

It is worth mentioning that GPs were not randomly allocated to the intervention and comparison groups at baseline and that, at this stage of the study, the parallel trends hypothesis was not tested. Therefore, it is assumed that, due to the neighbouring condition of practices in the intervention and comparison groups for each PACS, the pre-intervention parallel trends hypothesis holds in each case and in the aggregate. Nevertheless, in order to account for variables that could potentially be related to treatment assignment, to the integration of care and/or to the ACSA rate, we include a vector of GP characteristics X_{it} in models (2) – (4) and report the results of these alternative specifications in the Appendix. Following Exley et al (2019), the covariates incorporated in X_{it} are the total GP list size, the proportion of patients registered with the practice aged 65 and over, the proportion of patients that were male, the practice deprivation score, the number of FTE GPs in the practice and the proportion of FTE made up by male GPs **[12]**. X_{it} also includes the prevalence rates of hypertension, diabetes, heart failure and obesity amongst the registered GP population.

Figures 1-3 show the geographic location of each GP analysed and the change from baseline to endline in their concentration of outpatient referrals, expressed in the equivalent number of equal-sized hospitals to which each GP is referring patients (interactive maps of these figures are available as supplementary information). Each dot in the map represents a GP, they are purple when the concentration of referrals increased (1/HHI decreased) and green otherwise. The black solid line in each figure represents the geographic boundary of the CCG where the PACS was implemented. The area between the black and the light grey lines denotes the area where the comparison GPs are located. While there is not a clear geographic pattern in Northumberland and Somerset, the majority of GPs in Salford CCG observe an increase in the concentration of outpatient referrals.

Figure 1. Concentration of outpatient referrals in the Northumberland PACS

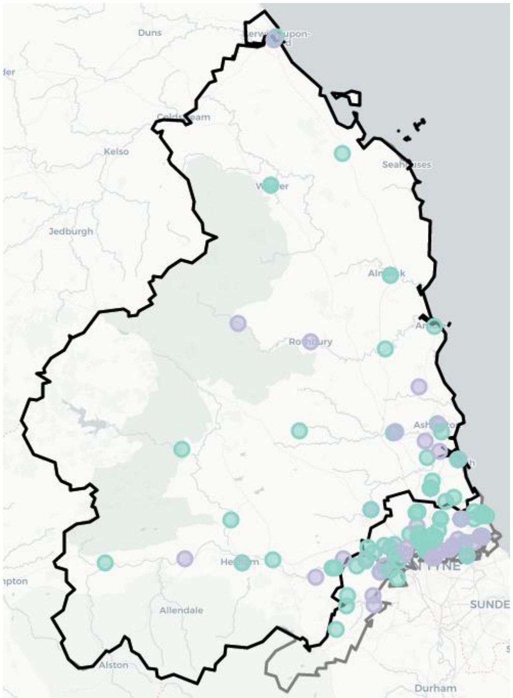


Figure 2. Concentration of outpatient referrals in the Salford PACS

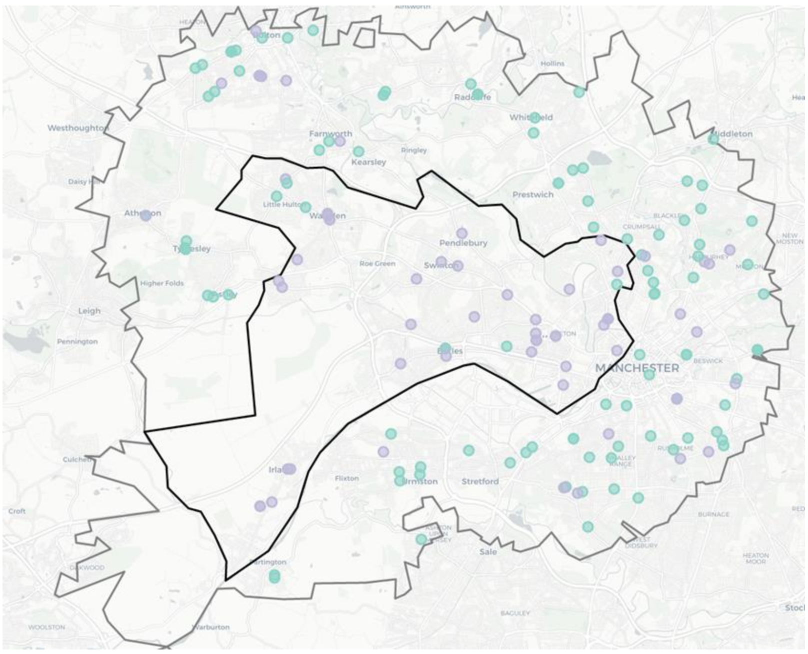
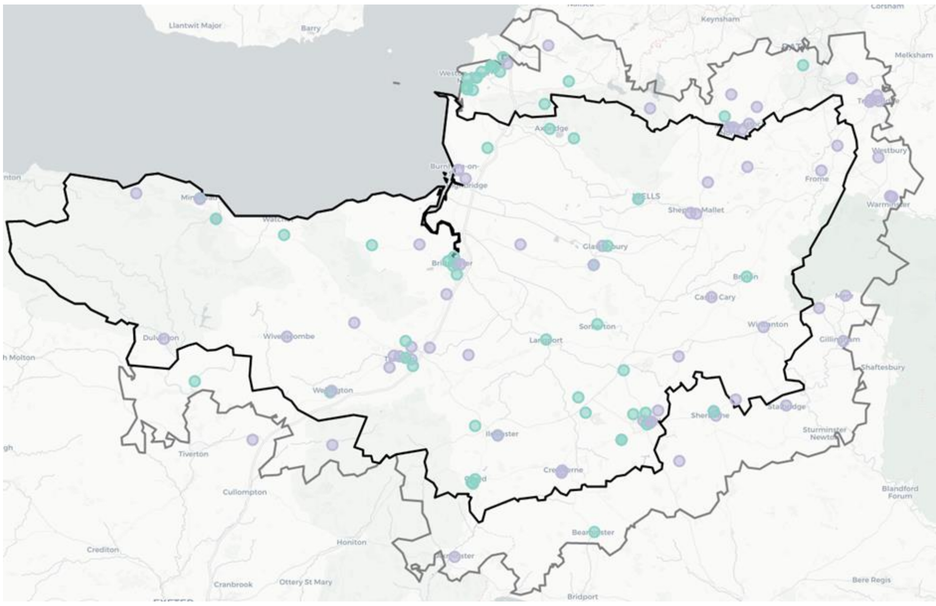


Figure 3. Concentration of outpatient referrals in the Somerset PACS



3.2 Mediation analysis

Table 2 reports the results of estimating models (2) – (4). In the aggregated analysis, we found that the effect of PACS on the concentration of care is not significant although the negative sign is in line with our expectations from our hypothesised causal framework (coefficient *a*). The positive sign of *b* (also in line with our expectations) and, thus, the negative indirect effect of integrated care on the ACSA rate per 1000 adults aged 65 years or older was also not statistically significant from zero. However, the direct and total effects of PACS on the ACSA rate was positive and significant at the 1% level. This finding suggests that one year after its implementation there are 2.6 more ACSAs per 1000 older population as a result of the PACS in Northumberland, Salford and Somerset. As shown in the Appendix, this result is no longer significant once GP characteristics are included in models (2) – (4).

Table 2. Mediation analysis: mediated effect of PACS on ACSAs through integrated care

	Aggregated PACS	Northumberland	Salford	Somerset
Observations	796	225	333	238
Coeff. a	-0.18 [-0.47, 0.11]	0.01 [-0.22, 0.23]	-0.51 [-0.80 , -0.22]***	0.02 [-0.25, 0.30]
Coeff. b	0.69 [-2.81, 4.19]	3.85 [-2.15, 9.85]	-5.04 [-8.35, -1.73]***	-2.82 [-4.32,-1.32]***
Indirect effect (a*b)	-0.12 [-1.25, 1.00]	0.04 [-1.18, 1.25]	2.57 [0.25, 4.89]**	-0.07 [-0.89, 0.75]
Direct effect (Coeff. c')	2.69 [1.37, 4.01]***	2.26 [-5.39, 9.92]	2.25 [-5.30, 9.80]	0.38 [-2.90, 3.67]
Total effect [(a*b) + c']	2.57 [0.73, 4.40]***	2.30 [-5.39, 9.99]	4.82 [-3.03, 12.68]	0.31 [-3.05, 6.68]

Estimates represent marginal change on the ACSA rate per 1000 adults aged 65 or older. 95% confidence intervals in brackets. *p < 0.10, **p<0.05, ***p<0.01.

The separate analysis for the Northumberland ACO yields no significant results. However, the positive sign in the direct and total effects on the ACSA rate found in the aggregate analysis persists. In the case of Salford Together, the negative coefficient *a*, statistically significant at the 1% level, indicates that this PACS increased integration of primary and secondary care in Salford. Furthermore, the significantly negative coefficient *b* and the likewise significant but positive indirect effect of integrated care altogether suggest that integrated care plays a mediator role in the relationship between PACS and the ACSA rate amongst older adults in Salford, albeit in the opposite direction of our expectation. This is true even if both the direct and total effects are not significantly different from zero. **Table A1** in the Appendix shows that the results suggesting this mediation are still significant even after conditioning for GP characteristics. Finally, the only significant result in the analysis for Somerset Symphony (negative *b* coefficient) implies that, conditional on the direct effect of the policy, the higher the integration (the lower 1/HHI) the higher the ACSA rate, similar to the findings for Salford. In the same line as the aggregate and the Northumberland and Salford cases, the direct and total effects on the ACSA rate are positive although the point estimates in the Somerset case are lower.

Table 3 presents the results of the DDD models that assess the effect of each PACS on the proportions of patients referred from intervention and comparison GPs to the participating hospital trust. Only the changes in the share of patients referred to the Salford Royal NHS Foundation Trust, partner of the Salford PACS, are significantly different from zero. It can be seen that Salford Royal shares of referrals from both intervention and comparison GPs increased, but that the increase is higher in referrals from intervention GPs. These results confirm that the higher concentration in Salford reported in **Table 2** is explained by an increase in the relative importance of the participating hospital trust as an outpatient care destination.

Table 3. Marginal effects on the referrals share, one year after vanguard

	Northumberland	Salford	Somerset
Referrals from intervention GPs	-0.0026	0.0593***	0.0070
Referrals from comparison GPs	-0.0081	0.0258***	0.0045

Marginal effects from a difference-in-difference-in-differences linear regression model.
***p<0.01

4 Discussion

In 2015, NHS England launched 50 vanguards as part of the New Care Models programme aiming to integrate health services within local health systems to allow better decision making and more sustainable use of resources with a focus on prevention and less reliance on emergency hospital care **[15].** Additional integrated care initiatives across England have also been implemented recently and existing evaluations have found mixed evidence usually showing either an increase on emergency and preventable hospital care or no effects at all **[7, 8, 12-14]**. However, to the best of our knowledge, none has explored the causal mechanism through which integrated care initiatives are assumed to reduce unplanned hospital care. Therefore, in an effort to contribute to this literature the present paper tests this hypothesised causal pathway using mediation analysis. We first posited that the integration of primary and secondary care can be measured using the concentration of outpatient referrals from GPs. We tested the effect of three integrated primary and acute care systems (PACS) in Northumberland, Salford and Somerset on integrating primary and secondary care and finally decomposed the effect of PACS on ambulatory care sensitive conditions amongst adults aged 65 or older. The evidence found in this analysis does not support the hypothesised causal mechanism that PACS increase integration of care and that through higher integration preventable hospital care will be reduced.

In this study we identified four necessary conditions to back this hypothesis: 1) a significantly negative effect of the PACS on the measure of health care integration; 2) that the spread of providers (low integration of care) leads to a high ACSA rate; 3) that integrated care mediates the effect of PACS by contributing to the reduction of the ACSA rate (negative indirect effect); and, 4) that the effect of PACS, adjusted for the mediation of integrated care, is negative and smaller in absolute terms than without this adjustment. While we found that the PACS have indeed increased integration of care in Salford, the relation between higher integration and ACSAs is contrary to what was originally hypothesised. In other words, we found evidence to suggest that a higher level of integration observed in Salford, as a result of the PACS, is associated with a higher ACSA rate. Furthermore, in the aggregate analysis we found that the direct and total effect of PACS on the ACSA rate was positive. The direction of these effects in the three separate analyses for each PACS remained, although they were not statistically significant. These results are consistent with findings from previous studies that even if they have not explored in detail the causal mechanism, have found either an increase in emergency admissions or no significant effect at all following the implementation of integrated care policies in England **[9, 12, 13]**.

Previous studies have found that integrated care initiatives affect the level of outpatient attendances **[9, 12].** In a context where total outpatient referrals decreased after the launch of PACS, a hospital increasing their share in the total number of patients referred from a given GP suggests the existence of a selective behaviour when referring patients which in turn could be interpreted as an increase in the coordination between the GP and the hospital in question.

The present study is subject to four main limitations. First, we did not test the sequential ignorability assumption, necessary to identify the mediated and the direct effects **[31]**. This assumption receives its name because two ignorability assumptions are made sequentially: 1) given the observed pre-treatment confounders, the treatment assignment is assumed to be statistically independent of potential outcomes and potential mediators (i.e. ignorable) **[31].** 2) The observed mediator is ignorable given the actual treatment status and pre-treatment confounders; that is, there are no unmeasured confounders that affect both the mediator and the outcome **[35]**. The first part of the assumption would have been satisfied if we had rejected the hypothesis that the intervention and the comparison GPs follow different trends in the pre-treatment period. While we did not formally test the latter, in the alternative specification reported in the Appendix we did condition for factors that may be related to treatment assignment, and the mediated effect for Salford remained significant. The second part of the assumption cannot be formally tested, but a semi-parametric approach can be used to indicate the plausibility of this assumption **[35].** To address this limitation, we plan to expand the study period to include data from 2012/13 that would allow us to test the parallel trends assumption and then we will also conduct the sensitivity analysis using semi-parametric methods.

Second, the assumption that PACS affect the level of integration of care which in turn affect the ACSA rate, presupposes a temporal ordering of the change in integrated care preceding that of ACSAs **[20, 32];** however, we measured changes in mediators and outcomes simultaneously when, in fact, the effect of these changes may not be immediate and more time might be needed to observe significant changes caused by integrated care initiatives **[36,**

37]. For this reason, our plan to extend the study period also considers post-treatment years in order to estimate the effect on integration two years after the launch of the PACS (2016/17) and then, as suggested by Shaw and Levenson (2011), we will allow one year of 'live' working (2017/18) to evaluate the mediated and direct effect of the policy on the ACSA rate.

Third, the concentration index used to measure integration of care may be subject to an endogeneity problem caused by either GPs and/or patients choosing to refer (or being referred) to hospital trusts providing better outpatient quality. The unplanned admissions rate at the GP level can be interpreted as an indicator of the quality provided by the GP in question, thus there may also be an additional problem of reverse causality if GPs providing better quality of care (lower unplanned admissions rate) tend to be more integrated with acute trusts providing better outpatient care. These problems are usually addressed in the literature using predicted patient flows rather than observed flows to compute the HHI **[38, 39]**. Since our interest is to assess the effect of PACS on integration of care and to use the latter to estimate a mediation effect on unplanned admissions, by using predicted flows instead of actual patient flows we will be missing the variation we are interested to capture. In our case, endogeneity problems as the ones described could be particularly problematic if a policy encourages GPs to integrate with a hospital trust perceived as providing quality of outpatient care (in comparison with neighbouring trusts) as GPs may choose not to integrate. As part of the next steps of this research, we will compare outpatient quality measures amongst neighbouring/competitor hospitals to examine the extent to which this behaviour may bias the results presented here.

Finally, by focusing only on the interactions between GPs and clinical specialists in the outpatient setting, we are focusing on just one out of several potential forms of coordination amongst health care providers that are encouraged by PACS. These include for example the integration of specialist doctors and nurses into neighbourhood care teams. Our findings are thus not necessarily representative of all forms of integration that might occur in the local health system as a consequence of PACS, but arguably an important one. Future research might focus on using other data sources to incorporate additional relationships between health and social care providers into a measure of integrated care.

5 Next steps

The cross-sectional analysis described above was recently extended to the longitudinal case for the period 2013/14-2017/18 and now includes all the nine PACS in England. We considered a grace period of one year (or four quarters) after the launch of the policy to estimate the effect of PACS on integration of care using a DiD model with GP fixed effects (equivalent to Model 2 in the cross-sectional case). The use of a grace period acknowledges that the policy may need to mature before influencing care integration. Then, two alternative approaches were taken. First, we estimated two DiD models to assess the extent to which integration of care mediates the effect of PACS on the quarterly ACSA rate (equivalent to Models 3 and 4 in the cross-sectional case). This approach assumes that the effect of integration of care on the ACSA rate is only simultaneous. Therefore, in order to relax this assumption, in an alternative specification we introduced a one-year lag (four quarters) of the indicator measuring integration of care in the model assessing the effect of PACS on the ACSA rate. This option assumes that integration of care only affects the future ACSA rate but ignores any simultaneous effect between integration of care and the ACSA rate. To address this challenge, we are considering the estimation of a marginal structural model following a recent study that conducts a mediation analysis with time varying exposures and mediators **[40].**

For the direct and the indirect effects of PACS on the ACSA rate to be correctly identified using a DiD approach, the pre-intervention parallel trends assumption between treatment and comparison groups for both the ACSA rate and the integration measure needs to hold. While this assumption was not rejected for the ACSA rate, it was rejected for the integrated care measure in most of the cases (pooled and separate analyses for each PACS). We then followed a lagged dependent variable approach as suggested by O'Neill et al. **[41],** but found evidence against the feasibility of the sequential ignorability assumption **[35]**. We will highly appreciate recommendations from the discussant or the audience on alternatives to address the challenges reported in this section.

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APPENDIX

Table A1. Mediation analysis: mediated effect of PACS on ACSAs through integrated care with covariates

	Aggregated PACS	**Northumberland**	**Salford**	**Somerset**
Observations	696	208	293	195
Coeff. a	-0.17 [-0.49, 0.14]	0.00 [-0.23, 0.23]	-0.54 [-0.83, -0.25]***	0.06 [-0.25, 0.36]
Coeff. b	-2.42 [-5.73, 0.89]	2.16 [-1.06, 5.37]	-3.12 [-6.23, -0.01]**	-2.14 [-3.53, -0.76]***
Indirect effect (a*b)	0.42 [-0.59, 1.43]	0.00 [-0.62, 0.63]	1.68 [-0.29, 3.65]*	-0.12 [-0.81, 0.56]
Direct effect (Coeff. c')	1.03 [-0.30, 2.36]	0.89 [-4.39, 6.18]	2.81 [-4.42, 10.03]	-0.71 [-3.82, 2.40]
Total effect [(a*b) + c']	1.45 [-0.76, 3.66]	0.90 [-4.38, 6.17]	4.48 [-2.96, 11.93]	-0.84 [-3.97, 2.30]

Estimates represent marginal change on the ACSA rate per 1000 adults aged 65 or older. 95% confidence intervals in brackets. *p < 0.10, **p<0.05, ***p<0.01. Covariates included in the models: GP list size, the proportion of patients registered with the practice aged 65 and over, the proportion of patients that were male, the practice deprivation score, the number of FTE GPs in the practice, the proportion of FTE made up by male GPs and prevalence rates hypertension, diabetes, heart failure and obesity amongst the registered GP population.