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Impact of 'Virtual Wards' on hospital use: a research study using propensity matched controls and a cost analysis

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Glossary of terms/abbreviations

Case management – coordination of health and social care services on behalf of a patient

CPM – Combined predictive model or "combined model": a predictive risk model that uses a combination of inpatient, outpatient, A&E and GP data to identify individuals at high risk of an unplanned hospital admission in the next 12 months

Community matron - a specialist nurse providing case management

DPM - Devon predictive model - a local variant of the combined model that has been weighted for Devon data

DH – Department of Health

EMIS - Egton medical information systems limited (a primary care software provider)

Emergency admission – we use the terms "emergency", "non-elective" and "unplanned" admissions interchangeably, having excluded maternity admissions from this definition

Exeter data - database of all patients registered with a GP practice in England

GP – General practitioner

HES – Hospital episode statistics (a research database of pseudonymous secondary care data)

HESid – Hospital episode statistics identifier (a unique, pseudonymous identification number of all patients with a Hospital Episode Statistics record)

IC - NHS Information Centre for health and social care

INR - International normalised ratio - a blood test measuring the degree of anticoagulation

LTC - Long term condition or chronic disease

NHS - National Health Service

NHS number - unique identification number for NHS patients in England

Non-elective admission - we use the terms "emergency", "non-elective" and "unplanned" admissions interchangeably, having excluded maternity admissions from this definition

ONS – Office for National Statistics

PARR – Patients at Risk of Readmission: a predictive risk model that uses SUS data to identify individuals at risk of an unplanned hospital admission in the next 12 months

PCT – Primary Care Trust

PPV – Positive predictive value (percentage of at-risk patients identified by a predictive model who experience an unplanned admission to hospital)

Predictive modelling – models based on routine data that identify individuals in a population who are at high risk of a certain future event

Prognostic matching – a method for identifying controls based on similar risks of experiencing a future outcome such as unplanned hospitalisation

Propensity matching - a method for identifying controls based on similar likelihood of receiving an intervention such as admission to a virtual ward

Pseudonymous data – data from which personal identifiable fields have been removed or collapsed, and in which the unique identifier has been replaced by a unique but meaningless pseudonym

Read code data–data from primary care electronic medical record that have been coded using a system developed by Dr. James Read

ROC curve– Receiver operating characteristics curve that illustrates the trade-off between true positives (sensitivity) and false negatives (1 – specificity) for a predictive model

Risk stratification– assigning risk of a particular outcome (e.g. future unplanned hospital admission) to each person in a population

Sensitivity - percentage of people who experience an unplanned readmission to hospital who are correctly identified by the model as being at risk

SHA – Strategic Health Authority

STROBE - Strengthening the reporting of observational studies in epidemiology (guidelines for reporting observational studies)

SUS – Secondary Uses Service

Unplanned admission – we use the terms "emergency", "non-elective" and "unplanned" admissions interchangeably, having excluded maternity admissions from this definition

Virtual wards – a form of preventive hospital-at-home for patients at high predicted risk of unplanned hospital admission

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Executive Summary

Background

Health care systems in many developed countries are currently under financial strain because of ageing populations, the rising prevalence of various chronic diseases, and budgetary constraints resulting from the global economic downturn.

The costs of providing health care are highly skewed across the population, with a small number of patients accounting for a large proportion of expenditure. Since unplanned hospital admissions account for a high proportion of costs, considerable resources could potentially be invested in providing preventive care for a relatively small number of costly patients and yet still potentially yield net savings overall from averted future hospital costs. In practice, however, such savings have been difficult or impossible to demonstrate.

One reason why preventive interventions may be unsuccessful at reducing demand is if they are offered to patients who are at insufficiently high risk of future unplanned hospital admission. In 2005, the Department of Health commissioned two "case finding" tools for improving the identification of high-risk patients in England. Known as "PARR" and the "Combined Model", these predictive risk tools are now used in many parts of the country to select which high-risk patients should be offered a hospital-avoidance intervention.

One such intervention is the "virtual ward". This model of care uses the staffing, systems and daily routines of a hospital ward to deliver preventive care to patients in their own homes in the aim of mitigating their risk of unplanned hospitalisation. Whilst virtual wards have been introduced in many parts of the UK and overseas, their efficacy and cost-effectiveness has yet to be determined.

Aims

The purpose of this study was to assess the extent to which multidisciplinary case management in the form of virtual wards led to changes in the use of health care and social care by patients at high predicted risk of future unplanned hospital admission.

Our primary aim was to determine whether virtual wards have led to changes in rates of unplanned hospital admission compared to matched controls, and if so at what cost. Our secondary aims were to assess the

impact of the intervention on rates of A&E attendance, social care provision, GP practice visits, and the use of community health services.

Methods

We studied a hospital avoidance intervention called "virtual wards" in three sites in England, namely Croydon, Devon and Wandsworth. We compared the health care and social care use of patients who received the intervention to those of matched controls. We used a range of matching techniques including prognostic matching and propensity score matching to draw controls from (a) national, and (b) local, individual-level pseudonymous administrative data. National data included Hospital Episode Statistics (HES), and mortality data from the Office for National Statistics (ONS). Local data included Secondary Uses Service (SUS) data, primary care clinical data from GP electronic systems, community health services data, and social care data from local operational systems.

We controlled for the observed differences between VW patients and control patients by selecting one or more control patients for each VW patient on the basis that they were similar in terms of a range of observed characteristics prior to the start of the intervention. The primary endpoints for this study were the comparative rates between VW patients and controls of unplanned hospital admission and mortality. The secondary endpoints were the rates and cost of A&E attendances, cost of social care provision, rates and cost of GP visits, and cost of community health services.

We determined the costs of establishing and running virtual wards in the three study sites from the perspectives of the NHS and local authorities using a combination of administrative data, interviews and diaries.

The study was designed to test the pooled results from all sites. However, the sample studied was highly unbalanced with the vast majority of cases coming from one site, Croydon.

Results

We found that each of the study sites had implemented variants on the virtual ward model as originally described. In Croydon, which was by far the largest of our three study sites, multidisciplinary preventive care was only offered during a short initial pilot period before changing to standard case management by community matrons. Our findings are therefore predominantly related to patients who received "standard" case management by a community matron rather than multidisciplinary case management from a virtual ward team.

It is important to remember that the pooled analysis may mask different results at the level of individual sites. The relatively small number of cases we were able to study in Devon and Wandsworth meant that it was not

possible for us to determine any statistically significant changes at the individual study site level.

We found difficulties in identifying sufficient matched controls from within the local study areas, therefore our conclusions on impact are based on our analyses using controls derived from national data. Compared with these matched controls, we found no evidence of a reduction in emergency hospital admissions for patients who received this type of care in the six months after starting the intervention. Nor did we find evidence of a reduction in ambulatory care sensitive hospital admissions in this period, nor in mortality.

We did, however, observe a reduction in elective hospital admissions and in outpatient attendances in the six months after starting the intervention. Both of these findings were significant at the $p<0.05$ level. However, we found no evidence of an overall reduction in hospital costs.

The direct costs of the interventions varied considerably between the three sites, ranging from approximately £3 per patient-day in Croydon and Devon to £17 per patient-day in Wandsworth, reflecting the heterogeneous nature of the interventions being studied. Over the 6 month follow up period of analysis these direct costs were of the order of £510-£2,890 per patient. These costs are approximations and the intervention in Wandsworth included a wider range of inputs to care, in particular in terms of GP support.

Conclusions

Whilst all three sites used the name "virtual wards" for their interventions, in fact most patients in this study received case management from a single provider undertaking standard case management activities. For this type of intervention, our principal conclusion is that we were not able to detect the anticipated reduction in unplanned hospital activity over a six-month period.

The significant reduction we did observe in outpatient attendances within the six-month timeframe could be attributable to better coordination of care for patients on a virtual ward. Similarly, the relative reduction we observed in elective admissions could reflect the fact that services were being undertaken by the virtual ward staff where ordinarily they would have required the patient to attend hospital. Alternatively, patients might have been making better informed choices where there was a degree of discretion over the need for an elective admission. Or another possibility is that the reduction in outpatient attendances might have lessened the use of inpatient services by stemming the so-called 'diagnostic-therapeutic cascade'.[1]

Using linked datasets, we were able to look at the broad range of services used by patients across the health and social care economy. The largest

service costs were associated with emergency hospital admissions, and so the lack of a reduction in these admissions meant that overall, there was not a net reduction in the health and social care service use of patients who received the intervention.

It is important to note that in our analysis of national data, the controls were drawn from matched areas of England. While we were careful to ensure that these matched areas did not have a virtual ward intervention or equivalent in place during the study period, our analysis shows that emergency admission rates were declining for matched control patients in these matched areas as well as for cases, having adjusted for the predicted risk score and other characteristics of the individuals concerned. This overall decline in admission rates suggests that there might have been other interventions or initiatives in place at the matched areas occurring at the same time as our study. It is therefore important to be cautious about interpreting the neutral findings in our analysis with regard to unplanned hospital activity.

The largest contributor of cases to our study was Croydon where, other than during an initial pilot period, the virtual wards delivered standard case management rather than multidisciplinary case management. One of the lessons for the health service from this evaluation therefore is that short term reductions in unplanned hospital admissions may not be amenable to reduction through standard case management. For areas Devon and Wandsworth we are aware that this initiative has also undergone some changes – particularly in Devon where the intervention has since expanded and consolidated. There is therefore a strong case to revisit some of our analyses with more recent and larger sample sizes.

Policymakers are attracted by the possibility that case management may generate net savings from averted unplanned hospital admissions whilst improving the quality of life for high-risk patients. This study forms part of a growing body of evidence that realising these benefits presents a major challenge. Further research may be needed to determine the characteristics of individual patients who are particularly amenable to preventive care and to tailor different preventive interventions to such characteristics - so-called "impactibility modelling".

The Report

Note that we have structured this report according to the STROBE statement of items that should be included in reports of observational studies.[2]

1 Introduction and background

Approximately 35 per cent of hospital admissions in England are classified as emergency admissions, costing approximately £11 billion a year.[3] Emergency admission rates in England have been rising relentlessly for many years but now there is an acute need to reduce emergency admission rates because of the combined pressures of rising health care costs, an ageing population, the increasing prevalence of various chronic diseases and a tightening of health care budgets.[4]

The costs of hospital care are highly concentrated in the population, with 5% of inpatients in England accounting for 49 per cent of inpatient bed days.[5] If admission rates could be reduced for these very costly patients then large net savings might be possible, even if the costs of the preventive care were high.[6] However, some disappointing results from government-funded trials of hospital avoidance schemes, such as the UK Evercare pilots and the Partnerships for Older People Pilots, and the US Medicare Health Support Experiment and the Medicare Coordinated Care Demonstration, are a reminder of how difficult it can be to make these potential savings.[7,8,9,10]

One reason why hospital avoidance interventions may fail is if they are offered to patients who are not truly at high risk of emergency admission. For example, the UK Evercare programme, which involved a comprehensive assessment and ongoing monitoring, was offered to patients aged 65 and older who had experienced two or more hospital admissions in the preceding twelve months.[11] However, today's high-cost patients tend to have markedly lower average costs and markedly fewer unplanned admissions in the future even without intervention. This is due to the phenomenon of "regression to the mean".[12] Indeed, an analysis of the UK Evercare programme by Gravelle and colleagues showed that there was actually no reduction in admission rates above what would have happened anyway due to regression to the mean.7 More recently, an evaluation of the Partnerships for Older People Pilots (POPPs) reached a similar conclusion, again because of regression to the mean.[10]

As the Evercare study and the POPPs study illustrate, hospital-avoidance programmes may best be offered according to the risk of *future* hospitalization rather than being offered to patients who are currently experiencing multiple hospital admissions.[13] One way to identify patients at risk of future hospitalization is to use a predictive risk model.[14,15] In 2004,

the English Strategic Health Authorities and the Department of Health commissioned two such models for the NHS in England: the Patients at Risk of Rehospitalisation tool (PARR) and the Combined Predictive Model.[16,17] The ways in which these models are used in practice varies across the country. In many areas, they have been used to find patients for community matrons or other case managers to work with. Elsewhere, they have been used to select which patients should be offered telephone-based health coaching and advice. In some areas, they have been used to identify patients who are offered multidisciplinary integrated care in the form of "virtual wards" (VWs).[18]

1.1 Policy background

Integrated care has been described as,

> "a term that reflects a concern to improve patient experience and achieve greater efficiency and value from health delivery systems. The aim is to address fragmentation in patient services, and enable better coordinated and more continuous care, frequently for an ageing population which has increasing incidence of chronic disease"[19]

Stronger co-ordination and collaboration between the primary, community and social care sectors is regarded as essential for the provision of high quality, safe and efficient services to people living with complex, long-term health and social care needs.[20,21,22,23,24] Previous studies have identified a range of 'essential ingredients' for the delivery of high quality integrated care.[20,24] Rosen and Ham classify these as "macro" (policy, financial and regulatory environment), "meso" (organisational and clinical structures and processes), and "micro" (patient interactions with different individuals and teams) levels of integration.[23]

The current study used the example of virtual wards,[25,18] which aim to integrate primary, community and social care at the meso (service delivery) and micro (clinical) levels. We explored the efficacy of this type of integrated, multidisciplinary case management in reducing emergency hospital admissions for patients at high predicted risk, as well as any impact on social care services. As Goodman and colleagues explain, case management is a "collaborative process which assesses, plans, implements, co-ordinates, monitors and evaluates the options and services required to meet an individual's needs".[26]

The original model for virtual wards was described by Lewis in 2006 (see Figure 1).[25] Virtual wards seek to improve integration through a number of strategies, including a shared record, multidisciplinary team meetings ("ward rounds") and an automated alert system for informing virtual ward

staff when a patient accesses another care service, such as attending local accident & emergency department. Another strategy for promoting integration was to include a social worker as a core member of the virtual ward staff. In this regard, it could be argued that virtual wards are an adaptation of the public health model of chronic disease management described by Kendall and colleagues but rather than integrating health and education, virtual wards instead aim to provide patients with a well-organised and coordinated service that crosses the health care and social care sectors.[27]

1.2 Existing evidence

As reported by Gravelle and colleagues,[7] a systematic review of home-based support for older people found no overall impact of such care on hospital admission rates, whereas a review of integrated care pilots for older people suggested that they can reduce admission rates and costs of care, but that the effects are highly dependent on the system concerned.[28] Two other reviews concluded that there is limited evidence that case management reduces the use of health services, but both reviews suggested that the results of individual studies may not be generalisable.[29,30]

Moreover, there is little evidence to date on the optimal configuration of community-based hospital avoidance initiatives. In England, the Department of Health issued guidance recommending that community matrons should have a caseload of 50-80 patients.[31] However, it is unclear what evidence supports this being the optimal number of patients in terms of quality and effectiveness. An analysis of the caseloads of 46 case managers concluded that higher case loads were associated with more reactive care and with increased hospital admissions.[32] This finding suggests that any intervention designed to reduce hospital admissions may be rendered ineffective if the caseloads are too large. However, whilst in general, smaller caseloads would be expected to increase the quality of a service, this increased quality might not be cost-effective when the opportunity costs are taken into consideration. Clearly, then, the caseload-versus-quality trade-off is of critical importance to case management, and it depends centrally on the types of patient seen, i.e. the "case mix" of patients. This suggests that an index for caseload targets needs to be developed.[33]

1.3 Virtual wards

The Chronic Care Model[34] summarises the prerequisites for improving care in health systems at the community, organization, practice and patient levels. Most chronic care interventions tend to work on a hub-spoke model of care where a central case manager, such as a community matron or a

guided care nurse,[35] acts as the patient's point of contact with all members of the team—drawing on specialities as required and communicating with each. For example the NHS Improvement Plan[36] describes the role of the community matron as being,

> "...one person who acts as both provider and procurer of care and takes responsibility for ensuring all health and social care needs are met."

Hospital avoidance interventions appear to be most successful with the highest-risk patients.[37,38] However a feature of high-risk patients is that they are typically older, with multiple chronic conditions that are often coupled with psychological and social problems.[16,17] Because of these interacting, complex needs, a flexible team-based approach in a community setting, such as virtual wards, might be preferable to a hub-spoke model for preventing emergency hospitalisation.[39] Virtual wards (VWs) build on a long tradition of hospital-at-home schemes, which may be defined as services that provide,

> "active treatment by health care professionals, in the patient's home, of a condition that otherwise would require acute hospital in-patient care, always for a limited period".[40]

A Cochrane review in 2005 concluded that there was insufficient evidence of so-called "early discharge hospital-at-home" services being cheaper than inpatient care, and recommended that future research should focus on "admission avoidance" hospital-at-home schemes.[41] A key difference between "traditional" hospital-at-home schemes and virtual wards is that the former are typically designed to provide reactive care following a hospital admission, whereas virtual wards seek to provide proactive, "upstream" care aimed specifically at hospital avoidance.

Potential virtual ward patients are identified using a predictive risk model, which identifies the individuals in a registered population who are at high risk of a future unplanned hospital admission. In other words, rather than waiting for such people to be admitted to hospital as an emergency, virtual wards instead aim to take the coordination of a multidisciplinary hospital ward team out to the patient in advance in order to deliver multidisciplinary, coordinated, preventive care in the community.

The virtual ward model was first developed at Croydon Primary Care Trust (PCT) in South London in response to the introduction of the NHS Combined Predictive Model and the instigation of a public service agreement requiring all PCTs in England to appoint community matrons and to reduce emergency bed-days for their population.[42] Figure 1 sets out the core components of the virtual ward model as it was originally designed in Croydon.

Figure 1. Original model of virtual wards

In 2006, Lewis described the following model of care known as 'virtual wards'[25]

- Each virtual ward is linked to a specific group of GP practices.
- The catchment population for a virtual ward is approximately 30,000 but varies depending on the density of high-risk patients living in an area (smaller catchment area where there are many high-risk patients and vice versa). Roughly 0.3% of the catchment population is cared for on a virtual ward at any given time.
- A patient is offered "admission" to a virtual ward if a risk prediction tool identifies him or her as being at high risk of a future emergency hospital admission.
- Patients remain in the community during their time on a virtual ward, and receive multidisciplinary care intended to maintain or improve their health status and reduce their risk of unplanned hospital admission. Care is delivered in person at the patient's home, by telephone and/or at a local clinic.
- Each virtual ward has a capacity for 100 patients, i.e. 100 "virtual beds" per virtual ward. These are subdivided into five "daily" beds, 35 "weekly" beds and 60 "monthly" beds, reflecting the frequency with which different patients are reviewed on a ward round.
- Virtual ward staff can move patients between different "beds" as the patients' needs change.
- Virtual ward staff discuss patients on office-based "ward rounds", participating either in person or by telephone.
- The composition of a virtual ward team will vary according to the needs of local high-risk patients. It may include a community matron (case manager), district nurses, a ward clerk, pharmacist, social worker, physiotherapist, occupational therapist, mental health professional and a representative from the voluntary sector.
- Certain specialist staff (e.g. tissue viability nurse) may cover several virtual wards in the same way that a hospital specialist nurse may visit several hospital wards.
- The role of the ward clerk is pivotal in supporting and co-ordinating the virtual ward team.
- The virtual ward staff share a common medical record.
- Systems are put in place to ensure that local hospitals, emergency departments and out-of-hours providers are aware of which patients are being cared for on each virtual ward, and the ward clerks' contact details are heavily publicised in order to promote integration and avoid unnecessary hospital admissions.
- When a patient has been assessed by all relevant virtual ward staff, and has been cared for uneventfully for several months in the 'monthly review' section of the ward, then the ward staff may feel that the patient is ready to be discharged back to the care of the GP practice.
- Virtual ward staff also receive a prompt when the patient's name drops below the 100 people with highest predicted risk in that virtual ward's catchment area according to the Combined Model.

1.4 Research aims

The primary aim of this study was to assess the extent to which integrating health care and social care services by means of virtual wards led to changes in the use of emergency hospital care and social care. We profiled the costs of setting up and running virtual wards and compared these to any changes observed in the utilisation of health and social care.

Our null hypothesis was that virtual wards had no effect on rates of unplanned hospital admission when compared with matched controls.

The objectives of this study were to:

- Calculate the impact of virtual wards on reducing rates of emergency hospital admission and their impact on intensive social care
- Establish the costs and savings of virtual wards from the perspectives of society, the NHS and local government
- Develop an index for determining the optimal case load for case management that accounts for the case-load versus quality of care trade-off (which itself depends centrally on the case-mix of patients offered the preventive care intervention)
- Develop an interactive cost model where users input local variables and the model advises the user as to the optimal configuration of virtual wards locally, taking into account the case-mix of patients being offered the intervention.

We acknowledge that virtual wards may have led to improvements in the quality of life of their patients and other potential benefits; however, these were beyond the scope of the current study.

2 Methods

We have previously published our research protocol for this study.[43] Our analysis was divided into two streams: (a) a difference-in-difference analysis of the effects of virtual wards on health care and social care use, and (b) an economic analysis on the cost of the intervention and any savings it generated from the perspectives of both the NHS and the local authority. See Figure 2.

(a) After obtaining approval from a research ethics committee, we set out to collect data from the NHS and local councils. The data we obtained described patterns of hospital, GP and social care use for people living in the study areas. We identified within these data all those people who had received care on a virtual ward, and attempted to describe the characteristics of these people using the data we had obtained. Then we tracked their health and social care use over time, and finally took these characteristics and attempted to identify people who appeared similar to virtual ward patients in the period before the latter were admitted to a virtual ward. Essentially, these are the people that we believe would have received virtual ward care had they lived in one of the study areas but in reality, the people in this 'comparator group' did not receive virtual ward care or an equivalent intervention. By analysing the data of these comparator patients, we were able to compare their experiences against those of people who did actually receive virtual ward care. We examined how the two groups compared in terms of their use of hospital and social care services.

(b) For our economic analysis, we worked closely with the virtual ward staff in each study site (i.e. the nurses, social workers, physiotherapists etc.) as well as their managers and finance officers, to determine what happens on a virtual wards in terms of the care delivered. We calculated the costs of running a virtual ward based on these findings. Then, using the 'comparator groups' described above, we calculated the costs for people who were not admitted to a virtual ward, based on information from routine data sources. We then synthesized all of this information in order to calculate the overall costs or savings of running a virtual ward.

Figure 2. Key elements of the research protocol

- Agreement of permissions and approvals
- Collection and collation of local and national data
- Link NHS and social care data using pseudonymous NHS number or pseudonymous constructed alternative ID
- Test and refine a propensity model (propensity scores reflect the likelihood of receiving the virtual ward intervention)
- Compare hospital utilisation (risk-adjusted, and with subgroup analyses) between the intervention groups and the comparator groups using a difference-in-difference approach, and an assessment of the impact on social care
- Sense-check the findings with the sites.
- Derive per-patient marginal costs and fixed costs for a virtual ward patient
- Calculate costs for people who are not admitted to a virtual ward (based on data of non-admitted patients from historical health and social care administrative data)
- Estimate the optimal configuration of a virtual ward in terms of the number and type of staff per ward; number of patients per ward; number of patients in the daily/weekly/monthly beds; and length of stay. The configuration of each virtual ward may differ across the boroughs according to local health and social care needs.

This chapter is structured according to the STROBE statement of items that should be included in reports of observational studies. The chapter begins with a description of our ethical approvals and study settings and the patients that received the intervention under study. We then describe our method for determining the impact of virtual wards on hospital activity and mortality (sections 2.4-2.9 inclusive) followed by our methods of economic analysis (sections 2.10-2.12 inclusive). There then follows a description of the various forms of bias that may have affected our study, a description of the power calculation we conducted. Finally, we describe our statistical methods and our sensitivity analysis.

2.1 Ethical approvals

We applied for ethical approval for this study through the Integrated Research Application System (IRAS) and received a favourable decision letter dated 28 April 2010 (National Research Ethics Service reference number 10/H0806/31). We then applied for so called "global and local" NHS research & development approval, which we received for all three sites. In addition, we applied to each of the three local authorities for permission to conduct this research through their research governance frameworks, and we received approvals from all three. Finally, we applied for and received letters of support from the local medical committees (LMCs) in Croydon, Wandsworth and Devon for the use of pseudonymous Read code data in this project.

The only amendment we made to our ethics approval (substantial amendment 1) related to the appointment of our NIHR SDO management Fellow, expanding the approval to permit the management fellow to conduct a programme of supplementary qualitative research (see Appendix 1). This amendment was approved on 6 June 2011.

2.2 Setting

We used a convenience sample of three virtual ward sites, namely Croydon, Devon and Wandsworth. At the time of our initial funding submission, we proposed two study sites: Croydon and Wandsworth. We chose Croydon because this was the original virtual ward site and had the largest number of patients; and we chose Wandsworth because it had specifically chosen to adopt the virtual ward model used in Croydon and because, being a neighbouring inner-London borough, it was likely to have broadly similar demographics, case-mix and other contextual factors that made it directly comparable to Croydon.

However, the SDO reviewers at the initial application stage commented that Wandsworth and Croydon were likely to be so similar that it would be difficult to generalise our findings to the rest of England. For this reason, when submitting our full funding application, we chose to add an additional study site – Devon – that was using the same model of virtual ward care but in a different context.

According to the Office for National Statistics, Croydon is defined as a 'London suburb' and Wandsworth is defined as 'London centre', whereas Devon is a 'coastal and countryside' area.[44] Devon also has fewer patients living in the most deprived quintile of lower super output areas (2% compared with 22% for Croydon and 14% for Wandsworth). Overall, the three study sites varied in terms of their population size and in their levels of deprivation, but none was in the most extreme deciles of the Index of Multiple Deprivation.[45]

Although all three sites all used the name 'virtual ward' for the intervention, during the course of this study we learned that they had in fact developed important differences in terms of their structure and organisation.[46] All three study sites employed a full-time community matron and ward clerk on each virtual ward, and in Wandsworth there was also a full-time GP on each virtual ward. All other staff participating in the virtual wards did so on a part-time basis, alongside their other clinical commitments. During an initial pilot phase at Croydon, the multidisciplinary team on each of the two pilot virtual wards was led by a community matron. After the pilot phase, additional virtual wards opened, and all of the virtual wards provided standard case management, where a community matron provided case management for patients. These community matrons received administrative support from their ward clerk but there were no regular

multidisciplinary ward rounds held after the end of the pilot phase. In Devon, the multidisciplinary team was also led by a community matron, but the team received ongoing support from a 'GP champion' as well as regular clinical input from a community geriatrician. In Wandsworth, each virtual ward's multidisciplinary team was led by a dedicated, full-time virtual ward GP ('VWGP') who jointly led the virtual ward team". Appendix 2 provides a detailed description of the three study sites, based on the taxonomy used by Boaden and colleagues.[11] Some of the key differences between the three sites are summarised in Table 1.

Table 1. Overview of the virtual ward intervention in each study site

	Croydon	**Devon**	**Wandsworth**
Project name	Virtual community ward (VCW)	Virtual ward (VW)	Virtual ward (VW)
Date first virtual ward opened	May 2006	October 2008	March 2009
Number of virtual wards under study	2 then 8	1	4
Funding	Croydon PCT	NHS Devon and Devon County Council	Wandsworth PCT and Wandsworth Council
Commissioner	Croydon PCT	Devon PCT	Wandsworth PCT
Full-time staff	Community matrons and ward clerks	Community matron and ward clerk	Community matron, virtual ward GP, and ward clerk
Number of part-time staff (wider multidisciplinary team)	Initial "pilot" virtual wards project: pharmacist, physiotherapist, occupational therapist, district nurses, health visitor for older people, representative of Croydon Voluntary Action After the initial pilot phase: none	Social workers, community psychiatric nurse (CPN), CPN for older people, staff grade elderly care doctor, physiotherapist, occupational therapist, voluntary sector representative, district nurses, GP, complex care team manager (joint health & social care appointment)	Social worker, district nurse, physical therapist, occupational therapist, pharmacist, drug & alcohol therapist.

At the start of the study we were unaware of the magnitude of the differences between the three sites. We had not proposed to evaluate the effects of individual models of virtual wards and our study was not powered to do so. So, it is important to note that we pooled our analysis across the three areas and that our findings are dominated by the largest study site - Croydon - which was not delivering multidisciplinary case management except during an initial pilot phase.

2.3 Participants

In Croydon and in Devon, patients were offered the virtual ward intervention if they scored highly on the combined predictive risk model (or a local variant, the Devon combined model). This model identifies patients who are at high risk of unplanned hospital admission in the next 12 months, based on prior patterns of inpatient, outpatient, A&E and primary care use.[17] In Wandsworth, the majority of virtual ward patients were referred by local GPs, although the PARR predictive model was used to identify approximately 25 per cent of patients at this site. All three sites implemented exclusion criteria for virtual ward patients, for example excluding patients with a history of violence or for whom another community service seemed more appropriate (see Table 2 for details).

The nature of the virtual ward intervention that participants received also differed between sites.[46] Table 2 outlines some of the principal differences.

Table 2. Selection of virtual ward patients in each study site	**Croydon**	**Devon**	**Wandsworth**
Patient identification: overview	Combined Predictive Model was used to identify patients for the virtual wards. There was a period from April 2007 – March 2008 when the predictive model was not run at all. Since then, the model has been run on a quarterly basis.	Between October 2008 and the winter of 2009, patients were solely identified as referrals from GPs. From the winter of 2009 onwards, approximately 85 per cent of patients were identified by a predictive risk model, with the remainder being clinical referrals. Between the winter of 2009 and March 2011, the Combined Model was used; and from March 2011 onwards, the Devon Combined Model (DPM) was used (a local variant of the Combined Model, weighted for Devon data). Both models are run on a monthly basis.	Initially, referrals came from clinicians only. From March 2009 onwards, the PARR++ model was used to identify a minority of patients, which was run every two to six months. However, approximately 75 per cent of patients are still referred by clinicians.

Table 2 Continued

	Croydon	**Devon**	**Wandsworth**
Predictive model	Combined predictive model	Combined Predictive Model / Devon Combined Model	PARR++
Proportion of patients identified by a predictive model	100 per cent	85 per cent	25 per cent
"Filtering" of patients	Community matrons sometimes reject "inappropriate" high risk score patients. Patients may be rejected if: • the patient is already being case managed by another professional • the GP states that they do not think case management will be effective for an individual patient • addiction/dependency issues • known severe mental health diagnosis • known risk to a lone worker (staff may try to see them in a clinic setting). • Language or social barrier that prevents the patient from engaging with the community matron.	Community matrons sometimes reject "inappropriate" patients. Patients may be rejected if: • they were referred by a clinician but were low risk on the DPM score • the community matron or GP felt the patient might benefit more from an alternative service (e.g. a young person)	Occasionally the VWGP and community matrons reject "inappropriate" high risk score patients, for example if a patient refused consent to be cared for by the virtual ward team. Another example would be patient with a high PARR score due to a recent transplant: such a patient might have frequent but necessary hospital admissions and would need care from more specialist resources than the virtual ward could provide.

Perceived characteristics of patients as reported by virtual ward staff	Perceived high proportion of patients with • Low socioeconomic status • Language barriers • Black and minority ethnic groups • Psychological issues	Perceived that a high proportion of patients were • Older people, rural with multiple LTCs, poor self-management, often high anxiety or lack of extended family, isolated.	There was a perception that a high proportion of patients seen were older people, socially isolated, and with concurrent chronic diseases (e.g. COPD, heart failure) with exacerbations of at least one of these. For many patients, the regimen of medications they were taking had not been optimised and often their adherence with medication was low.

The eligibility criteria for inclusion our difference-in-difference analysis were based on admission to virtual wards in our three study sites before 30 September 2010. We excluded patients if they were admitted to a virtual ward before the official launch date of the intervention in the particular site. In addition, we excluded patients admitted to a virtual ward in Croydon during 2007/8 because the results of the predictive model in Croydon were not updated during this period. Finally, we excluded a small number of patients because staff at the NHS Information Centre for health and social care were unable to link the NHS number provided to them by the study site to a HESid.

Table 3 shows the time periods we used to define the cohorts of patients included in the study. The longer time period and larger size of the Croydon project meant that it contributed the majority of cases to the pooled analyses.

Table 3. Study time period in each site

Site	Period of study
Croydon	15 May 2006–1 September 2010
Devon	1 October 2008–1 September 2010
Wandsworth	1 March 2009–1 September 2010

We were able to follow up both cases and controls in routine databases as follows:

- For the analysis of national data, these included the HES and ONS mortality databases (although for the latter, only data relating to deaths in hospital were available for analysis for the period after the intervention).
- For the analysis of local data, these included the Exeter and SUS databases as well as local extracts of GP Read code data, community health services data and social care data.

2.4 Techniques for retrospective analyses

We conducted our analysis in two streams: (a) a difference-in-difference analysis of the effect of virtual wards on health and social care use, which is described in sections 2.4-2.9 inclusive; and (b) an economic analysis on the cost and any savings of the intervention from the perspectives of the NHS and the local authority, which is described in sections 2.10-2.12 inclusive.

Our difference-in-difference analysis aimed to test whether the virtual wards had an impact on the utilisation of health and social care, such as emergency admissions to hospital and admissions to care homes. We compared the health and social care utilisation of virtual ward patients with that of a control group that had been chosen retrospectively to match the characteristics of the virtual ward patients as closely as possible in the period leading up to the start of the intervention.

The use of a control group is essential for estimating what might have happened in the absence of the intervention (the "counterfactual"). It is particularly important in the context of hospital avoidance interventions because typically, many of the patients offered such interventions have previously experienced high levels of hospital use. Such patients have a natural tendency to show reductions in hospital use over time, even in the absence of a specific intervention. This is due to a statistical phenomenon called "regression to the mean".[12] Although the virtual ward design involved selecting patients on the basis of a predictive model that seeks to take account of this phenomenon, reductions in service use over time are nevertheless possible and need to be accounted for.

The gold-standard approach to selecting a control group is often considered to be the randomised controlled trial.[47] This is because randomisation has the potential to balance both observed and unobserved characteristics between different groups asymptotically. In the current study, however, we chose to evaluate the effect of the intervention on patients who had already received the intervention, so randomisation was not possible. Instead, we used large administrative data sources to select control groups of patients that appeared similar to the virtual ward patients in the period prior to the start of the intervention, but who did not receive the intervention themselves.[48] While this approach ensured that the groups were similar in terms of what we could observe, it is possible that the groups differed systematically in ways that we could not observe, thereby threatening the validity of our findings.

We used two methods for ensuring that the control groups were as similar as possible to the intervention group across a distribution of characteristics, namely propensity score matching and prognostic matching.

- **National matching**: we drew patients from comparable areas of England - the ONS Corresponding Health Areas,[49] having first excluded any areas that had a virtual ward, or equivalent, operational during the study period. We identified patients for inclusion as so-called "national controls" by matching on a range of variables derived from hospital data (HES), mortality data, as well as an area-level deprivation score called the index of multiple deprivation.[50]

- **Local Matching**: we drew patients drawn from the same PCT area who were not admitted to a virtual ward - our so-called "local controls". We matched these patients using a combination of

variables derived from hospital (SUS) data, GP clinical data, community health services data, social care data, index of multiple deprivation scores, and mortality data.

We used three methods - propensity matching, prognostic matching and genetic matching- to ensure that the control groups were as similar as possible to the intervention group across a distribution of characteristics (see Figure 3).

Figure 3. Methods for selecting controls

A variety of analytical methods exist to select matched control groups. However, the principle is always to select, from a larger population, a subgroup of patients who are similar to the patients receiving the intervention with respect to variables recorded for all individuals. We investigated three methods, propensity matching, prognostic matching and genetic matching, and chose the one that produced the control group that was more closely matched.

The **propensity score** is an estimate of the probability that a given individual will be recruited to the intervention.[51] It summarises a wide range of variables such as age and prior hospital use into a single quantity. Controls that are selected on the basis of having a similar propensity score are thus expected to be similar in terms of the wider set of variables reflected in the score, if the propensity score model is correctly specified.[52] Balance can be further improved by simultaneously matching on key variables predictive of future health and social care utilisation along with the propensity score,[51] using a multivariate distance measure such as the Mahalanobis distance.[53]

An alternative strategy for finding controls is to match on the estimated probability of experiencing the outcome (for example, an emergency hospital admission), where this is calculated assuming that the intervention is *not* in place. This score is called the **prognostic score**, and the approach is called prognostic matching.[54] Prognostic matching can be combined with matching on other variables using the Mahalanobis distance.

The final method, **genetic matching**, is an iterative technique that aims to optimise balance between groups using a genetic search algorithm. It is a generalisation of matching using the propensity and prognostic scores as these scores can be included in the assessment of balance used in the search algorithm.[55]

When we implemented these approaches, we used matching without replacement so that the control group consisted of distinct individuals. We also chose to calculate propensity and prognostic scores on a monthly basis in order to reflect recent activity. This gave us a choice, for a given virtual ward patient, of whether to use the risk score calculated at the month-end immediately prior to being admitted to the virtual ward, or the score calculated at the month-end immediately following admission. Using the risk score from the month before did not capture very recent events that occurred in the few days before bring admitted to the virtual ward.

We assessed the similarity of the matched control group to the group of virtual ward patients by using the standardised difference. This is defined as the difference in means as a proportion of the pooled standard deviation.[56] Although the standardised difference would ideally be minimised without limit, Normand and colleagues have suggested that a value greater than 10 per cent is indicative of a meaningful difference between the groups.[57] Other metrics, such as formal t-tests, are not recommended or observational data. [58] We did not conduct statistical tests to assess the similarity of the matched control group to the virtual ward patients. As argued by Imai and colleagues,[58] statistical tests do not form a good stopping rule for matching algorithms because they are a product of the sample size. They argue (1) that a statistical test would therefore favour scenarios in which cases were dropped from a matching analysis, when this was not in fact desirable; and (2) that statistical tests are also inappropriate from a theoretical point of view because in this context, similarity is a property of the samples rather than of some hypothetical population.

2.5 Local matching

For the local matching, we selected controls from a list of all people aged over 18 who were registered with a general practice in the virtual ward area. This information is recorded in the National Health Application and Infrastructure Services (NHAIS), commonly known as the "Exeter system". We excluded all individuals who were admitted to a virtual ward from being controls.

Our local matching relied on variables derived from the following datasets: hospital data (SUS), GP clinical data, community health services data, social care data, index of multiple deprivation scores, and mortality data. Using these data, we calculated combined model scores for all virtual ward patients and for all potential controls. For Croydon and Devon in particular, where the combined model is used as the predominant method for selecting virtual ward patients, we expected these scores to provide a good approximation of the risk scores used by the sites to identify the set of patients to offer virtual wards. We were less confident of this approach in Wandsworth, where the majority of patients were referred by clinicians.

We aimed to select local controls who were similar to virtual ward patients in terms of a range of factors including predictive risk scores, age, sex, prior health care and social care utilisation, number of chronic health conditions, the presence of a variety of specific health needs, and the index of multiple deprivation.

A key strength of the local matching was the broad range of data sources available for analysis. However, the virtual wards were well established in Croydon and here a large number of high-risk patients had been admitted. It was therefore possible that too few patients might be available to act as controls in this area. This phenomenon is known in the literature as "limited common support". We expected this issue to be particularly problematic for patients with high scores on the combined model, because the majority of such individuals may have been expected to have been admitted to a virtual ward. Moreover, it is possible that those high-risk individuals who were not admitted to a virtual ward might have differed systematically from those high-risk patients who were admitted to a virtual ward - either due to self-selection by patients and/or the exclusion criteria adopted by sites.

For these reasons, we employed a second approach to matching, which involved selecting controls from larger, national datasets.

2.6 National matching

Rather than drawing controls from across the whole of England, we limited our population of potential controls to people who lived in twelve matched areas of the country. So, for our national matching we used a two-stage approach, where first we matched at the area level and then at the individual person level. We limited the pool of potential controls in this way because hospital utilisation rates vary by area.[59,60] An additional advantage

of this approach is that it also greatly improved the computational ease of finding controls. One assumption is that for areas such as Devon, the participating practices were sufficiently similar to the county a whole.

We selected four potential comparator sites for each of three virtual ward study sites, based on the Office for National Statistics (ONS) Corresponding Health Areas.[49] See Table 4. The ONS selects these sites based on their squared Euclidean distance for a range of 42 variables related to demographics, household composition, housing, socioeconomic factors, employment and industry.[61,62] The ONS considers health areas to be "extremely similar" if the squared Euclidean distance (SED) is less than 2.02; "very similar" if it is less than 5.06; "similar" if it is less than 10.12; "somewhat similar" if it is less than 20.24; and "less similar" if the SED is greater than 20.24.[49]

Table 4. Comparator areas used for national matching

Site	Period of study	ONS corresponding health areas	Squared Euclidean Distance	Similarity of corresponding health area
Croydon	15 May 2006–1 September 2010	Enfield	3.39	Very similar
		Waltham Forest	4.86	Very similar
		Greenwich Teaching	6.35	Similar
		Redbridge	13.22	Somewhat similar
Devon*	1 October 2008–1 September 2010	Somerset	1.54	Extremely similar
		Cornwall and Isles of Scilly	1.77	Extremely similar
		Shropshire County	1.78	Extremely similar
		Herefordshire	1.95	Extremely similar
Wandsworth	1 March 2009–1 September 2010	Hammersmith and Fulham	3.61	Very similar
		Camden	10.72	Somewhat similar
		Islington	12.79	Somewhat similar
		Westminster	16.94	Somewhat similar

We contacted the Director of Nursing at the primary care trust in each potential comparable area to check whether a virtual ward scheme or equivalent was operating during the study period. Based on the responses we received, we excluded two such areas, namely North Yorkshire and York PCT and Dorset PCT. Instead, we used Shropshire County PCT and Herefordshire PCT as the third and fourth comparator areas for Devon, having confirmed that neither site had virtual wards or equivalent in operation during the study period.

We excluded individual residents of the comparator sites who had previously been resident in one of the virtual ward study sites, or who had registered with a general practice in the virtual ward study sites, from being controls. This was because such patients might have been affected

indirectly by the operation of the virtual ward (a so-called "spill-over" effect). All residents of the remaining comparator sites were eligible to be selected as control patients, provided they were aged over 18.

Details of our approach for national matching are described in Figure 4.

Figure 4. Methods for selecting national controls

We sought to match each virtual ward patient to at least one control based on variables derived from datasets that were available to us nationwide, namely Hospital Episode Statistics (HES) data, index of multiple deprivation scores, and a dataset from the Office for National Statistics containing dates of death for individuals with a HES record. We chose controls who were similar to the intervention patients in terms of their prognostic score, age, sex, various categories of prior hospital utilisation, total number of chronic health conditions, area-level deprivation score,[50] as well as 15 markers of specific health needs from the inpatient hospital record in HES, namely: anaemia, angina, asthma, atrial fibrillation and flutter, cancer, cerebrovascular disease, congestive heart failure, chronic obstructive pulmonary disease, diabetes, history of falls, history of injury, hypertension, ischemic heart disease, mental health conditions, and kidney failure.

We based the prognostic score we used for the national matching on a predictive risk model that we developed using HES data. In two of the sites (Croydon and Devon), this model differed from the predictive risk scores used to identify patients who were offered admission to a virtual ward, as the latter used a model that included GP clinical data, which were not available nationally. In the remaining site (Wandsworth), the PARR model was used, which does not include GP clinical data.

For each study site, we developed a series of prognostic models to predict the likelihood of an individual's experiencing an emergency hospital admission in the next 12 months, calibrated according to local patterns of hospital use. These built on variables used in the PARR model [63] but predicted admission rather than readmissions. In building these models, we excluded any information about patients who were ever admitted at a virtual ward, because we assumed that their pattern of hospital use might have been altered by the intervention.[54]

We developed the prognostic models using a split-sample approach and we described the accuracy of the models in terms of their positive predictive value (PPV) and sensitivity, as well as the area under their receiver-operating characteristics (ROC) curves.[15]

After fitting the prognostic score model, we applied the calculated beta coefficients to the intervention group and to patients resident in the comparator sites in order to generate the scores.

2.7 Study endpoints

The primary endpoint for this study was the comparative rates of emergency hospital admission (defined in HES as hospital admission methods 21-28) for the virtual ward patients versus controls. We used comparative mortality rates as a test of unobserved confounding.

Our secondary endpoints were the comparative rates of A&E attendances, use of local authority funded social care, rates of GP surgery visits, and rates of community health service contacts. We also analysed notional costs of health and social care, derived by applying hospital reimbursement tariffs and notional costs of primary and social care provision to the recorded levels of activity, as well as the costs of the virtual wards intervention.

We considered using a range of primary and secondary outcome endpoints at the individual patient level from 90 days to 360 days following admission to a virtual ward. However in order to maximise the sample size with sufficient follow up we focussed the analysis on changes at 180 days.

2.8 Data sources

We obtained data from a range of sources as detailed in Table 5. We asked the study sites to render all of their data pseudonymous by: removing all names and addresses; replacing dates of birth with years of birth; replacing postcodes with lower super output areas; and replacing the NHS number or other personal identifier with a unique, secure, pseudonym in such a way that within any one site, all data would be pseudonymised in exactly the same way to enable the researchers to link disparate datasets at the individual level.[64]

Table 5. Date ranges for the data extracts used for local and national matching in the three study sites

			Croydon	Devon	Wandsworth	All sites
			Start	Start	Start	End
National data	Virtual ward patients	Patient list	15 May 2006	1 Oct 2008	1 March 2009	30 September 2010
	Hospital activity	HES	1 April 2003	1 April 2005	1 April 2005	31 March 2011
	Mortality	ONS	15 May 2006	1 Oct 2008	1 March 2009	31 August 2010
		HES	31 August 2010	31 August 2010	31 August 2010	31 March 2011
Local data	Virtual ward patients	Patient list	15 May 2006	1 Oct 2008	1 March 2009	30 September 2010
	Member file	Exeter	1 April 2006	1 April 2008	1 April 2008	31 March 2011
	Hospital activity	SUS	1 April 2003	1 April 2005	1 April 2005	31 March 2011
	Community health services	Community health services data	1 April 2004	1 April 2006	1 April 2006	31 March 2011
	Social care	Social care data	1 April 2004	1 April 2006	1 April 2006	31 March 2011
	Primary care	GP Read code data	1 April 2003	1 Nov 2008	1 April 2006	31 March 2011

For the national matching, we asked the sites to send their list of virtual ward patients securely to the NHS Information Centre for health and social care (IC). This patient list included full names, dates of birth, sex, postcodes of residence and unencrypted NHS numbers of all patients who received the intervention, in addition virtual ward name and the dates of admission and discharge to the virtual ward. The IC then matched this information to HES, replaced the NHS number with a HESID, and removed the identifying fields before sending the now pseudonymous patient list to the research team for analysis.

We used the HESIDs we received from the IC to identify virtual ward patients within national HES datasets. These datasets were also supplied by the IC and were held securely at the Nuffield Trust.

For the local matching, we used encrypted NHS numbers as the primary linkage field in Devon and Wandsworth. However, in Croydon, the NHS number was not widely available in the social care data, so in this site we asked local analysts to create an encrypted alternative identifier based on gender, date of birth and initials. We used this for data linkage in Croydon, in addition to an encrypted postcode of residence. We had used this approach previously in a separate research project in Croydon and knew that this method of data linkage performed well.[65,66]

Each site supplied us with at least one pseudonymous 'member file' of all people registered with a GP in their area spanning the dates shown in Table 5. This file provided the base dataset onto which we linked all variables, including those constructed from the following pseudonymous databases: GP read code data, community health services data, hospital data (inpatient, outpatient and A&E activity) from SUS, and social care data extracted from local authority systems.

We held two seminars during the course of the research in which we sense-checked our understanding of the intervention in each site, the data provided, and our emerging findings.

2.9 Costing care activity

We calculated the costs of primary care (GP visits and community care teams), secondary care (inpatient, outpatient and A&E) and social care received by cases and controls in each site. We considered these costs separately from the costs of the intervention (i.e. the costs of delivering virtual ward care).

Our general approach to costing was to assign normative reference costs to units of care activity. Normative costs tend to increase over time, and so they depend on the year in which they were assessed. To ensure that all care costs were directly comparable throughout the study period, we used the 20010/11 normative reference costs for all care types. Likewise, care costs tend to vary between sites because of unavoidable differences in the cost of providing services, such as the local labour market and land rents. In the case of secondary care, providers increase their prices by a set amount to account for these extra costs. To ensure that care costs remained directly comparable between sites, we chose not to apply this additional factor.

2.10 Costing primary care

We categorised GP practice activity by role of staff seeing the patient (GP, practice nurse, health visitor etc) and determined the costs of these contacts using the PSSRU 2010 unit costs.[67] In Devon, the primary care data we received did not record the staff role, so we applied an average appointment cost calculated from Croydon and Wandsworth, using activity that had a cost greater than £0, and applied this on a per visit basis. We

did not calculate prescribing costs because of difficulties in obtaining the necessary data.

We divided community care provision for the three sites into the following types: district nurse, community matron and nurse specialist. We mapped these staff roles to the best match in the PSSRU 2010-11 reference costs, which reported costs per hour of client contact (all types) and per average consultation (district nurse and community matron only).

Where hourly reference costs were available and time used for a visit was recorded in the data, we multiplied this time multiplied by the hourly cost and divided by 60. Otherwise, we used the per consultation value.

2.11 Costing secondary care

We costed all secondary care activity by using the 2010/11 Payment by Results (PbR) national tariff.[68] In cases where the secondary care activity did not have a tariff, we estimated costs from the 2007/08 national reference costs,[69] taking account of inflation to make them comparable with the 2010/11 tariff. In this way, we calculated costs as the cost to the commissioner of care, rather than the actual costs of providing care. We have used this approach to costing in another study commissioned by the Department of Health. [70]

We established the costs of inpatient admissions by calculating the Healthcare Resource Group (HRG) for each patient's whole stay in hospital. We derived the full cost using the PbR rules[71] to combine the HRG, admission method and other details of the hospital stay. This included the unit cost of the HRG and any payments due because of an unexpectedly long stay in hospital, or for any specialist care or additional treatments and tests (so-called unbundled payments). We also calculated outpatient and A&E costs as recommended by the PbR rules.

We conducted the costing process separately for the local SUS data (for local analysis) and then again on the national HES data (for national matched control analysis) in all cases for both cases and controls.

2.12 Costing social care

We costed social care activity by analysing the social care data we received from the sites in nine service groups. We costed the following per day that individuals received the service: "Residential care", "Nursing care", "Meals", "Day care" and "Direct payments" based on weekly prices drawn from PSSEX1 2010/11 divided by 7 for a daily cost.[72] We assumed that "Respite" and "other accommodation" had the same costs as residential care. We costed "Home care" per hour, again drawn from PSSEX1 2010/11. Lastly, we costed "Equipment and adaptations" per installation. No reference price was available for this, so we calculated it based on the gross national spend on equipment for older people,[73] the extrapolated number of older people

receiving equipment nationally[74] and the mean number of installations per person receiving any installations as recorded in the local data we received.

2.13 Economic analysis

In standard economic evaluation, the outcome is measured in terms of health improvement (mortality, quality of life, utility) whilst the cost measures the full opportunity cost of the intervention compared to usual care. The problem with undertaking an economic evaluation of virtual wards was that the intention of the intervention was to reduce hospitalisation. So the objective of this research project was more narrow in scope than usual, comparing as it did the direct cost of the intervention against any reduction in costs of hospitalisation. In other words, we set out to test whether the NHS as a whole saved resources from treating patients in a community setting. For this reason, the principal aim of the economic evaluation was to examine the costs to a commissioner of setting up and running a virtual ward, and to balance these costs against the net benefit of any avoided utilisation of health care or social care.

Prior to undertaking the evaluation, we did not know the extent to which the same resources were used across patients who were receiving virtual ward care versus those who were not receiving the intervention. Therefore, we used a resource diary and questionnaire to help determine the costs of patients who were receiving virtual ward care compared to patients who were not.

In order to establish the direct and indirect costs of running virtual ward we collected information about staff costs. These costs to the NHS of the virtual ward included the time spent by virtual ward staff consulting with patients in person and on the telephone, the time they spent attending ward rounds, plus the time spent by non-virtual ward staff (GPs, specialists etc.) in consulting with the virtual ward staff members.

2.14 Administrative data

We obtained financial data from the three sites that enabled us to calculate the costs of virtual wards. Table 6 sets out the different costs that we included in our calculations.

Table 6. Calculation of travel, capital and management costs

Type of cost	Basis of calculation
Staff costs	Whole time equivalent staff costs plus 25% on-costs
Travel costs	Reimbursement for public transport or mileage paid to staff.
Land, computers and fixed capital costs	Lease costs paid for these items.
Management costs	Costs of management time actively spent on virtual ward activity using full time equivalents and salary bands.

We also included the set-up costs of the virtual wards in our cost estimates, including the cost of generating the predictive risk scores, based on the interview responses of management and finance staff in each site.

We ignored the pharmaceutical and laboratory costs of virtual ward patients because of difficulties in obtaining the necessary data. We assumed that these costs would be broadly similar for the intervention and control populations and we confirmed the reasonableness of this assumption during our interviews with virtual ward clinical staff.

2.15 Interviews, questionnaires and diaries

As well as using financial data from each site, we validated the costs of the intervention by means of staff interviews, questionnaires and work diaries. We aimed to identify a representative sample of the staff working on virtual wards projects in each of the three sites, including clinical staff, managers and finance staff. Such were identified on the basis of their job title and designation. Since the purpose of the interviews was to establish that there were no externalised costs of savings that we needed to be concerned about, the most important interviews were those with the finance staff.

At each site, we therefore identified and interviewed the lead budget holder and management personnel for the virtual ward project. We also sought to interview the manager who was responsible for commissioning the program

at the PCT. We also requested interviews with frontline staff including GPs, community nurses and ward clerks.

Requests for diary completion were sent in the first instance to front line staff managers and requested to be distributed anonymously. However, the response rates were low and our ethics committee approval only permitted us to send one reminder.

Members of staff were asked to provide written consent to participate in this element of the study, and we incorporated a number of measures in the study design to ensure the confidentiality of respondents. This included the use of participant codes to ensure that the research team did not receive any identifiable staff data. In certain cases, we rounded salary costs up or down in order to protect confidentiality where there were small numbers of staff involved.

We conducted semi−structured interviews with a range staff in each of the three study sites, including GPs, nurses, finance department staff, and social care workers where appropriate.

The interviews were audio−recorded, following consent by participants. In the interviews, we sought to explore:

1. the interaction of patients and carers with the virtual ward
2. the patient journey through the intervention
3. services delivered to virtual ward patients
4. any cost issues (financial and otherwise) that might have been externalised onto service users or their carers.

The topic guides for the interviews can be found in Appendix 4.

We also invited virtual ward clinical staff to complete questionnaires and two-week work diaries (see Figure 5 and Figure 6).

Figure 5. Staff questionnaires

Clinical staff

- Do you know that you are working with virtual ward patients?
- Do you have face-to-face or telephone contact with virtual ward patients as part of your job?
- In a typical working week, how frequently do you communicate with people in the following groups either about patients / service users, or about services in general: hospital doctors, GPs, nurses, pharmacists, case managers, therapists, social workers, care workers
- What is your occupational group?
- What is your job title?
- How many hours a week are you contracted to work?
- How many hours a week does your job relate specifically to work on the virtual ward?

Figure 6. Staff diaries

We asked staff to complete a new row of their diary every time they saw or talked to a virtual ward patient or discussed a patient with a colleague.

Each row recorded the following information:

- Date
- Start time
- Age of patient (10-year bands)
- Sex of patient
- Risk score of patient (10 risk-score bands, or unknown)
- Consultation type (home visit, clinic appointment, telephone consultation, discussion with another professional, ward round or team meeting, other)
- Time spent with patient (minutes)
- Time spent travelling to the patient's home, if relevant (minutes)
- Specific care activities undertaken
- Extra burden on carers, such as accompanying a patient to an appointment (minutes)

2.16 Bias

We used a number of approaches to minimise potential sources of bias in this study.

2.17 Selection bias

Selection bias occurs when there is a systematic difference between members of groups that are being compared (in our case, between virtual ward patients and control patients). In non-randomised studies, a particular threat to validity is that the groups differed systematically in ways that could not be observed. We aimed to minimise the risk of selection bias by:

- *Careful selection of the areas from which controls were selected:* Our local matching analysis selected controls from the same areas that offered the intervention. This meant that virtual ward patients and controls would be expected to share the same set of contextual factors, for example the configuration of local health care services. The national analysis selected controls from outside the intervention areas, but we selected the areas were to be similar to the intervention areas in terms of demographics, household composition, housing, socioeconomic factors, employment and industry.[61,62]
- *Assembly of a large collection of data sources:* We extracted a range of data sources and linked at person level, so that we could compare the characteristics of virtual ward patients and the controls. The variety of data sources collected, particularly for the local matching, meant that we could observe the most important predictors of future healthcare use, thereby minimising the scope for unobserved differences.
- *Use of a range of matching methods:* We used both propensity and prognostic matching to construct control groups that were closely matched on observed variables.
- *Multiple control groups:* We selected two control groups, one local and one national, so that our findings from the two analyses could be compared.
- *Using difference-in-difference analysis:* A difference-in-difference analysis can remove the impact of unobserved differences between groups, on the assumption that the impact of the unobserved variable is constant over time (a "time-invariant confounder").
- *Testing for the impact of unobserved variables:* Following the suggestion of West and colleagues,[75] we compared an additional endpoint between the two groups, namely mortality. Although theoretically possible, we did not expect the virtual ward interventions to affect mortality over 180 days, so if we observed a difference in mortality rates between groups, this would be suggestive of unobserved differences - for example, that the virtual

ward patients were sicker than control patients in ways that were not recorded in routine datasets. Unfortunately, for the national matching analysis, only data relating to deaths in hospital were available for the period after intervention, so the observed differences could also be due to changes in the place of death. However, for the local matching analysis, data on all deaths were available to us.

- *Sensitivity analysis to illustrate the scope for a hypothetical unobserved confounder to influence the findings:* We conducted a sensitivity analysis that hypothecated the existence of an unobserved confounding variable that led to unobserved differences between the virtual ward and control groups. Although, clearly, the sensitivity analysis cannot indicate whether such a confounding variable exists, it did allow us to quantify the strength of confounding that would be required for our findings to have been substantially altered.

2.18 Sample selection bias

Sample selection bias relates to differences between the sample of individuals we analysed and the larger population. By using routine datasets, we were able to analyse a substantial proportion of the individuals who received the virtual wards intervention. The only exclusions we made were related to non-linkage of data or to people recruited when the virtual wards were not fully operational, as discussed above.

Another form of selection bias may occur if certain characteristics of individuals are inversely associated with enrolment into the intervention. In this situation, these characteristics can be expected to be relatively more prevalent in the set of people resident in the local area who did not receive the intervention. Conversely, these characteristics may be less prevalent among people residing in other areas. This type of bias is very difficult to assess because the variables cannot be observed. However, on the assumption that the unmatched prevalence rate of such variables was more similar among the general population of the other areas than among residents of the intervention areas who did not receive the intervention, we considered that we would be more likely to balance these unobserved variables in our "national" matching where we selected controls from other areas.

2.19 Threats to external validity

Another form of bias relates to external validity, which refers to the generalisability of our findings. In other words, the degree to which the conclusions from our study would apply to virtual wards offered in other areas of England. Compared to randomised studies, non-randomised studies have some important advantages. We were able to observe an intervention that had developed organically within the NHS, without altering it by means of the techniques adopted to assess its impact. Indeed, in the

largest of the virtual ward projects we studied – Croydon – the majority of patients we analysed had been recruited before this evaluation was conceived. However, this study related to a specific set of interventions that evolved in response to local factors and these may not be the same as those that would affect the development of virtual wards in other parts of the country. Although we evaluated three different models of virtual wards in this study, Croydon contributed the largest proportion of participants, so our findings disproportionately reflect that model.

2.20 Attribution bias

Attribution bias is a cognitive bias that can exist in the interpretation of research findings. It relates to the determination of what was responsible for the differences observed between groups. Differences in health care and social care utilisation may not be attributable to the effect of virtual wards if some other causal agent was acting. While it would be possible to compare trends in hospital admission rates at the area level between virtual ward areas and other areas, hospital activity can be affected by the operation of other interventions operating in the same area or by local policy decisions. Falsely attributing trends at the area level to changes in a subset of individuals is known as the ecological fallacy.[76] However, the individual-level nature of our analysis should increase the likelihood that our findings are attributable to virtual wards, compared with analyses conducted at the area-level.

2.21 Residual confounding

Residual confounding can lead to a hidden bias in the estimated treatment effect of an intervention. This phenomenon may occur in matching studies where the intervention and control groups appear to be similar in every way that can be observed, yet they differ systematically from each other according to some other unobserved factor or factors. The possibility of residual confounding was particularly problematic in our study because we had no control over the range of data that were collected and made available to us for analysis.

2.22 Loss to follow-up

For our national matching, once identified within HES, the only ways in which a virtual ward patient or control patient could be lost to follow-up were through migration out of England. We assume that rates of migration were low among virtual ward patients because they were on average older people with a high burden of chronic disease.

For our local controls, a virtual ward patient or control patient could be lost to follow-up if they re-registered with a GP practice outside the study area.

We included individuals in the analysis regardless of subsequent death. We were unable to link a small number of virtual ward patients to routine datasets, so we compared the characteristics of cases who were linked versus those who were not linked.

2.23 Study size

Before conducting this study, we estimated the number of patients that we would need to analyse in order to ensure that we had sufficient data to determine whether virtual wards had an impact on rates of emergency hospital admission rates with an acceptable degree of statistical error.

We thought it was reasonable to suppose that, if effective, virtual wards might lead to a relative change in the rate of emergency hospital admission of 20%.[16] We wanted to have a 90% probability of detecting this degree of change should it have occurred (1-Type II error). On the assumption that a difference in admission rates was detected, we wanted there to be no more than a 5 per cent probability that it was due to chance rather than due to a real difference between the groups (Type I error).

Based on actual data provided by one of the sites, we took the rate of emergency hospital admission to be 1.65 emergency admissions per patient with a standard deviation of 2.5 for control patients receiving usual care. Using the formulae provided by Friedman and colleagues,[77] we calculated that the required sample size was 1,206 patients. We did not plan to conduct any subgroup analyses and the study was not powered to do so.

2.24 Quantitative variables

For both the national and local matching, we constructed a set of independent variables documenting prior hospital use in addition to diagnostic morbidity information. These variables were based on those developed for the PARR predictive model[16] and the Nuffield Trust Social Care Predictions models.[65] The variables included counts of admissions or attendances by type over various periods of time, as well as flags to indicate the presence of chronic diseases and other diagnostic disease groupings.

For the local matching we additionally created Combined Predictive Model variables[16,17] using hospital data (SUS) and GP clinical data.

The social care data we received was structured at the person level, linking together events recorded in the social care record. Though different local authorities offered similar types of services to people, they coded these services in slightly different ways. So, for example, while one site used a

total of 400 distinct codes to specify services and client groups, another captured equivalent information in a much simpler set of 39 descriptors.

To take account of these differences, we classified the care services into a common typology, grouping together local descriptions under the following headings:

- residential care and nursing home
- home care
- residential respite care
- other accommodation
- equipment and adaptations
- direct payments made to users
- day care meals
- other

2.25 Statistical methods

We used a difference-in-difference approach to analyse all of the study endpoints, with the exception of mortality which is not amenable to such an approach because cases cannot have died before the intervention started. Testing for a difference-in-difference, we examined whether rates of health care and social care utilisation changed by a smaller or larger amount in the virtual ward group than would have been expected given the underlying trend suggested by the control groups. An important advantage of the difference-in-difference approach is that if there are residual differences between the virtual ward and control groups after matching due to imbalances in unobserved variables, then some of this discrepancy may be cancelled out by the differencing. However this assumes that the effect of these residual balances remained constant over time and that the difference-in-difference model was correctly specified.

We conducted the difference-in-difference analysis using ordinary least squares regression for the following predictors: intervention group (virtual ward or control), period (before or intervention) and the interaction between intervention group and period. We did not include any other predictors (called "fixed effects") in the regression because our matching approach ensured that virtual ward and control patients were similar in terms of observed characteristics. However, we did allow for the expected correlation structure of the data by including random effects in the regression. We included two random effects: one at the site level, and one at the level of the "block", consisting of matched virtual ward and control patients. We did not include any effect modifiers.

The majority of analysis and data manipulation was conducted in SAS® with some selected elements of matching using R.[78,79]

Our modelling strategy is summarised in Table 7.

Table 7. Modelling strategy

Outcomes/Outputs	Emergency hospital admission, mortality, A&E attendances, use of local authority funded social care, rates of GP surgery visits, and rates of contact with community nurses, notional costs.
Exposures	Whether individuals were admitted to a virtual ward or not.
Predictors	Intervention group (virtual ward or control), period (before or intervention) and the interaction between intervention group and period.
Potential confounders	Variables controlled for in the matching, including prognostic score, age, sex, categories of prior hospital utilisation, total number of chronic health conditions, area-level deprivation score, and markers of specific health needs. In addition, for the local controls we matched for an additional set of variables including prior utilisation of primary care and social care.
Effect modifiers	None

2.26 Sensitivity analysis

Although our matching algorithm aimed to reduce observed differences between virtual ward patients and controls, it is nevertheless possible that some systematic unobserved differences existed between the groups. In order to estimate the effect of such a hypothetical unobserved confounder, we performed an additional analysis by using a simulation technique outlined by Higashi and colleagues.[80] This involved making assumptions about the strength of a hypothetical unobserved confounder, and then estimating what impact controlling for that variable would have had on the analysis of emergency admissions.

We simulated a continuous confounder based on a range of assumptions about its correlation with emergency admissions and recruitment into the virtual wards intervention. In each scenario, we simulated the variable using a rejection sampling approach.[81] We then incorporated the simulated variable into the difference-in-difference regressions to estimate the effect of the intervention whilst adjusting for the simulated values of the unobserved confounder.

3 Findings: effectiveness based on local data

This chapter describes our difference-in-difference findings based on an analysis of *local data* (Chapter 4 describes our findings based on an analysis of national data). The chapter begins with a description of the patients who received the virtual ward intervention: the numbers of patients, their length of stay on a virtual ward, and their characteristics in terms of predictive risk scores and other metrics. Next, we describe how closely we were able to find matched controls. Finally, we describe the observed differences between the virtual ward patients and these 'local' controls.

3.1 Numbers of patients under study

We received data relating to 2,008 individuals who had been admitted to virtual wards a total of 2,056 times. Our analysis of local data focussed on patients who were first admitted to a virtual ward within specified time periods (Table 5). We excluded patients who were admitted to a virtual ward in Croydon between April 2007 and March 2008, because the combined model was not refreshed in Croydon during this period.

We excluded 161 patients who could not be linked to the GP registration data (Exeter data) that formed the basic member file for our analysis. After applying the restrictions based on the time of admission to a virtual ward, we were left with 1202 participants (Table 8). A further 213 participants were excluded at a later stage in the analysis because they could not be matched to a control. Overall, we included 989 patients in the main analysis of local data.

Table 8. Numbers of cases selected for local matching

	Croydon	Devon	Wandsworth	All sites
Cases identified by sites	1,658	122	228	2,008
Unable to link to registration data	64 (3.9%)	27 (22.1%)	70 (30.7%)	161 (8.0%)
Not recruited in relevant period	627 (37.8%)	18 (14.8%)	0 (0%)	645 (32.1%)
Unable to find matched control	180 (10.9%)	1 (0.8%)	32 (14.0%)	213 (10.6%)
Cases included in matched analysis	787 (47.5%)	76 (62.3%)	126 (55.3%)	989 (49.2%)

3.2 Length of stay on virtual wards

The median length of stay on virtual wards across all three sites was 338 days (11.1 months), although 25 per cent of individuals stayed 144 days

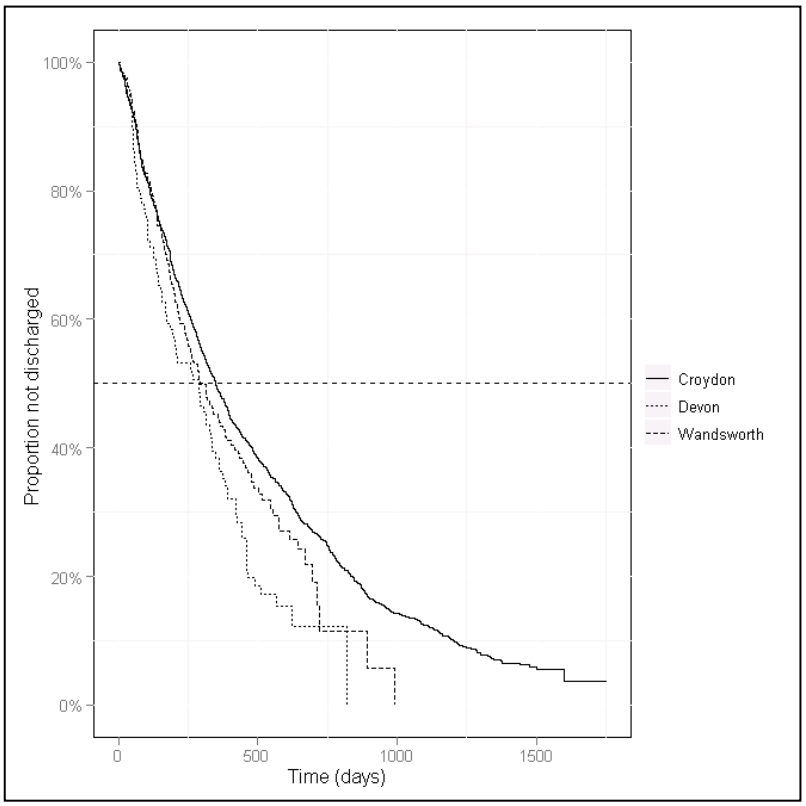
(4.7 months) or fewer, and 25 per cent of individuals stayed 720 days or more (2 years) (Table 9).

Table 9. Estimated length of stay on virtual wards

	Croydon (N=1713)	Devon (N=118)	Wandsworth (N=225)	All (N=2056)
	Days [95% confidence interval]			
25th centile	147 [134,166]	104 [61,140]	140 [112,175]	144 [132,157]
50th centile (median)	348 [328,372]	288 [175,336]	291 [247,373]	338 [316,357]
75th centile	749 [694,779]	460 [391,568]	645 [518,722]	720 [668,759]

Figure 7 illustrates how virtual ward stays were typically longer in Croydon than in the other two sites.

Figure 7. Length of stay on virtual wards



3.3 Characteristics of patients admitted to virtual wards

Croydon and Devon used combined predictive model scores to identify a large proportion of their participants.[17] In Wandsworth, the PARR predictive model[16] was used to identify approximately 25 per cent of patients, with the remainder being referrals from clinicians. The availability of GP data in our local analysis meant that we could calculate combined model scores for cases and local controls.

The information we obtained from the sites included the date that an individual patient was admitted to a virtual ward. However, the combined model score used locally to identify an individual would have been calculated at an earlier date than this due to a number of lags, including lags in the administrative data systems, the time required to run the model, the time taken to identify patients, the time taken to apply any exclusion criteria, and the time taken to enrol patients. Discussions with representatives of the sites suggested the total elapsed period was approximately four weeks where local hospital datasets were used in the combined model, and slightly longer where SUS data were used.

Figure 8 shows a box and whiskers plot of the median combined model scores of virtual ward patients, together with the inter-quartile range and extreme values. As can be seen, the median combined model scores peaked at around 0.65, with this peak occurring about five months before admission to a virtual ward. Over a quarter of participants had combined model scores lower than 0.40, suggesting that the interventions were not exclusively targeted at high-risk patients.

Figure 9 shows the distribution of combined model scores of virtual ward participants. As can be seen, some of the selected patients had low risk scores despite the apparent availability of patients with higher combined model scores. Some of these latter patients might have been un-contactable or unwilling to be admitted to a virtual ward or otherwise deemed to be somehow "unsuitable" for virtual ward care.

Figure 8. Trends in the combined model risk score over time

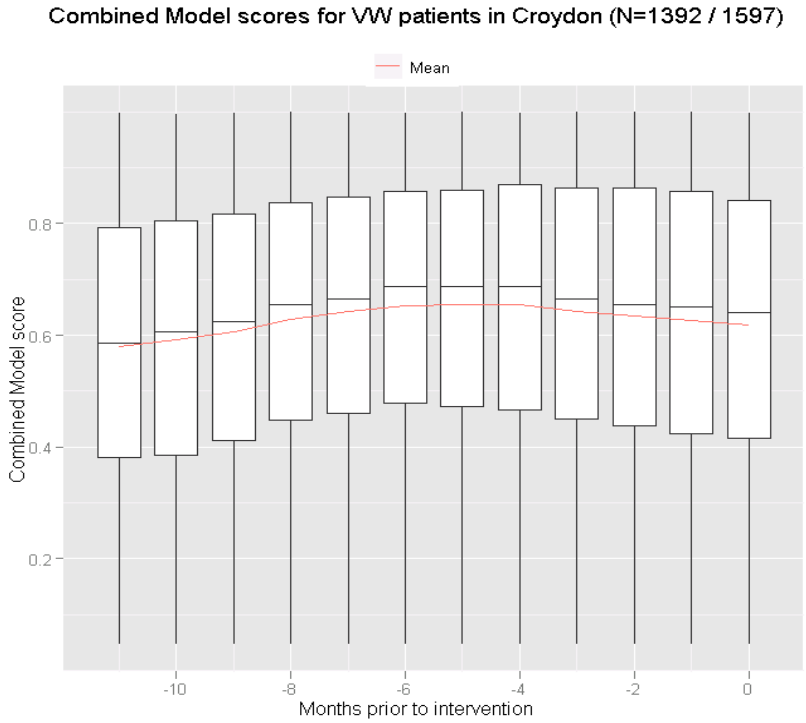
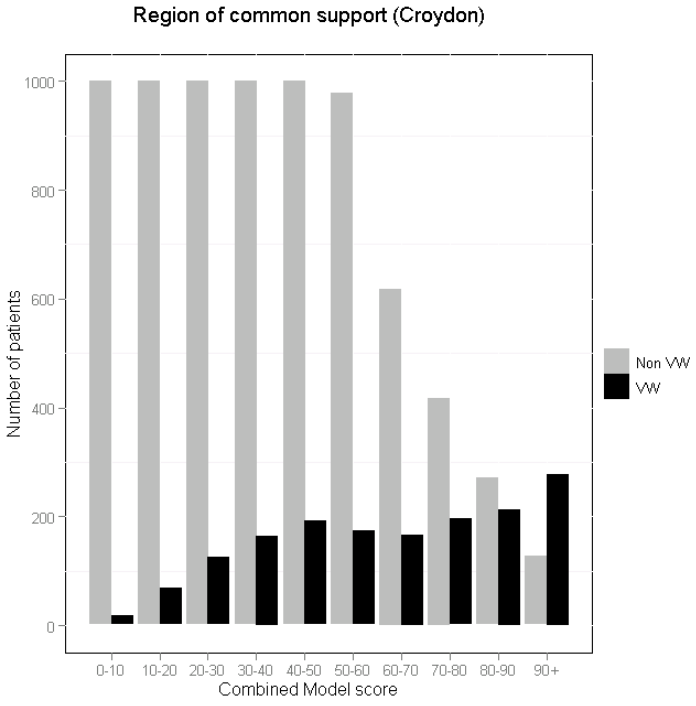


Figure 9. Combined model scores of Croydon virtual ward participants compared to other local residents prior to starting the intervention



The virtual ward patients had a mean combined model score of 0.63 compared with a mean combined model score of 0.06 for the rest of the population of the study areas. Table 10 shows that in the 12 months before receiving the intervention, the virtual ward patients:

- Had a higher rate of emergency hospital admissions (2.64 per patient compared with 0.06 for the rest of the population)
- Had more general practice surgery visits (42.99 visits compared with 5.55 for the rest of the population)
- Were much more likely to have been in contact with community nurses (68.6 per cent of virtual ward patients had been in contact with community nurses in the year before receiving the intervention compared with 1.0 per cent for the rest of the population)
- Had 2.48 chronic health conditions recorded in their inpatient record on average, compared with 0.07 conditions for the rest of the population
- Were more likely than the rest of the population to have had a history of hypertension (65.1 per cent compared with 2.5 per cent) and injury (39.6 per cent compared with 2.4 per cent)
- Were more likely to have received social care services from the local authority. For example, 19.3 per cent of virtual ward patients had received home care at some point in the previous twelve months, compared with 0.5 per cent for the rest of the population. Likewise, 4.1 per cent of virtual ward patients had received residential care in that year compared with 0.4 per cent for the rest of the population.

Differences in social care utilisation, however, appeared to be less marked than the differences in the use of emergency hospital services and primary care.

Table 10. Comparison of virtual ward patients before matching with other residents in the study areas

	All sites		
	Intervention (N=1,202)	**Other residents in the intervention areas (N=1,360,375)**	**Standardised difference**
Combined Model score	0.63 (0.26)	0.06 (0.07)	304.6%
Demographics			
Age	73.08 (16.85)	40.85 (22.01)	164.5%
Female (%)	54.7%	50.5%	8.4%
Hospital contacts (prior year)			
Emergency admissions	2.64 (2.74)	0.06 (0.31)	132.5%
Accident and Emergency visits	3.87 (4.63)	0.24 (0.87)	109.1%
Elective admissions (non day case)	0.30 (0.71)	0.03 (0.31)	49.7%
ACS admissions	1.10 (1.65)	0.03 (0.23)	90.8%
Outpatient attendances	10.22 (12.27)	0.83 (2.50)	106.1%
Primary care contacts (prior year)			
GP surgery visits	42.99 (24.51)	5.55 (8.80)	203.4%
Community care input (%)	68.6%	1.0%	201.3%
Community care visits	16.75 (52.32)	0.14 (4.25)	44.7%
LA social care use (prior year)			
Home care (%)	19.3%	0.5%	66.2%
Day care (%)	3.4%	0.3%	23.0%
Meals (%)	7.4%	0.2%	38.2%
Residential care (%)	4.1%	0.4%	25.5%
Nursing home care (%)	2.2%	0.1%	19.9%
Direct payments (%)	1.5%	0.1%	15.7%
Diagnoses from inpatient record			
Number of chronic conditions	2.48 (1.65)	0.07 (0.40)	200.2%
Anaemia (%)	21.5%	0.5%	71.1%
Angina (%)	21.5%	0.6%	71.0%
Asthma (%)	19.1%	0.9%	64.0%
Atrial fibrillation and flutter (%)	25.0%	0.8%	77.7%
Cancer (%)	13.9%	1.2%	49.7%
Cerebrovascular disease (%)	16.7%	0.4%	61.0%
Congestive heart failure (%)	20.1%	0.4%	68.9%
COPD (%)	21.0%	0.3%	71.1%
Diabetes (%)	28.2%	1.0%	83.5%
History of falls (%)	20.8%	0.9%	67.8%
History of injury (%)	39.6%	2.4%	102.5%
Hypertension (%)	65.1%	2.5%	176.5%
Ischemic heart disease (%)	35.0%	1.0%	98.8%
Kidney failure (%)	11.5%	0.3%	48.9%
Mental health (%)	25.6%	0.7%	79.3%

3.4 Factors associated with admission to a virtual ward

Another way of illustrating the factors associated with admission to a virtual ward is by using a propensity model. This is a model that predicts admission to a virtual ward based on prior characteristics recorded in administrative data.

The estimated propensity model for one study site (Devon) is shown in Table 11, for illustration. This shows that the combined model score was strongly predictive of admission to a virtual ward, but that compared to other people with a high combined model score, virtual ward patients were: more likely to have a history of A&E admissions, falls and asthma; more likely to be known to community services; and less likely to have a history of emergency hospital admissions. Prior social care use was not predictive of admission to a virtual ward after controlling for these other factors.

Table 11. Estimated propensity model for admission to a virtual ward in Devon

(N=77)	Coefficient	P value
Intercept	-9.2894	<0.0001
Combined Model score (logit)	1.1405	<0.0001
Age	0.021	0.0265
Emergency admissions (180-365 days)	-0.4411	0.031
A&E medical attendances (180-365 days)	0.3599	0.0248
Falls recorded in primary care	1.4729	<0.0001
Incontinence recorded in primary care	0.9378	0.0275
Asthma recorded in primary care	1.6604	0.0001
Increase in bronchodilators prescribed in primary care	-1.5897	0.0003
Number of GP surgery visits (360-720 days)	0.0215	<0.0001
Number of GP surgery visits (0-360 days)	-0.00527	0.0027
Community care visit (0-360 days)	3.6953	<0.0001

Note: The performance of the propensity model (95% bootstrapped standard errors) was as follows: area under ROC curve 0.882, PPV 71%, Sensitivity 19%.

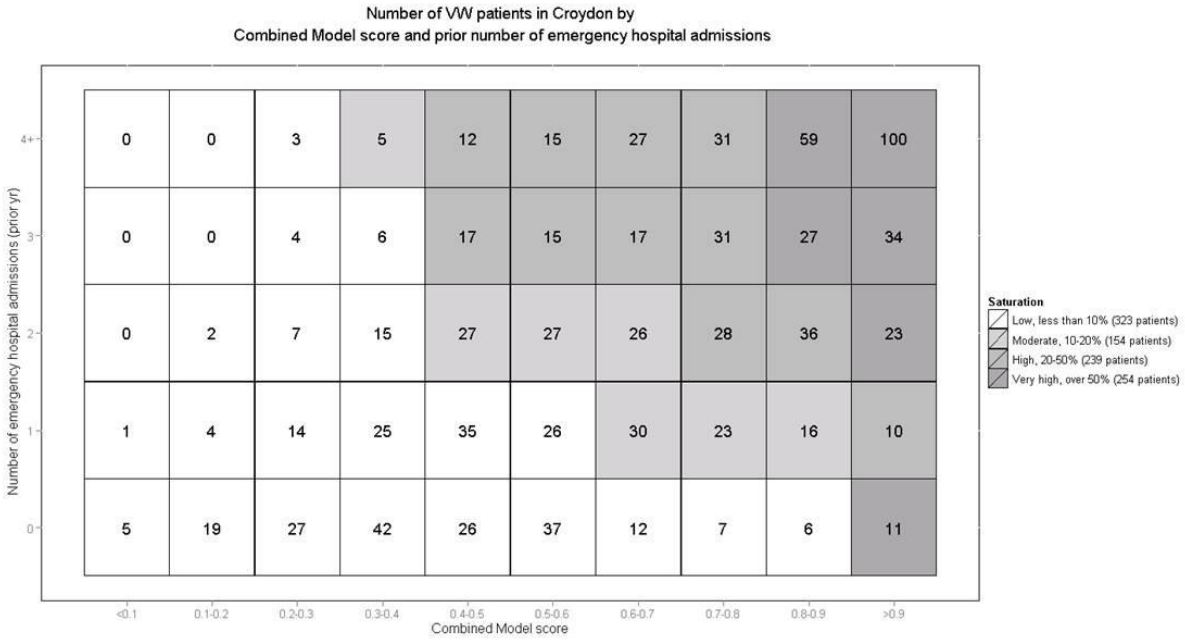
3.5 Selection of controls

Successful matching requires a degree of overlap between the characteristics of the intervention patients and their potential controls - in this case, other residents living in the same area. We found a substantial overlap in patients with low combined model scores, but very little overlap at higher risk scores. As expected, this was particularly the case in Croydon, where the intervention had been in operation for many years. The degree of overlap was especially low for Croydon patients whose combined

model scores were high predominantly by virtue of their having a high number of emergency hospital admissions in the prior period.

The shading in Figure 10 represents the "saturation" of the intervention, defined as the proportion of different population subgroups who were admitted to a virtual ward. A high degree of saturation reflects a low availability of control patients with similar characteristics to the intervention patients. Overall, 254 intervention patients (26.2 per cent) belonged to a population subgroup in which over 50 per cent of people were admitted to a virtual ward. A further 239 patients (24.6 per cent) belonged to a subgroup with a saturation of between 20 and 50 per cent. We anticipated that we would find it difficult to identify controls for virtual ward patients in these subgroups, and this was confirmed in the analysis that follows.

Figure 10. Availability of local controls in Croydon



We restricted our matching analysis to those virtual ward patients who could be matched to a control. Specifically, we required that a control patient exist with the same age band and sex, and that they had a similar combined model score. Note that since we selected our controls without replacement, matching a control for one patient meant that fewer patients were available to be used as controls for the remaining virtual ward patients.

Although we investigated propensity and prognostic matching techniques, ultimately genetic matching resulted in the lowest standardised differences, and so was used in the final analyses. We were able to match 989 virtual ward patients. The characteristics of these patients are shown in Table 12. Compared with the characteristics of the whole of the intervention group (see Table 10 above), the patients included in the matching analysis had:

- Slightly lower combined model scores, with a mean score of 0.57 compared with 0.63 for the entire set of virtual ward patients linked to GP registration data.
- Slightly lower rates of hospitalisation (2.18 emergency admissions per person per year compared with 2.64)
- Slightly lower rates of general practice visits (40.64 visits per person per year compared with 42.99).
- A similar prevalence of recorded health diagnoses, except in relation to COPD, which was recorded in 14.9 per cent of the matched patients compared with 21.0 per cent for the group of virtual ward patients as a whole.

We assessed the performance of our matching by comparing the characteristics of the included virtual ward patients with their matched controls. The control patients had very similar combined model scores (mean 0.57, standard deviation 0.24). However, in relation to other patient characteristics, some of the differences between the two groups were relatively large. Many of the standardised differences were above the threshold of 10 per cent, which is generally taken to suggest a meaningful difference between groups. In particular, the prior use of secondary care services, primary care services and social care was lower in the matched controls than in the matched virtual ward patients. Equally, the matched virtual ward patients had a higher average number of recorded chronic health conditions than their matched controls (2.32 conditions compared to 1.65). However, diagnoses of cancer and COPD were relatively higher in the matched controls.

Although the intervention patients had a higher number of chronic conditions and consumed more services, mortality rates in the six months following intervention were substantially lower among intervention patients than controls (mortality of 5.6 per cent compared with 9.8 per cent for controls).

Table 12. Success of local matching

	All sites (N=989 matched pairs)		
	Intervention patients included in local matching analysis	**Matched controls**	**Standardised difference**
Combined Model score	0.57 (0.24)	0.57 (0.24)	1.4%
Demographics			
Age	73.06 (16.70)	72.93 (16.49)	0.8%
Female (%)	55.9%	55.9%	0.0%
Hospital contacts (prior year)			
Emergency admissions	2.18 (2.10)	1.65 (1.86)	27.1%
Accident and Emergency visits	3.14 (3.33)	2.35 (3.31)	23.9%
Elective admissions (non day case)	0.30 (0.69)	0.28 (0.68)	3.4%
ACS admissions	0.89 (1.27)	0.65 (1.19)	19.0%
Outpatient attendances	9.47 (11.16)	6.46 (7.77)	31.3%
Primary care contacts (prior year)			
GP surgery visits	40.64 (23.68)	31.90 (19.12)	40.6%
Community care input (%)	67.9%	49.7%	37.6%
Community care visits	16.64 (52.12)	7.88 (27.29)	21.1%
LA social care use (prior year)			
Home care (%)	19.3%	14.3%	13.6%
Day care (%)	3.3%	2.2%	6.8%
Meals (%)	7.8%	5.6%	8.9%
Residential care (%)	4.0%	3.4%	3.2%
Nursing home care (%)	2.4%	1.6%	5.7%
Direct payments (%)	1.4%	0.4%	10.7%
Diagnoses from inpatient record			
Number of chronic conditions	2.32 (1.59)	1.65 (1.54)	42.7%
Anaemia (%)	19.3%	10.7%	24.2%
Angina (%)	20.6%	9.9%	30.1%
Asthma (%)	15.5%	14.6%	2.5%
Atrial fibrillation and	23.5%	21.1%	5.6%

flutter (%)			
Cancer (%)	13.0%	17.2%	-11.6%
Cerebrovascular disease (%)	16.0%	10.2%	17.1%
Congestive heart failure (%)	18.1%	13.9%	11.6%
COPD (%)	14.9%	19.5%	-12.4%
Diabetes (%)	28.5%	19.3%	21.7%
History of falls (%)	19.8%	15.5%	11.4%
History of injury (%)	37.3%	28.7%	18.4%
Hypertension (%)	63.2%	47.6%	31.7%
Ischemic heart disease (%)	33.4%	19.0%	33.1%
Kidney failure (%)	11.0%	6.7%	15.4%
Mental health (%)	23.7%	20.4%	7.8%

3.6 Differences after intervention

Some of the differences we observed between the virtual ward patients and their matched controls in the period before the start of the intervention were substantial. However, as mentioned above, the difference-in-difference approach may be expected to cancel out some of the effects of these residual imbalances, on the assumption that the effects of these residual balances remained constant over time.

As can be seen in Table 13, in the six months after starting to receive the virtual ward intervention, the number of emergency hospital admissions reduced by 0.27 per person per six months among intervention patients, but reduced by 0.60 among controls. This suggests a net difference-in-difference increase in emergency admissions of 0.33 per person per six months ($p<0.01$).Visits to accident and emergency departments also increased by 0.38 per person per six months relative to controls ($p<0.01$).

However, outpatient attendances fell by 0.98 per person per six months among the virtual ward patients but only by 0.16 among matched controls, suggesting a net reduction of 0.81 attendances per person per six months ($p<0.01$).

GP surgery visits increased by 1.57 per person per six months among intervention patients but reduced by 1.29 among matched controls, suggesting a net difference-in-difference increase in GP surgery visits of 2.86 visits per person per six months ($p<0.01$). Contacts with community nurses also increased, by 8.67 per person per six months relative to controls. However, both of these apparent increases may reflect a degree double-counting. For example, GPs were delivering virtual wards in Wandsworth and they recorded their activity within routine GP data. Likewise, our data on community nurse contacts included contacts with district nurses and community matrons, and these staff were delivering virtual ward care in all of the sites.

We found no evidence of changes in social care use among virtual ward patients relative to their matched controls with regard to home care and residential or nursing home care.

Table 13. Difference-in-difference analysis

	Intervention patients			Matched controls			Differences	
	6 months prior	6 months post	Change	6 months prior	6 months post	Change	DiD	p-value
All sites (989 matched pairs)								
Emergency admissions	0.96	0.69	-0.27	1.15	0.55	-0.60	0.33	0.00
A&E attendances	1.44	1.04	-0.40	1.57	0.79	-0.78	0.38	0.00
Elective admissions	0.37	0.34	-0.03	0.44	0.37	-0.07	0.03	0.61
OP attendances	4.76	3.78	-0.98	4.01	3.85	-0.16	-0.81	0.00
GP surgery visits	21.23	22.79	1.57	18.05	16.76	-1.29	2.86	0.00
Community nurse contacts	10.41	20.60	10.19	5.28	6.80	1.52	8.67	0.00
Home care (wks)	3.11	3.21	0.10	1.80	2.30	0.50	-0.41	0.28
Residential/nursing care (wks)	0.95	1.10	0.15	0.72	1.12	0.40	-0.25	0.27

Note that this study was not powered to assess the impact of virtual wards in the three study sites separately and is somewhat dominated by the findings in Croydon (which was not delivering multidisciplinary care except in an initial pilot). Nevertheless, we have included a site-specific analysis in Table 14 to illustrate the contribution of each of the sites to the overall result.

All three sites saw a relative increase in emergency hospital admissions and in accident & emergency visits, although the numbers of patients in Devon and Wandsworth were too small for these findings to be statistically significant. Similarly, all three sites saw relative reductions in outpatient attendances.

The increase in GP surgery visits was largest in Wandsworth, as would be expected because of the nature of the intervention in this site, where GPs were delivering virtual ward care. Here, GP surgery visits increased by an additional 7.21 visits per person per six months amongst virtual ward patients compared with their matched controls. However, an increase was also seen in Croydon, albeit much smaller at 2.14 per person per six months. All three sites saw increases in community nurse contacts, although the difference in Devon was small and was not statistically significant at the $p<0.05$ level.

Table 14. Difference-in-difference analysis by site for the six months after starting the intervention

	Intervention patients			Matched controls			Differences	
	6 months prior	6 months post	Change	6 months prior	6 months post	Change	DiD	p-value
Croydon (787 matched pairs)								
Emergency admissions	1.05	0.74	-0.32	1.33	0.62	-0.72	0.40	0.00
A&E attendances	1.48	1.03	-0.45	1.70	0.80	-0.90	0.45	0.00
Elective admissions	0.42	0.37	-0.05	0.49	0.43	-0.06	0.01	0.91
OP attendances	4.97	3.80	-1.18	4.05	3.83	-0.22	-0.95	0.00
GP surgery visits	23.28	23.93	0.65	19.44	17.95	-1.49	2.14	0.00
Community nurse contacts	8.32	12.69	4.38	5.16	6.38	1.23	3.15	0.03
Home care (weeks)	2.90	2.93	0.03	1.39	1.88	0.50	-0.47	0.20
Residential/nursing care (weeks)	1.13	1.26	0.12	0.61	1.12	0.50	-0.38	0.12
Devon (76 matched pairs)								
Emergency admissions	0.13	0.08	-0.05	0.26	0.16	-0.11	0.05	0.65
A&E attendances	1.09	0.70	-0.39	0.92	0.59	-0.33	-0.07	0.79
Elective admissions	0.20	0.24	0.04	0.21	0.12	-0.09	0.13	0.39
OP attendances	2.83	2.63	-0.20	2.17	2.03	-0.14	-0.05	0.94
GP surgery visits	18.68	21.82	3.13	17.26	17.34	0.08	3.05	0.11
Community nurse contacts	15.67	14.59	-1.08	4.39	2.75	-1.64	0.57	0.89
Home care (weeks)	3.85	4.02	0.17	3.74	3.76	0.03	0.14	0.92
Residential/nursing care (weeks)	0.59	0.94	0.35	1.32	1.18	-0.14	0.49	0.49
Wandsworth (126 matched pairs)								
Emergency admissions	0.89	0.76	-0.13	0.56	0.37	-0.19	0.06	0.69
A&E attendances	1.41	1.32	-0.10	1.14	0.86	-0.29	0.19	0.44
Elective admissions	0.17	0.21	0.04	0.25	0.17	-0.08	0.12	0.18
OP attendances	4.58	4.39	-0.19	4.89	5.07	0.18	-0.37	0.69
GP surgery visits	9.96	16.33	6.37	9.87	9.02	-0.85	7.21	0.00
Community nurse contacts	20.32	73.63	53.31	6.60	11.87	5.28	48.03	0.00
Home care (weeks)	3.99	4.48	0.49	3.22	4.04	0.83	-0.34	0.71
Residential/nursing care (weeks)	0.03	0.25	0.22	1.00	1.07	0.07	0.15	0.78

4 Findings: effectiveness based on national data

This chapter, which describes the findings of our analysis of national data, begins with a description of our matched controls and our construction of the predictive models required for matching. We then describe the characteristics of virtual ward patients and their matched controls. Section 4.6 outlines the key findings of the difference-in-difference analysis, which is followed in section 4.7 by a number of supplemental analyses that we conducted based on our findings.

4.1 Participants and national controls

For the national matching, we used hospital data from other parts of the country to create control groups. The major advantage of this approach is that it was possible to call on a wider pool of possible controls. However, the major disadvantage was that matching and comparisons were limited to information contained in datasets that were available consistently across the country. In this case, this meant the use of HES datasets covering inpatient admissions, outpatient appointments and A&E visits.

We identified virtual ward participants based on linkage undertaken by the NHS Information Centre for health and social care. A small number of virtual ward patients could not be linked to HES, and were therefore lost to the analysis (overall 0.4 per cent). Table 15 summarises the records we received and the participants we excluded at various stages.

We excluded virtual ward patients where:

- Their basic demographic information could not be linked to a HESid. This may have arisen through errors in the transcription of patient details in the sites or because individuals did not have a record of hospital activity in England since 1997 (for example, they may have been a recent migrant).
- The timescales for the study cohorts were agreed in advance with the sites, and some patients were recruited before the agreed start dates for each site whilst others were recruited too late meaning that we would have had insufficient data for follow up.
- Patients who had a HESid but did not have a hospital inpatient admission in the two years before admission to the virtual ward. This exclusion was used partly because inpatient data were our source of health needs variables, and so we could more fully characterise people with a recent inpatient admission. Furthermore, people without a recent hospital admission typically have low rates of hospital admission in the near future, so the scope for any intervention to reduce hospital utilisation for such patients was very

limited. Nevertheless, we did analyse these excluded patients separately.

- For some virtual ward patients, we were unable to find a suitable match within the control areas.

Table 15. Numbers of cases included in the national matching analysis

	Croydon	Devon	Wandsworth	All sites
Cases identified by sites	1,658	225	114	1,997
Unable to link to a HESID	2 (0.1%)	6 (2.7%)	0 (0%)	8(0.4%)
Cases rejected too early or too late	658 (40.0%)	14(5.5)	30(26.3 %)	702 (35.2%)
No hospital history	34 (2.1%)	17 (7.6%)	3(2.6%)	54 (2.7%)
Unable to match	17 (1.0%)	8 (3.6%)	0 (0%)	25 (1.3%)
Matched records	947 (57.1%)	180 (80%)	81 (71.1%)	1,208 (51.5%)

4.2 Constructing predictive models on national data

Our local matching relied on the combined model scores, but these required GP data which were not available for our national analyses. As an alternative, we constructed a series of models using national data that aimed to predict future emergency hospital admissions. We constructed these for a population of people who had experienced a hospital admission in the three years before a defined date.

We constructed models on a monthly basis (54 models in total) using a split-sample approach to validation. This approach allowed for changes over time in the set of variables that were predictive of future emergency hospital admissions. An example predictive model for one of the early months is described in Table 16. Variables derived from accident and emergency datasets were included for later months, when they became available in HES.

Table 16. Illustrative predictive model

Variable	Beta coeff	Variable	Beta coeff
Intercept	-3.009	Other mental health	0.283
Emergency admissions (0-30 days)	0.670	Parkinson's Disease	0.287
Emergency admissions (30-90 days)	0.494	Cerebrovascular disease	-0.198
Emergency admissions (90-180 days)	0.425	Angina or ischemic heart disease	-0.376
Emergency admissions 180-365 days)	0.295	Number episodes per spell emergency (0-365 days)	0.152
Emergency admissions (365-730 days)	0.246	Number episodes per spell emergency (366-730 days)	0.120
Emergency admissions (730-1095 days)	0.197	Number episodes per spell emergency (731-1095 days)	0.111
Elective admissions* (0-30 days)	0.405	Number episodes per spell elective (0-365 days)	0.104
Elective admissions* (30-90 days)	0.173	Number episodes per spell elective (366-730 days)	0.053
Elective admissions* (180-365 days)	-0.069	Number episodes per spell elective (731-1095 days)	0.078
Day case admissions (0-30 days)	0.146	Number of chronic conditions	0.244
Day case admissions (30-90 days)	0.090	Outpatient attendances (0-30 days)	0.061
Day case admissions (180-365 days)	0.029	Outpatient attendances (30-90 days)	0.027
ACS admissions (180-365 days)	0.068	Outpatient attendances (90-180 days)	0.014
ACS admissions (365-730 days)	0.037	Outpatient attendances (180-365 days)	0.014
ACS admissions (730-1095 days)	0.061	Outpatient attendances (730-1095 days)	0.022
Cancer, malignant	0.231	Outpatient DNAs (0-180 days)	0.156
Cancer, benign	-0.103	Age 50-64	0.065
Alcohol / drugs	0.663	Age 65-74	0.416
Hypertension	-0.270	Age 75-79	0.705
Congestive heart failure	-0.284	Age 80-85	0.939
COPD	0.207	Age 85-89	1.208
Fractures	-0.329	Age 90+	1.396

* *Excluding day cases.*

4.3 Characteristics of patients admitted to virtual wards

As would be expected, the virtual ward patients had significantly higher risk scores than the population of residents in the control areas, and had higher levels of hospital use and a higher prevalence of a range of healthcare diagnoses (Table 17).

Table 17. Comparison before matching of virtual ward patients with residents in the selected control areas

	All sites		
	Intervention (N=1,208)	**Residents of the selected control areas (N=2,081,077)**	**Standardised difference**
Predictive risk score	0.59 (0.24)	0.08 (0.09)	278%
Demographics			
Age	71.37 (16.73)	39.87 (23.32)	155%
Female (%)	55%	55%	0%
Ethnicity (% white)	23.99 (10.87)	24.59 (11.91)	5%
IMD 2010 score			
Hospital contacts (prior year)	2.52 (2.31)	0.14 (0.56)	142%
Emergency admissions	2.86 (3.28)	0.21 (0.88)	110%
Accident and Emergency visits	0.86 (1.8)	0.26 (0.95)	42%
Elective admissions (non day case)	1.01 (1.38)	0.06 (0.32)	95%
ACS admissions	10.33 (12.2)	1.95 (3.72)	93%
Outpatient attendances			
Diagnoses from inpatient record	2.67 (1.63)	0.21 (0.66)	198%
Number of chronic conditions	24.8%	1%	74%
Anaemia (%)	22.6%	1%	69%
Angina (%)	20.1%	3%	56%
Asthma (%)	26.7%	2%	77%
Atrial fibrillation and flutter (%)	15.6%	3%	46%
Cancer (%)	19.1%	1%	63%
Cerebrovascular disease (%)	22.8%	1%	73%
Congestive heart failure (%)	22.9%	1%	72%
COPD (%)	29.4%	3%	78%
Diabetes (%)	24.3%	2%	69%
History of falls (%)	44.1%	7%	94%
History of injury (%)	69.1%	7%	167%
Hypertension (%)	37.3%	3%	97%
Ischemic heart disease (%)	13.2%	1%	50%
Kidney failure (%)	29%	2%	79%
Mental health (%)	0.59 (0.24)	0.08 (0.09)	278%

4.4 Selection of controls

There were in total 1,233 records available for our national analyses, with the majority being from one site - Croydon (964).

Our matching process for the national datasets was as follows. First, we chose our pool of potential controls from ONS matched comparator areas. Then we matched individuals according to their similarity with regard to:

- Risk score
- Age
- Index of multiple deprivation
- Site
- Sex
- Emergency admissions in the prior quarter and prior year
- Elective inpatient admissions in prior quarter and prior year
- Outpatient activity in prior year
- Presence of one of a range of chronic diseases

Using this process, we matched 1,082 cases each to a single control.

An analysis of the unmatched virtual ward patients revealed that the vast majority were cases who had a very high predictive risk score (>0.85). Such patients typically have multiple illnesses, and it was much harder to find controls for these people. Rather than simply exclude these cases, where possible we chose to use a slightly less comprehensive matching algorithm for them. This algorithm required a matched control to have a very similar predictive risk score to the virtual ward patient, and sought to select a control group that overall had a similar age, sex, area-level deprivation score, prior hospital activity and recorded diagnoses of health conditions to the group of virtual ward patients. However, this algorithm did not place as much emphasis on requiring that individual case-control pairs were similar in terms of specific diagnoses such as cancer, diabetes and COPD. After this second matching stage we had matched 1,208 cases to a control.

These results are summarised for a subset of the most important variables in Table 18. For all these variables, the standardised differences are below 10 per cent, which is the level that has been suggested to describe meaningful differences between groups.

Although the selected controls were much more similar to the intervention group than the wider population of the control areas, the matches still fell short for a number of variables. In most cases, the intervention cases had slightly higher values than their controls. This indicates that the cases had marginally more severe illness, more complex co-morbidities or made greater use of hospital services in the period before the start of the intervention. Thus, for example, for outpatient appointments, the best match that we were able to obtain had a standardised difference that was 30 per cent lower in the controls than in the intervention group.

Table 18. Summary measures on national matching pooled across all study sites

	All sites (N=1208 matched pairs)		
	Intervention patients included in national matching analysis	**Matched controls**	**Standardised difference**
Predictive risk score	0.59 (0.24)	0.58 (0.23)	4%
Demographics			
Age	71.37 (16.73)	71.94 (17.66)	3%
Female (%)	55%	56.7%	4%
Ethnicity (% white)	70.5%	73.8%	7%
IMD 2010 score	23.99 (10.87)	25.38 (10.32)	13%
Hospital contacts (prior year)			
Emergency admissions	2.52 (2.31)	2.07 (2.02)	21%
Accident and Emergency visits	2.86 (3.28)	2.44 (3.29)	13%
Elective admissions (non day case)	0.86 (1.8)	0.63 (1.49)	14%
ACS admissions	1.01 (1.38)	0.82 (1.17)	15%
Outpatient attendances	10.33 (12.2)	7.11 (8.48)	31%
Diagnoses from inpatient record			
Number of chronic conditions	2.67 (1.63)	2.22 (1.61)	28%
Anaemia (%)	24.8%	17.7%	17%
Angina (%)	22.6%	19.5%	8%
Asthma (%)	20.1%	18.4%	4%
Atrial fibrillation and flutter (%)	26.7%	23.9%	6%
Cancer (%)	15.6%	13.7%	5%
Cerebrovascular disease (%)	19.1%	15.6%	9%
Congestive heart failure (%)	22.8%	17.2%	14%
COPD (%)	22.9%	14.7%	21%
Diabetes (%)	29.4%	24.9%	10%
History of falls (%)	24.3%	24.6%	1%
History of injury (%)	44.1%	45.8%	3%
Hypertension (%)	69.1%	62.1%	15%
Ischemic heart disease (%)	37.3%	32.6%	10%
Kidney failure (%)	13.2%	9.6%	11%
Mental health (%)	29%	25.6%	8%

An analysis of the time of year suggested that there was a similar profile of start dates for the cases and matched control groups. This meant that any observed differences in hospital activity in the six months following this start date would not be biased by one group's having, for example, a higher proportion of start dates in the winter months.

We only had available to us data on in-hospital mortality for all cases. This was because the out-of-hospital data had not been released for the period

following our end date of August 2010 at the time of analysis. We therefore tested for differences in the in-hospital mortality rates observed in cases and controls. If mortality rates in the cases were significantly higher than controls, then it might have indicated that confounding variables were present in virtual ward patients but not in the control group - usually because of limitations in the data collected on electronic hospital records. Table 19 summarises the numbers of people who died in hospital in both cases and controls in the six months after the start date for receiving the intervention. In the pooled data, there was very little difference between cases (5.3 per cent) and controls (6.4 per cent), and the direction of this small difference did not suggest a problem with hidden confounding variables linked with mortality. The picture was the same for those cases where out-of-hospital deaths were accessible.

However, there were some differences between sites, with rates in Croydon being much lower than elsewhere. This is most likely to be an indication of differences between sites in the characteristics of cases admitted to their virtual wards.

Table 19. Summary of mortality amongst cases and controls

Site	Group	In hospital deaths	N	% in hospital deaths	% all deaths (where data available)
Croydon	Case	42	947	4.4%	7.7%
	Control	56	947	5.9%	8.8%
Devon	Case	7	81	8.6%	14.8%
	Control	7	81	8.6%	12.3%
Wandsworth	Case	15	180	8.3%	15.0%
	Control	12	180	6.7%	11.7%
All	Case	64	1208	5.3%	9.3%
	Control	75	1208	6.2%	9.4%

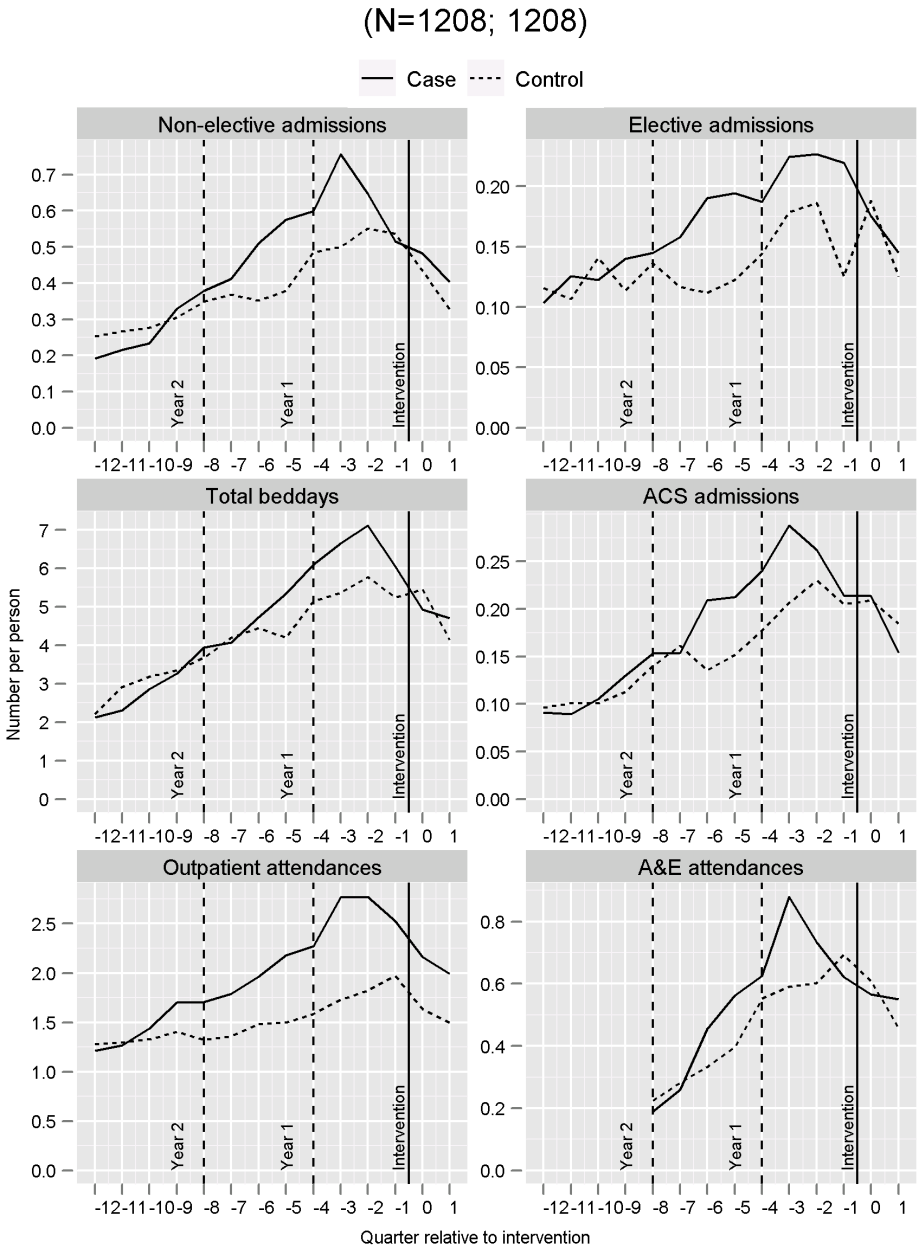
4.5 Outcome data (national matching)

Figure 11 summarises the successive quarterly observations of key output indicators for cases and controls from the three years before starting the intervention to six months afterwards. As with the local data, we focussed on the trends in the first six months in order to maximise the sample size.

The virtual ward patients showed a trend of high and increasing hospital activity – an indication that these were a group of people that had serious health problems that were worsening over time. At its highest, the rate of emergency admissions reached almost 0.8 admissions per person per quarter. As a comparison, the average population admission rate in the control areas was 0.05 admissions per person per quarter.

The pattern of ambulatory care sensitive (ACS) admissions was almost identical to that of the total unplanned admissions.

Figure 11. Output indicators for cases and controls



We weighted the matching process towards events that occurred just prior to admission to a virtual ward. At periods over two years before admission, the intervention and control groups appeared to be very closely matched. However, one important observation is that the rate of emergency admissions was highest 6-9 months before the patients began the intervention. This peak occurred in all of the outcomes of interest. It was also seen independently in Croydon and Devon but not in the third site -

Wandsworth, where patients were predominantly identified by clinical referral.

The control patients also showed this same characteristic peak in emergency activity as in the intervention group, although in most cases, the rates were lower in the controls. These lower levels of hospital activity seen in the controls reflect the challenge of matching patients with complex health needs - even though control cases still displayed emergency hospital activity levels around ten times higher than for an average population.

Of all the outcomes of interest, our matching for outpatient attendances was the least successful, with outpatient activity amongst the control groups being markedly lower than for the cases.

4.6 Difference-in-difference analysis

Though we sought to match cases and controls as closely as possible, the use of a difference in difference method helped to reduce the impact of imperfect matching. Table 20 below shows the average number of admissions and attendances per person for cases and controls in the six month period before and after starting the intervention, pooling across the three sites. Figure 12 shows the scale of the differences and associated confidence intervals for the various outcomes of interest.

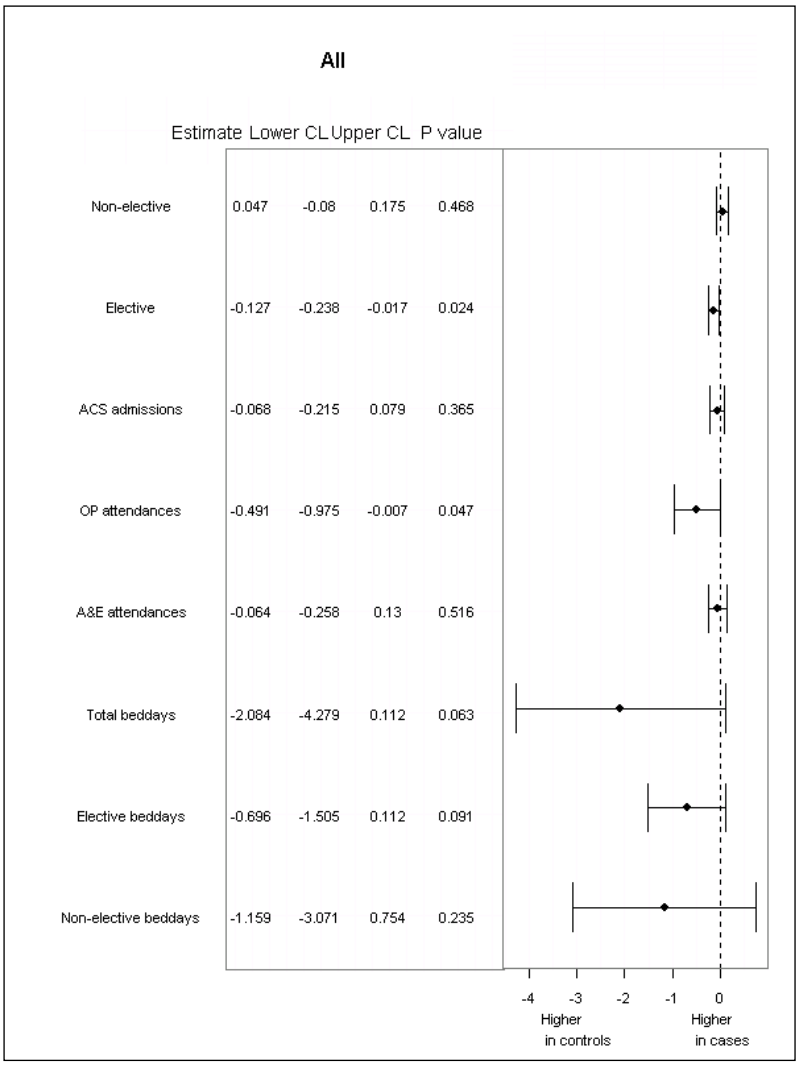
Table 20. Difference-in-difference analysis for national matching

	Cases (average number per person)		**Controls (average number per person)**			
Measure	**Pre-intervention**	**Post-intervention**	**Pre-intervention**	**Post-intervention**	**DiD Estimate**	**p value**
A&E attendances	1.4	1.1	1.3	1.1	-0.01	0.52
ACS admissions	0.5	0.4	0.4	0.4	-0.07	0.37
Elective admissions	0.4	0.3	0.3	0.3	-0.13	0.02
Elective beddays	1.9	1.2	1.1	1.1	-0.70	0.09
Non-elective admissions	1.2	0.9	1.1	0.8	0.05	0.47
Non-elective beddays	10.4	7.9	9.3	8.0	-1.16	0.24
OP attendances	5.3	4.2	3.8	3.1	-0.49	0.05
Total beddays	13.2	9.6	11.0	9.6	-2.08	0.06

The key observations from this pooled analysis were:

- the intervention group did not exhibit a greater reduction in emergency admissions than the control group
- though there were relatively large reductions in total bed-days in the intervention group, the probability of 0.063 indicates that the difference was not statistically significant at the $p<0.05$ level
- There appeared to be a greater reduction in elective admissions ($p=0.024$) and outpatient attendances ($p=0.047$) in the intervention group, both of which were significant at the $p<0.05$ level

Figure 12. Effect size of virtual wards



When the services elements were costed, the overall pattern remained much the same. Figure 13 shows the time series for cases and controls, showing the costs per person per quarter for each of the different care activities.

Figure 13. Trends in hospital activity for cases and controls

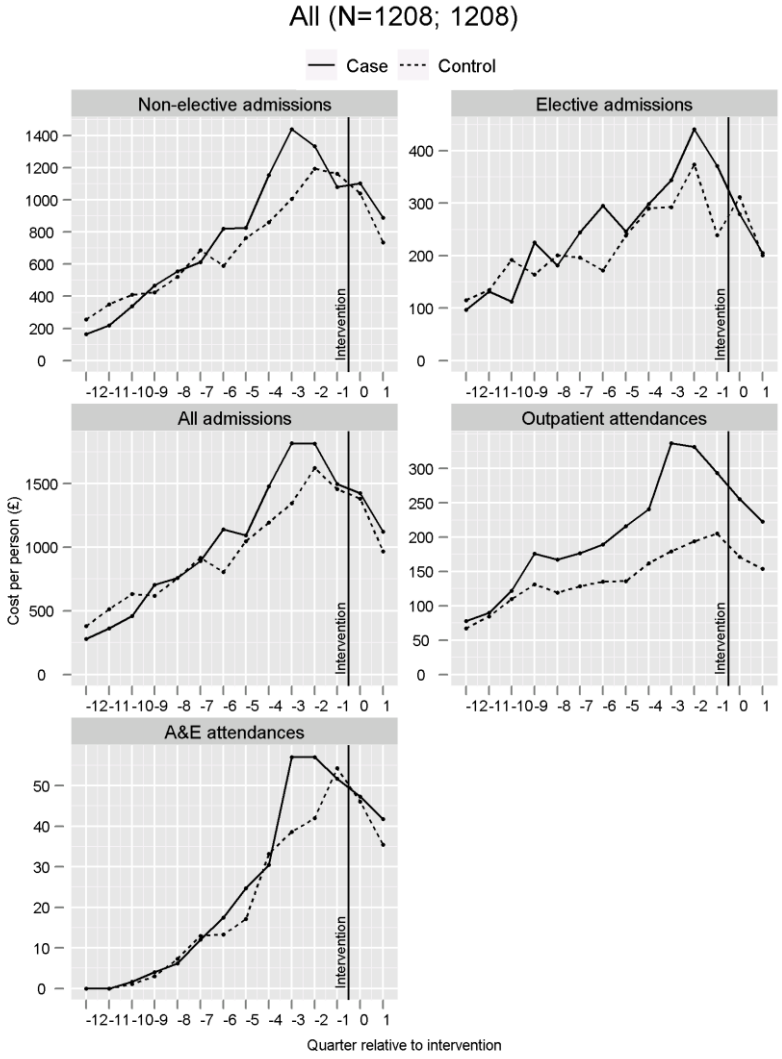
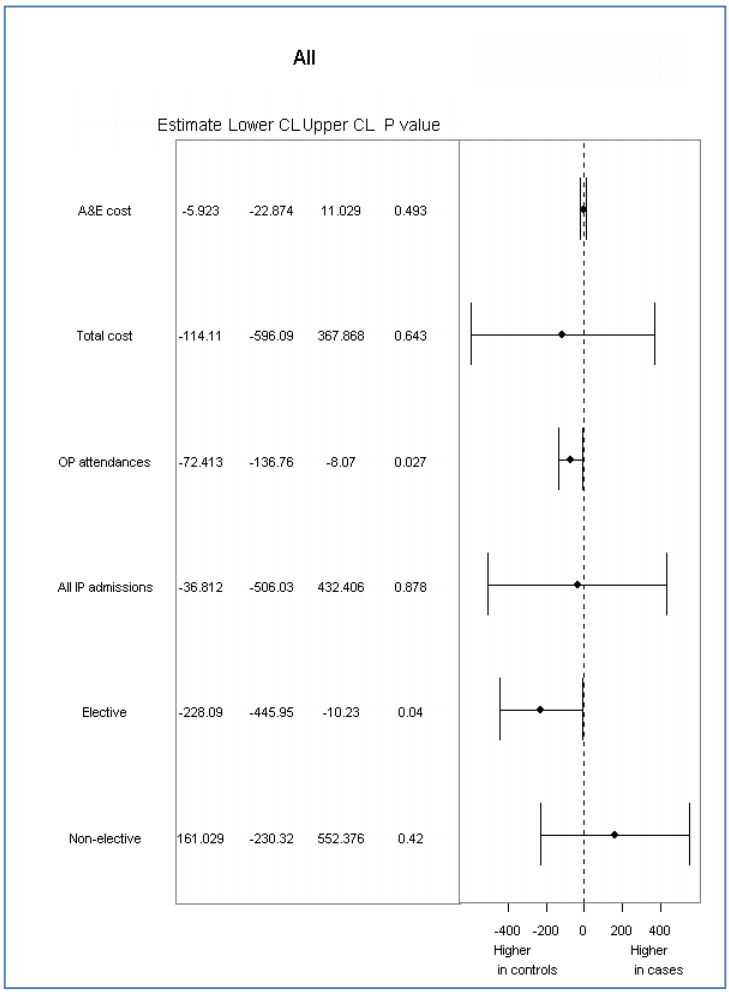


Table 21 summarises the difference-in-difference analysis based on cost per person for different outcome measures for cases and controls in the six months before and after starting the intervention. Figure 14 shows these data with associated 95 per cent confidence intervals. Though both cases and controls showed a reduction in overall costs, once again the costs associated with elective inpatient care and outpatient attendances appeared to be lower in the intervention group. There was no detectable reduction in the costs of emergency inpatient care.

Table 21. Summary results of difference-in-difference analysis of hospital cost per person using national matching

	Cases (average cost per person)		Controls (average cost per person)			
Measure	**Pre-intervention**	**Post-intervention**	**Pre-intervention**	**Post-intervention**	**DiD Estimate**	**p value**
A&E cost	£109	£89	£96	£82	-£4.88	0.49
All IP admissions	£3,311	£2,546	£3,080	£2,351	-£36.80	0.88
Elective admissions	£813	£484	£613	£513	-£228.08	0.04
Non-elective admissions	£2,414	£1,992	£2,359	£1,776	£161.03	0.42
OP attendances	£625	£479	£399	£325	-£72.41	0.03
Total cost	£4,045	£3,113	£3,575	£2,757	-£114.11	0.64

Figure 14. Summary of the difference-in-difference analysis



This study was not powered to assess the impact of virtual wards in the three study sites separately and is somewhat dominated by the findings in Croydon (which was not delivering multidisciplinary care except in an initial pilot). Nevertheless, we have included a site-specific analysis in Table 22 to illustrate the contribution of each of the sites to the overall result.

There were no significant changes in emergency hospital admissions for any of the sites, with two showing relative increases, and the third showing a fall. Consistent with the pooled analyses, significant relative reductions in elective admissions and outpatient attendances were seen in Croydon. No significant changes were seen for any measure in either Wandsworth or Devon.

Table 22. Difference in difference results by site based on national matching.

		Cases (average number per person)		Controls (average number per person)			
Site	**Measure**	**Pre-inter.**	**Post-inter.**	**Pre-inter.**	**Post-inter.**	**DiD**	**p value**
Croydon	A&E attendances	1.3	1.1	1.3	1.1	0.03	0.83
	ACS admissions	0.4	0.3	0.4	0.4	-0.07	0.46
	Elective admissions	0.5	0.3	0.3	0.3	-0.17	0.01
	Elective beddays	2.0	1.0	1.3	1.0	-0.74	0.09
	Non-elective admissions	1.1	0.9	1.1	0.8	0.06	0.40
	Non-elective beddays	9.3	7.5	9.2	8.4	-1.04	0.35
	OP attendances	5.5	4.0	3.9	3.2	-0.78	<0.01
	Total beddays	11.5	8.5	10.9	9.7	-1.79	0.14
Devon	A&E attendances	1.1	0.8	0.7	0.4	-0.05	0.83
	ACS admissions	0.6	0.3	0.2	0.2	-0.22	0.13
	Elective admissions	0.5	0.4	0.6	0.3	0.14	0.57
	Elective beddays	1.9	1.3	0.8	1.0	-0.78	0.44
	Non-elective admissions	1.3	0.8	0.8	0.5	-0.21	0.36
	Non-elective beddays	10.3	6.0	7.7	5.2	-1.91	0.43
	OP attendances	4.3	3.7	2.9	2.2	0.15	0.85
	Total beddays	22.0	14.5	11.5	8.9	-4.91	0.32
Wandsworth	A&E attendances	1.9	1.2	1.8	1.3	-0.23	0.35
	ACS admissions	0.6	0.5	0.5	0.4	0.00	1.00
	Elective admissions	0.3	0.3	0.2	0.2	-0.03	0.73
	Elective beddays	1.7	2.4	0.2	1.4	-0.42	0.78
	Non-elective admissions	1.4	1.0	1.2	0.7	0.08	0.61
	Non-elective beddays	15.8	10.8	10.7	7.2	-1.44	0.60
	OP attendances	4.8	5.0	3.7	3.1	0.73	0.34
	Total beddays	17.9	13.2	11.5	9.1	-2.34	0.47

4.7 Other analyses

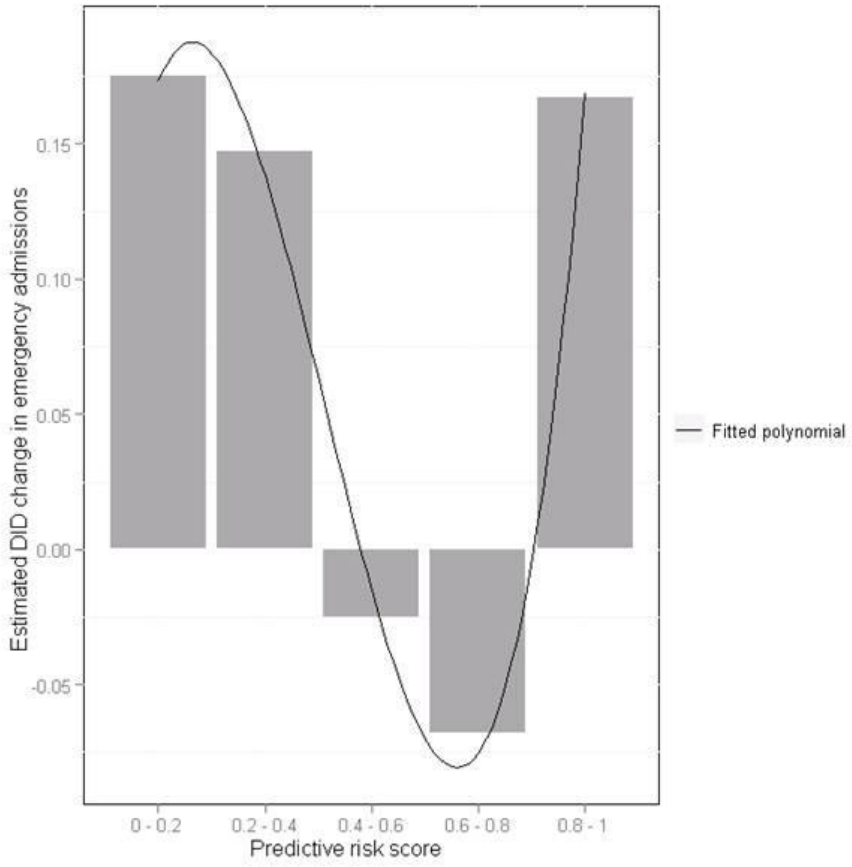
In order to understand better the patterns observed in these pooled results, we conducted some further analyses to examine the effects of various subgroups of patients on the overall difference-in-difference analysis.

Looking at the reduction in elective inpatient admissions, we tested the effects of an International Classification of Diseases (ICD) chapter-level interaction term within the difference models. Only one ICD chapter showed a p value below 0.05, namely for diseases of the eye (p=0.041). Otherwise, the reduction in activity was spread across a range of diagnostic chapters rather than being largely due to one case type.

A similar analysis we conducted, looking at outpatient specialty, suggested that the effects were not linked with only one speciality but rather they included a range of different case types. However, in this case there was a borderline reduction in general medicine attendances (a reduction of 0.14 attendances per person per six months, p=0.06), and a significant reduction in clinical haematology (reduction of 0.24 attendances per person over the same time period, p=0.03). These reductions both contributed considerably towards the overall reduction of 0.49 attendances per person over the six months.

We also compared rates of emergency hospital admission within subgroups defined by the predictive risk score. As this study was powered on the basis of pooled analysis across all patients, these comparisons must be interpreted with caution. The pattern in the difference-in-difference estimates formed a "U" shape (Figure 15), with virtual ward patients with a predictive risk score of between 0.4 and 0.8 seeing relatively greater reductions in emergency admissions than controls, and virtual ward patients with scores of less than 0.4 or more than 0.8 seeing relative increases. Although the reductions are not statistically significant with the numbers of patients available for these analyses, the Figure as a whole is suggestive of a pattern that may warrant further research with larger sample sizes. Note that the predictive risk scores illustrated here are based on the model that we calibrated to national HES data, rather than the Combined Model used by sites to recruit patients.

Figure 15. Pattern in difference-in-difference estimates



5 Findings from economic analysis

This chapter describes how we determined the costs of the virtual ward intervention. We begin by presenting the costs of the virtual wards in the three study sites as determined from administrative data. We then describe how we attempted to corroborate these costs based in turn on the interviews that we conducted, and the surveys and work diaries that we administered.

5.1 Administrative data

Table 23 shows a summary of the elements included in costing the virtual wards as derived from administrative data for each site, together with the estimated cost per virtual ward admission and the estimated cost per patient day of being cared for on a virtual ward.

Table 23. Costing elements from administrative data

Site	Elements included in costing	Estimated cost per virtual ward admission	Estimated cost per patient day on virtual ward
Croydon	Staff costs, travel costs, land, computers and fixed capital costs, management costs, administration costs (including costs of the predictive model)	£1,684	£3.26
Devon	Staff costs, travel costs, land, computers and fixed capital costs, management costs, administration costs (including costs of the predictive model)	£1,833	£3.17
Wandsworth	Staff costs, land, computers and fixed capital costs, management costs	£4,868	£16.73

5.2 Costs of the Croydon virtual wards

We calculated the cost of running a virtual ward in Croydon based on the labour costs of the nursing and clerical staff and the actual expenditure on ancillary items such as travel, stationery and rent. Table 24 provides the breakdown of these costs, which we took directly from Croydon's budgets.

Unlike the other two sites, Croydon did not have weekly staff meetings or "ward rounds" except during a brief initial pilot period. Instead, all costs of co-ordination of care were borne by the staff employed as part of the "virtual ward", namely the community matrons and ward clerks.

Table 24. Costs of the Croydon virtual ward

	2008	2009	2010	Average
Direct cost of VW				
Nursing	£440,440	£495,961	£527,861	£488,087
Clerical and Admin	£82,358	£103,171	£126,352	£103,960
Travel and communication	£9,726	£10,507	£8,545	£9,593
Consumables and other	£4,950	£24,314	£9,417	£12,894
TOTAL	£537,474	£633,953	£672,175	£614,534
Staff costs as a % of total cost	97%	95%	97%	96%
Nursing costs as a % of total cost	82%	78%	79%	80%
Aggregate Patients Days p.a.	197,748	201,652	171,531	£190,310
Average patients per day	542	552	470	521
Cost per day	£1,472.53	£1,736.86	£1,841.58	£1,683.66
Cost per patient day	£ 2.72	£ 3.14	£ 3.92	£3.26

To calculate the average cost of a patient per day on a Croydon virtual ward, we used the admission and discharge dates of patients, and summed the total number of patient-days of care delivered per year. The Croydon virtual wards cared for an average of 489 patients per day at an average variable cost of £2.66 per patient per day, and the average variable cost per patient's stay was £1,156.12. Data from 2007 showed atypical costs associated with the first year of operation of the project in Croydon. As these may have been misleading, we focused on the average of the years

2008-2010 to portray a more reliable picture of the routine operation of the intervention in this site.

5.3 Costs of the Devon virtual ward

In this evaluation, we only considered a single virtual ward in Devon, namely South Molton & Chulmleigh. Given the small number of staff involved in this intervention, we rounded salaries up or down by £3,000 in an attempt to preserve the confidentiality of sensitive information.

The Devon virtual ward employed a full-time community matron and a part-time ward clerk. However, the major cost in Devon was the weekly ward rounds attended by a multidisciplinary team. Table 25 shows the composition of the multidisciplinary team that attended these ward rounds. We understand that each member of the team attended for 2 hours per week. Using approximate salary bands, we calculated the cost of full-time equivalent salaries of this group at £30,000. This yielded an annual cost of £48,750.

Table 25. Costs of the Devon virtual ward

	2009	**2010**	**TOTAL**
Full Time Community Nurse	£34,410	£34,410	£68,820
Ward Clerk	£7,387	£7,387	£14,774
Weekly Staff Meetings	£48,750.00	£48,750.00	£97,500
Travel (total - since Oct 08)	£1,207.50	£1,207.50	£2,415.00
Total	£91,755	£91,755	£183,509
Total Patient days	11789	15329	27118
	£7.78	£5.99	£6.77
		Cost per patient admitted	£1,833.87
		Cost per patient per day	£3.17

Table 26. Attendance at the Devon multidisciplinary ward rounds

Community matron
Community psychiatric nurse
Social care representative (social worker)
Social care representative (community care worker)
Social care representative (care manager / occupational therapist)
Cluster manager (health and social care)
Community rehabilitation representative (administrator)
Community rehabilitation representative (occupational therapist)
Community rehabilitation representative (physiotherapist)
Community rehabilitation representative (rehabilitation nurse)
District nursing representatives (x 2)
Voluntary sector representative
Community hospital doctor
Ward clerk

5.4 Costs of the Wandsworth virtual wards

The travel costs and administration costs for Wandsworth were not made available to us. Compared with Croydon and Devon, the virtual wards in Wandsworth were a considerably more expensive intervention because they used general practitioners to provide virtual ward care. The large differences seen in the costs per person-day over time are a reflection of the reduced activity in the start-up year. We would suggest therefore that the values for 2010 are the better estimate of the running costs for this model of virtual wards.

Table 27. Costs of the Wandsworth virtual wards

Wandsworth	**2009**	**2010**	**TOTAL**
Patient days	15889	42273	59287
Total Costs	£707,250	£707,250	£1,414,500
Cost per patient day	£44.51	£16.73	£23.86

Cost per admitted patient	£7,062.12

5.5 Additional costs

Table 21 in the previous chapter summarises the difference-in-difference analysis based on the cost per person for different costs measures for cases and controls in the six months before and after starting the intervention. This reflects additional cost-savings that could theoretically be used to offset the direct costs of the virtual wards.

Although both cases and controls showed a reduction in overall costs, the costs associated with elective inpatient care and outpatient attendances appeared to be lower in the intervention group but there was no detectable reduction in the costs of emergency inpatient care. Overall, the cost of the additional resources used by virtual ward patients was £114.11 less than the control group, although this difference was not statistically significant at the $p<0.05$ level. Given that the direct cost of virtual ward care ranged from £1,684 to £4,868 per patient, the offsetting reduction in other service utilisation by virtual ward patients represent less than 6 per cent of costs.

5.6 Interview, survey and diary data

From the questionnaires, we were able to ascertain that the core virtual ward staff exclusively cared for virtual ward patients. In particular, virtual ward and non-virtual ward patients did not share these same staff. This means that we did not have to apportion staff between virtual ward patients and non-virtual ward patients.

The diaries were intended as a contingency arrangement in case some of the virtual ward clinical staff were treating virtual ward and non-virtual ward patients in a way that was not separated in administrative or budgetary data.

Whilst we did implement the questionnaires and diaries as a confirmatory exercise, the response rate was very low despite sending the one reminder permitted by our ethics approval. We were unable to ascertain whether there were any major biases in the sample of staff who completed the diaries – although from informal discussion with staff we had the impression that nursing staff on the virtual wards were keen to fill out diaries in order to establish that they were working "harder" than they were being given credit for. This means there is a possibility that the resource diaries might have somewhat over-stated the number of patient contacts per member of staff per day.

5.7 Interviews

We interviewed a total of 14 members of staff, including at least one manager, finance officer and clinician from each of the three study sites (see Table 28). The interview schedules are included in Appendix 4.

Table 28. Numbers of interviews

	Manager	Finance officer	Clinician	Total
Croydon	1	1	2	4
Devon	2	1	2	5
Wandsworth	1	1	3	5
Total	4	3	7	14

We used the information obtained during the course of the interviews to provide context and confirmation of the costs derived from administrative data. We also used the information to corroborate the detailed site descriptions recorded in Appendix 2.

5.8 Surveys

We issued 40 surveys and diaries and our response rate was 25 per cent. Our ethics approval only permitted us to send one reminder to potential participants, so we were unable to take further steps to increase the number of responses we received.

Table 29. Surveys and diaries distributed and received

	Croydon	Devon	Wandsworth
Distribution			
Diaries	12	10	18
Questionnaires (management / financial staff)	4	6	5
Questionnaires (frontline staff)	12	10	18
Responses received			
Community matron	4	1	1
Ward clerk / ward administrator	1	1	0
GP	0	1	0
Allied Health Professional	0	1	0
Total	5	4	1

*the diaries and questionnaires were delivered on 23 June 2011 and were completed in July 2011

Prior to undertaking the project, we were concerned that staff might be working across virtual ward and non-virtual ward patients. However, given that virtual ward staff worked exclusively with virtual ward patients, this was not a major issue. Indeed, all ten of the respondents reported knowing that they were working with virtual ward patients. Six respondents reported having "frequent" face-to-face or telephone contact with virtual ward patients, and the remaining four respondents said that they had "occasional" such contact.

Interaction with other professionals was important to ascertain the degree to which the virtual ward costs correctly reflected the resources being used to care for the patients.

Table 30. Frequency with which virtual ward staff reported interacting with other professional groups

	Number of responses				
	Never	Rarely	Occasionally	Often	Constantly
Hospital doctors	1	1	5	3	0
GPs	0	0	2	2	4
Nurses	0	0	1	3	6
Pharmacists	2	2	3	2	0
Case managers	0	2	3	2	2
Therapists	0	0	3	6	1
Social workers	0	1	2	5	1
Care workers	0	1	4	5	0

The high degree of interaction with other staff was unsurprising given the case management nature of their role.

In Devon, interactions occurred formally in a weekly meeting and we included the working time of these additional professionals in the cost of the Devon virtual ward - although interviews with staff suggested that these interactions also occurred extensively during the day.

To the extent that the professionals were using their time to discuss virtual ward patients rather than non-virtual ward patients, this question was intended to identify the extent to which the costs of the virtual ward spilt-over to other professionals, and therefore under-stated the cost of the intervention.

The mean number of hours that respondents were contracted to work was 35.9 hours (standard deviation 6.3). However, some staff undertook duties during their working week that were unrelated to the virtual ward. This was reflected in the fact that respondents reported working a mean of 28.1 hours (standard deviation 13.8) per week on virtual ward activities.

5.9 Diaries

Six out of the ten completed diaries were from community matrons.

We asked those staff completing a diary to record every patient contact they made. A contact was defined as any occasion on which the staff member saw or talked to a virtual ward patient, or when they discussed a patient with one or more of their colleagues. The purpose was to ascertain whether there were any obvious inefficiencies in the use of resources, for examples in the time spent travelling versus the time spent caring for patients. If there were any obvious inefficiencies then we would have overstated the costs of the virtual ward compared to an optimised version of the intervention.

The total number of contacts recorded by respondents was 506. Table 31 shows that the average duration of a patient contact was 23.4 minutes (standard deviation 24.3). In addition, where a time was recorded for travelling to or from the contact, the mean travel time was 15.8 minutes. This implies that travel time was almost 30 per cent of the total time spent on a patient in these cases.

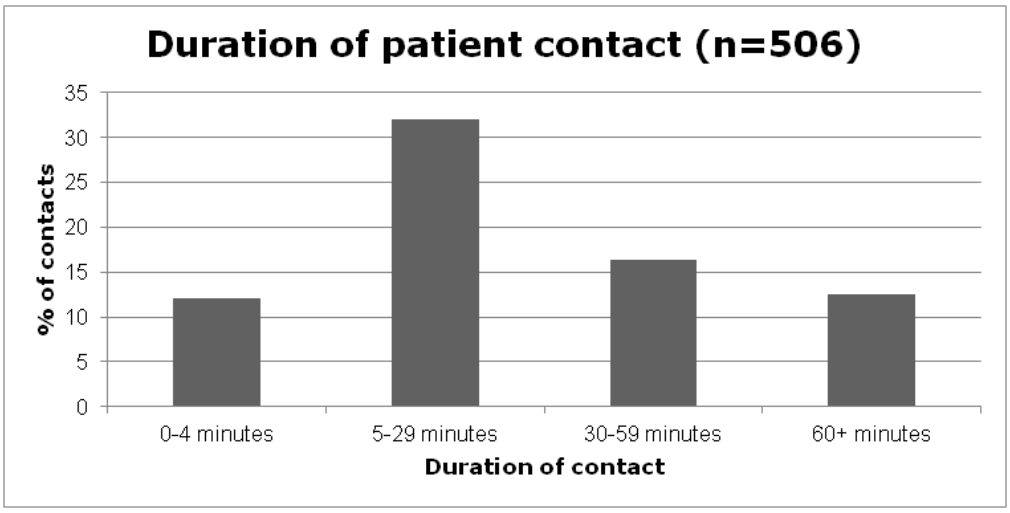
Diary respondents were also asked to estimate the average time burden on informal carers for each contact, such as accompanying a virtual ward patient to an appointment. Where such a time burden was estimated, the average duration was 21.1 minutes

Table 31. Time burden for patient contacts

	Mean (minutes)	Standard Deviation
Staff time spent on the contact	23.4	24.3
Staff time spent travelling to and from the contact	15.8	8.4
Extra burden on informal carers	21.1	24.4

Figure 16 shows the distribution of the duration of patient contacts. The most frequent duration of a contact was 5-29 minutes, accounting for approximately one third of all contacts. However, over 10 per cent of contacts lasted between 0-4 minutes and another 10 per cent or so lasted an hour or more.

Figure 16. Duration of patient contacts



We observed a correlation between patients' predicted risk score and the frequency of a recorded contact (r = 0.78) (see Figure 17). There was also a much weaker correlation between risk score and the duration of the contact (r = 0.03) (see Figure 18).

Figure 17. Frequency of contacts

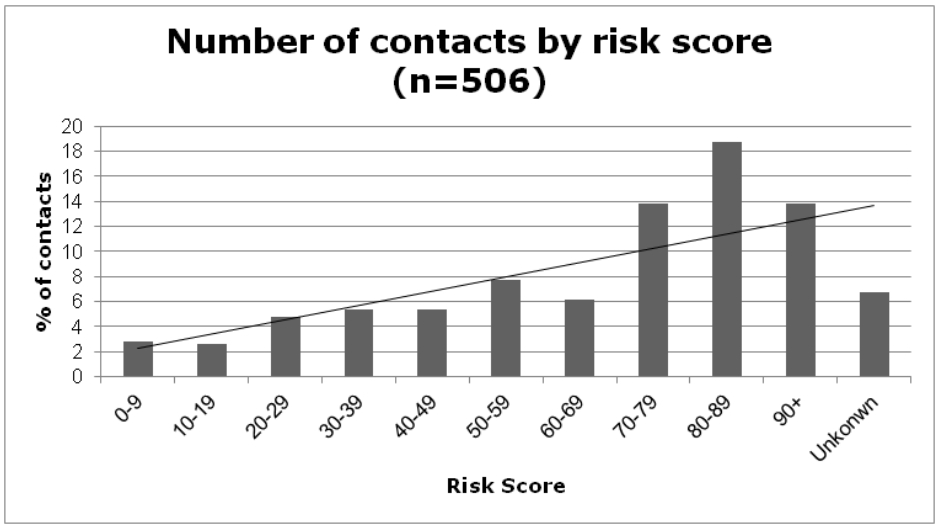
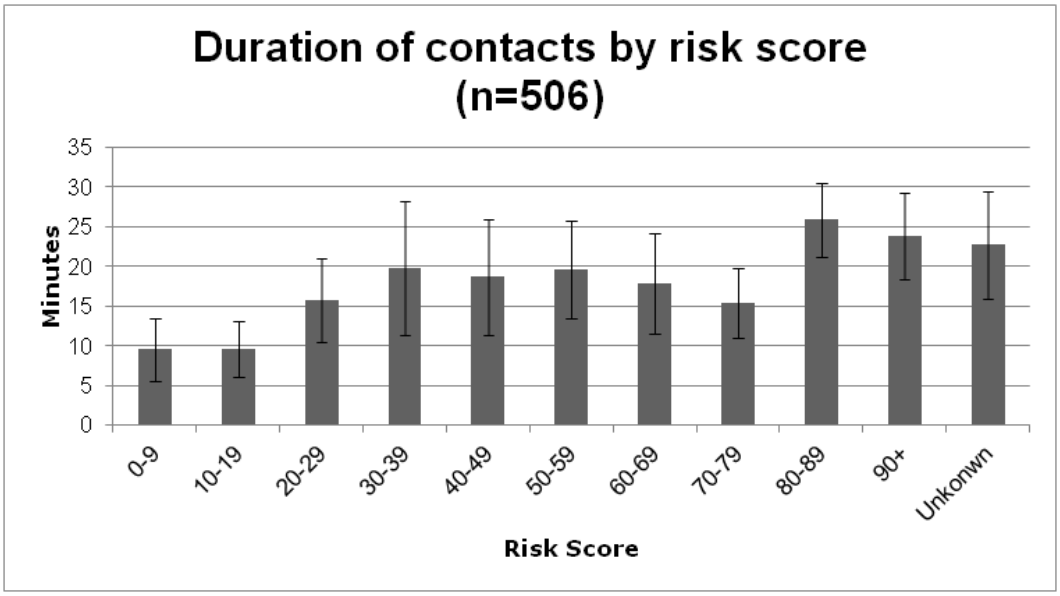
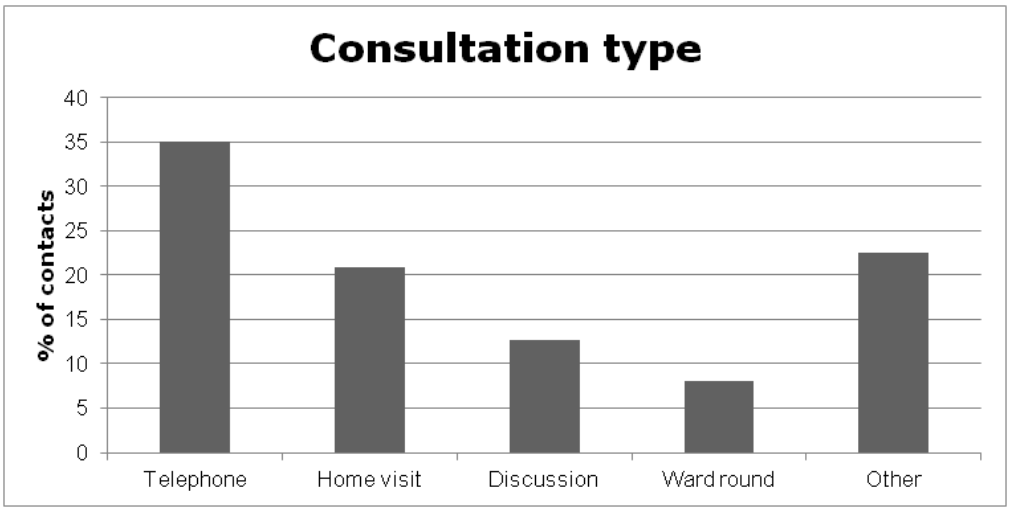


Figure 18. Duration of patient contacts by risk score



The most frequent consultation type, accounting for over a third of all contacts, was a telephone call. The next most common consultation types were home visits, informal discussion with colleagues, and discussion on ward rounds (see Figure 19)

Figure 19. Consultation type



6 Synthesis of quantitative and economic analysis

This chapter considers the information on the costs of establishing and running virtual wards, and balances this against the outcomes of reduction in hospitalisation. Note that this comparison does not include other benefits that might have accrued from the intervention, such as unrecorded improvements in patient outcomes, patient experience, quality of life or other hidden resource elements.

We begin by summarising the direct costs of virtual wards and then compare virtual ward costs to average service costs. Next, we explore two hypothetical scenarios of virtual ward configuration (high cost and low cost) and seek to determine the intervention effect size that would be necessary in the two scenarios in order for them to break-even financially.

6.1 Summary of direct costs of virtual wards

The previous chapter presented the results from costing the direct resource elements of the virtual wards our three study sites. There were marked differences between the sites in terms of the resource inputs and so it is difficult to generalise about the typical resource inputs for virtual wards. Some of the factors that differed between sites included:

- Level of staffing
- Types of staff used, especially GP versus nursing roles
- Breadth of responsibilities for virtual ward staff
- Length of stay on the virtual ward

With this in mind we have suggested some typical direct costs of running a virtual ward, structured as two alternative configurations of the intervention (see Table 32). Note that these costs are an average of averages, and that some individual patients will experience shorter periods on the virtual ward with more intensive care and therefore higher per diem costs.

Table 32. Typical direct costs of different configurations of virtual wards

	Configuration	Cost of delivery
Low cost scenario	Nurse-led, high volume service with a mean length of stay of180 days	£3 per patient day £510 per patient over six months
High cost scenario	GP-led service with lower volumes of patients and a mean length of stay of 180 days	£17 per patient day £2,890 per patient over six months

No immediate inferences should be drawn from the relative patient costs of the two configurations. The difference in patient costs may be offset by the total costs generated from the number of patients recruited to a virtual ward and the intensity of the intervention. The selection of risk threshold used to offer virtual wards will also have implications for the services costs incurred by these patients. The important question from a commissioning point of view is whether the more expensive intervention saves more in terms of reduction in hospital utilisation.

6.2 Comparing typical virtual ward costs to average service costs

Against this, we may offset the cost reduction in other services. The average service use costs per person in the six months before and after intervention by type of service (derived from local analyses) are presented in Table 33.

Table 33. Individual service use costs on the six months before and after starting the intervention (n=989)

	% with a cost (pre or post)	Total Cost Pre(£000s)	Avg Cost pp pre(£)	% Total (pre)	Avg Cost pp Post (£)	% total Cost Posts
GP	92%	135	501	8.0%	538	9.0%
Community	62%	396	401	6.4%	837	14.0%
A&E	60%	748	136	2.2%	100	1.7%
Elective	26%	2,407	757	12.0%	504	8.4%
Emergency	55%	496	2,433	38.8%	1,867	31.1%
Out Patients	78%	555	561	8.9%	437	7.3%
Social Care	32%	1,473	1,489	23.7%	1,714	28.6%
Total		6,210	6,279	100.0%	5,996	100.0%

As Table 33 shows, approximately 38 per cent of service use costs in the six months before starting the intervention were associated with emergency inpatient care. The next most expensive cost element was local authority funded social care at 23.7 per cent per cent of costs. The community care cost associated with virtual ward patients increased from 6.4 per cent to 14 per cent of the total. However, as noted earlier, this increase will be largely due to double-counting of the virtual ward activity and so should be discounted. Similarly, the pattern of primary care use seen in patients in Wandsworth shows the impacts of a GP led service with a very sharp increase in GP activity. This apparent increase in primary care will be associated with running the virtual ward and should also be discounted.

The observed differences in secondary care utilisation using national matched controls (Chapter 4) indicated cost differences of the order of a reduction in £918 per case for virtual ward cases against a reduction of £818 for controls – so a net intervention effect of only £114 which was not statically significant at the $p<0.05$ level. The observed differences in primary care and social care utilisation suggested by local matching (Chapter 3) would be expected to produce an intervention cost effect of the same order.

The final effect fell some way short of the savings required to match the costs of the virtual ward.

6.3 What intervention effect would a low-cost scenario need to generate to break-even?

An important question from a practical commissioning point of view is what sort of savings in other recorded activity would be needed in order to ensure that the direct cost of the virtual ward was recovered.

Consider the low cost scenario. Under this scenario, community nursing contacts will be "double counted" since it is included in the direct cost of the intervention. Therefore we would expect the average service cost per virtual ward patient in the 6 months following the intervention to be £5,122 (i.e. £5,996 less community nursing of £837). Suppose further, that GP visits did not change – that is, assume the "pre-intervention" rate of GP visits at £501.

In order to break even and recover the £510 cost of the low-cost intervention within a six month window, the virtual ward would have to generate a further 10 per cent in reduced service use.

Some scenarios that could achieve this goal are:

- Reduce emergency admissions by a further 30 per cent
- Reduce emergency admissions and social care expenditure by a further 15 per cent each

- Reduce GP utilisation, elective admissions and outpatient attendances by 25 per cent , and reduce emergency admissions and social care by 5 per cent

6.4 What intervention effect would a high-cost scenario need to generate to break-even?

With the high cost scenario for virtual wards, GP utilisation is double-counted. This means that the service costs should exclude the GP services cost of £538 and freeze community nursing costs at the "pre" value of £401, leaving a service cost of £5,022. Scenarios for breaking even with the high cost intervention (delivered at £2,890 per person) include:

- Elimination of all secondary care utilisation
- Reduce emergency admissions, elective admissions and social care expenditure by 70 per cent

6.5 Would making the intervention more targeted help the intervention break-even?

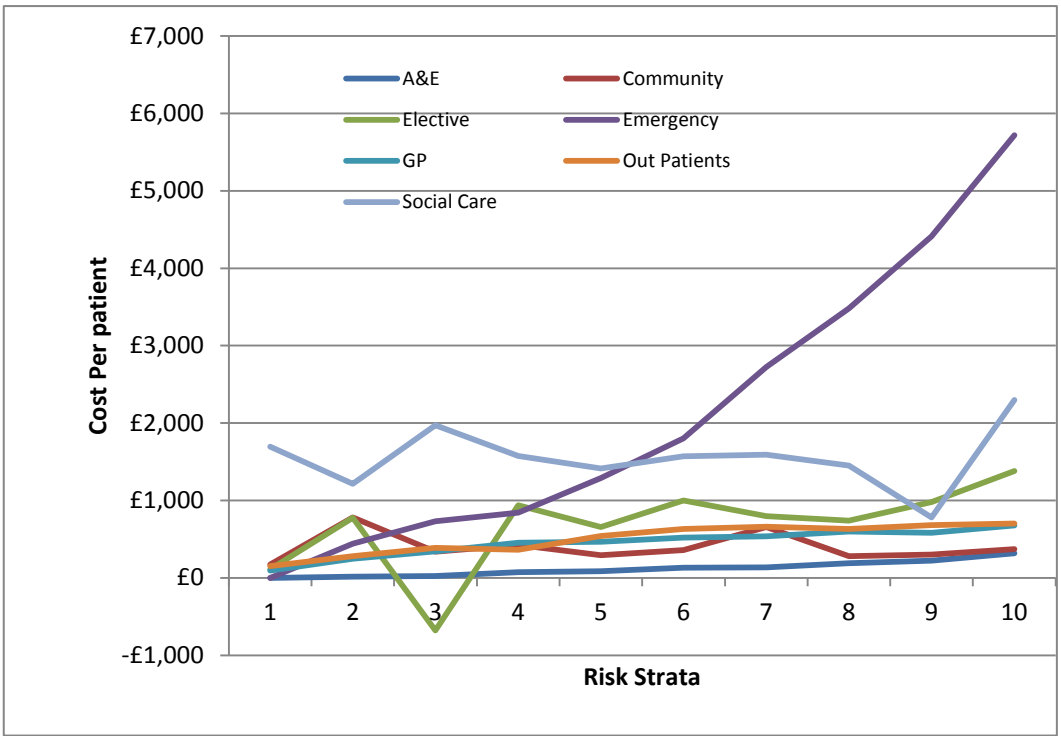
The ability to achieve reductions in hospital activity will partly depend on the underlying levels of activity before the intervention commences. Thus, stratifying virtual ward cases by risk profile before admission to a virtual ward gives some indication of the level of differences in baseline costs. Table 34 breaks down the service costs in the six months prior to admission to a virtual ward. Values shown are expressed as costs per patient. The different profiles of costs are shown graphically in Figure 20 and demonstrate the importance of the emergency inpatient costs for the high risk patients.

For the 66 patients in the highest risk category (scores 0.9-1), the cost of emergency inpatient admissions averaged £5,719 over a six month period. In fact, the costs of emergency inpatient care increases linearly up from zero as the risk level increases. In contrast, the other service cost elements stay reasonably stable.

Table 34. Service cost elements in the six months before admission to a virtual ward (cost per person, £)

Risk band	0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5-0.6	0.6-0.7	0.7-0.8	0.8-0.9	0.9-1	Grand Total
N=	22	54	71	104	121	135	147	130	139	66	989
A&E	0	14	23	73	86	132	135	191	223	317	136
Community	174	782	338	425	291	358	655	279	299	372	401
Elective	110	775	-680	939	658	998	796	738	979	1379	757
Emergency	0	442	731	843	1289	1802	2726	3480	4412	5719	2433
GP	94	246	341	453	468	520	536	600	582	676	501
Out Patients	152	281	386	363	542	632	661	631	683	702	561
Social Care	1693	1215	1970	1573	1415	1570	1593	1453	782	2300	1489
Grand Total	2224	3755	3109	4669	4750	6013	7102	7372	7961	11464	6279

Figure 20. Costs of service use in the six months before starting the intervention according to risk band



However, the ability to achieve an efficient virtual ward by focussing solely on a certain risk categories may face some practical problems:

- The actual costs of care for high risk patients will tend to be higher as evidence from the resource diaries indicated
- The interventions may require a minimum level of activity to occupy the staff - so there may be a lower limit to the effective size of a ward.

7 Discussion and recommendations

This chapter begins with a statement of our principal findings as they relate to the nature of the virtual ward intervention, their impact on care use and costs, as well as the limitations of our study. We then discuss a number of implications of our findings for the organisation and practice of health care, followed by some recommendations for future research. Finally, we set out our dissemination plans for this project.

7.1 Principal findings

The primary objective of this study was to determine whether a community-based intervention called virtual wards had an effect on unplanned hospital admission rates, and at what cost. The original description of this model of care consisted of two linked elements, namely (i) using a predictive model to identify people who are at high risk of future emergency hospitalization, and (ii) offering these individuals a period of intensive, multidisciplinary preventive care at home using the systems, staffing and daily routines of a hospital ward.

7.2 Nature of the "virtual wards"

Overall we found we found that all three sites had adapted the virtual ward intervention locally, such that it differed to a greater or lesser degree from the "original" model described by Lewis in 2006.[25] Figure 21 outlines some of the key differences between the study sites in terms of staff inputs, use of risk scores, patterns of prior risk and timing of the predictive risk models.

This heterogeneity is common in the implementation of complex interventions. Such adaptations are a reflection of the way that changes in service delivery inevitably reflect the local environment for care, and it is often the case that the implementation of a new intervention leads to a succession of wider changes that lead to important differences in the models of care that are actually delivered. However, differences between the sites makes the interpretation of our evaluation results that much more challenging.

Moreover, the nature of the intervention changed within each site over time. For example, in one site the use of the predictive risk model was not applied in the same way during the study period. The other two sites did not initially use a predictive model to identify virtual ward patients. Most importantly, however, in Croydon there were changes made to the extent to which the virtual ward provided multidisciplinary care. Following a brief pilot period, a model of care evolved that was much closer to standard case management from a community matron supported by an administrative assistant rather than full multidisciplinary care management.

Figure 21. Key distinguishing features of virtual wards in the three study sites

Croydon began with an initial pilot that closely followed the original virtual wards model described by Lewis.[25] However, from 2007 onwards, patients were not in fact offered multidisciplinary case management. Instead they received standard case management delivered by a community matron supported by an administrative assistant. After the end of the pilot, specialist community staff could only become involved in the care of virtual ward patients by means of normal referral processes.

In Croydon, the Combined Predictive Model was used to identify potential virtual ward patients. With the exception of a 12-month period when the predictive model was not refreshed, the intervention was offered solely according to the most recent output of this model. Croydon offered standard case management at scale over a prolonged period of time. As such, this represented an organisational commitment and investment in preventive care for high risk patients. Compared to the other two sites, however, the involvement of local GPs seemed less visible in Croydon.

The length of stay was longer in Croydon than in the other sites. One potential reason for this Croydon had a key performance indicator (KPI) for the virtual wards always to be case managing at least 500 patients at a time, which may have acted as a disincentive to discharge patients.

In Wandsworth, a radically different model of care was implemented for high-risk patients, including the creation of the virtual ward GP (VWGP) role. As a type of "generalist-intensivist", this new role can be viewed almost as the primary care analogy of intensive care doctors in a hospital. There are several potential theoretical advantages to the VWGP role, including the ability to review patients rapidly, to manage uncertainty, and to take a leading role in managing all primary and community care services for these high-risk patients. However, these putative advantages need to be balanced against the additional cost of employing a GP as part of the virtual ward team.

The virtual ward staff in Wandsworth had direct access to GP clinical systems. There was also a clear GP champion supporting the project, and social care colleagues were closely involved. However, the virtual wards in Wandsworth accepted clinical referrals, with only a minority of patients being identified by the PARR model as being at risk of unplanned hospitalisation. This pragmatic approach may have helped earn and maintain the ongoing support of GP colleagues, but it may at the same time have potentially lessened the impact of the project if referred patients were not at as high risk of future unplanned admission as patients with a high predictive risk score.

In Devon, after an initial pilot, all patients were identified using a predictive risk model. The project in Devon was firmly rooted in primary care, with a clear GP champion supporting the implementation and development of virtual wards. The virtual ward had direct access to community beds and virtual ward staff in Devon had direct access to GP clinical systems. The scope of the virtual wards project was limited in Devon initially. In this study, we only considered one virtual ward in Devon, the virtual ward in South Molton & Chulmleigh. However, more recently the intervention has been rolled out at scale, and there are currently over 20 virtual wards in operation across the county.

It is unfortunate that despite our efforts, we did not uncover until the detailed interview stage that one of the case studies had morphed into standard case management. We had held a series of meetings and visits in Croydon before submitting the preliminary funding application to the NIHR-SDO and again when preparing our full submission. During these meetings, we were assured by the

then Director of Nursing and others that the virtual wards were maintaining fidelity to the virtual ward model as originally described. However, this initial information was not subsequently corroborated in the detailed interviews with staff that were conducted as part of the economic evaluation and by the SDO management fellow. That said, it could be argued our study reflects an 'intention to treat' and therefore our findings may offer a helpful caution to those tempted to champion 'virtual wards' without considering the detail of such a programme, its practical implementation, and its sustained need for a champion of multidisciplinary case management.

Although our research was not designed to address the issue of why the pilot virtual wards in Croydon morphed into standard case management models, we suspect that the following factors may have played a role:

a) Unlike in Devon and Wandsworth, there were no doctors involved in the Croydon project beyond the pilot phase to champion the multidisciplinary model. Indeed, the feedback from the interview subjects at Croydon was that the local GPs perceived the Croydon virtual wards to be a nurse-led initiative (in contrast to the other sites, which were GP led). As a result, GPs in Croydon tended not to engage meaningfully with the virtual wards. This suggests that whilst the initial set-up of a virtual wards project was multi-disciplinary, unless the vision of multi-disciplinary case management is embedded in the local GP culture, the commitment to this model may fall away over time.
b) In Croydon, the staff were resistant to holding frequent ward rounds because when the first virtual wards opened initially, there were relatively few patients to discuss on ward rounds so the ward rounds were of short duration. As a result, the staff did not appreciably adapt their working week to fit other commitments around ward rounds and so the culture of holding ward rounds was not fully embedded;
c) Staff in Croydon did not face any formal repercussions for failing to attend ward rounds, and a behavioural shift occurred away from standard case management towards multidisciplinary care.
d) Newly appointed senior managers did not seem to embrace the multidisciplinary model as well the previous managers and so the support for the multidisciplinary teams was reduced. The community matrons were dedicated to delivering and working with other members of the multidisciplinary team but as time progressed, this became more challenging for them in the absence of senior managerial support for multidisciplinary care.
e) The transition of community services into the local acute NHS trust created further challenges for the community matrons.
f) A new role had been created in health visiting in Croydon to support older people, and the GPs in the area were able to refer directly to this service. The community matrons were very clear that referrals to virtual wards could only be via the risk prediction tool and this created a tension with the GPs who were happier with the seemingly more responsive service from the older people's health visiting teams.

7.3 Impact on care use

We derived some important insights from our analysis of the prior use of health and social care services for cohorts of patients on the virtual wards. Firstly, we note the important observation that virtual ward patients had a high and increasing level of hospital use in the months prior to the start of the intervention. This pattern was seen in all three sites. At their peak before the start of the intervention, patients were having emergency hospital admissions at the rate of 0.8 per quarter.

The severity of these patients' illness is also reflected by the proportion of patients who died in the six months after starting the virtual ward intervention. This ranged from 9 per cent to 15 per cent of virtual ward patients depending on the case-mix at the sites.

Finally, we were surprised to see that emergency hospital activity in virtual ward patients was highest some months before admission to a virtual ward. This effect was strongest in Croydon which, being the largest sample, tended to dominate all of our findings. However we also observed the same phenomenon in Devon to a certain extent. Ideally, we might have hoped to see unplanned hospital activity and predictive risk scores to be at their peak just as patients started the virtual ward intervention. However, the apparent lag we observed suggests that there may have been some delay between the calculation of risk scores and the start of the intervention. This could be due to problems in the way that the combined model calculates a risk score. Alternatively, it could be a consequence of the lag in accessing administrative data, as well as the inevitable lags in running the model in practice and then recruiting patients to a virtual ward.

As a result of this lag, it appeared that on average, hospital activity was falling for virtual ward patients before they started the intervention. However, a subgroup analysis by predicted risk stratum suggests that this fall did not occur for the highest risk group of patients.

Our main analysis was based on two different approaches to creating a matched control group, against which we performed difference-in-difference analyses to determine the differential use of health and social care services of cases and controls.

Our analyses using local controls benefitted from the availability of very rich datasets, which included records of primary care, community health care and social care provision in addition to patterns of hospital use. However, the more limited number of individuals in these local datasets meant that we encountered problems in identifying local controls—particularly for high-risk patients, where saturation of the intervention was particularly high. For this reason, we purposefully excluded high risk cases from our analyses using local data. However, we were still left with a concern that the control groups were not completely independent of the cases.

Given our difficulties in identifying valid controls from the local data, our main conclusions are therefore based on our analyses using national data. Here, we were able to select control groups that matched the intervention groups well in terms of age, sex, prior hospital utilisation, markers of specific health needs, total number of chronic health conditions, an area-level deprivation score and a prognostic score.

As an additional check on the validity of our national matches, we compared the changes we observed in cases and controls using a difference-in-difference approach. Overall, we feel that the results of the national matching represent a more reliable picture of the impact of the virtual wards.

Based on a comparison of activity in national data for pairs of cases and controls, our key findings were:

- We found no evidence of a reduction in emergency hospital admissions for patients admitted to the virtual wards during the six months after starting the intervention
- We found no evidence of a reduction in ambulatory care sensitive hospital admissions during this period
- We did observe a reduction in elective admissions and, particularly, in outpatient attendances in the six months after starting the intervention, which was significant at the $p<0.05$ level
- We found no evidence of a reduction in hospital costs

It is worth reiterating that these findings are dominated by the higher number of patients from Croydon, where the intervention consisted of standard case management rather than multidisciplinary care.

Our study was not powered to detect any differences in health and social care activity at the individual study sites. We did observe some differences that were approaching statistical significance at the $p<0.05$ level although of course some degree of caution is required to take account of the problem of multiple comparisons.

Overall, the national matching was generally satisfactory, however it was by no means perfect and so we used a difference-in-difference method to help make more reliable comparisons. We were encouraged by the finding that both the intervention and control groups had similar patterns of mortality, and also that the month of the start of the intervention was not related to the outcome.

The observation that virtual ward patients did not demonstrate significant reductions in emergency admissions within the six months after starting the intervention time period is consistent with other studies of case management, including, for example, the evaluation of the UK Evercare pilots,[7] Medicare Coordinated Care Demonstration,[8] Medicare Health Support Experiment[9] and the Partnerships for Older People Pilots.[10] Overall, a 2010 review by Purdy found that there is insufficient evidence to support many of the hospital

avoidance interventions currently being implemented, and concluded that case management is not effective in reducing generic hospital admissions - although there was some evidence that preventive hospital-at-home might do so.[82]

The reduction in outpatient and elective activity is a more encouraging finding. The patterns of outpatient use may be a direct result of better care coordination if patients are less likely to attend hospital for care deemed by the community matron to be unnecessary or superfluous. This would be consistent with the observation that the outpatient specialty showing the greatest fall was haematology, for example if anticoagulation clinic appointments were cancelled because the community matron was able to monitor INR results in the community.

The observed reduction in elective activity has implications for the comparison of costs. It did not seem to be associated with any particular diagnostic group. One explanation may be that it was in part a consequence of reduced outpatient activity with fewer internal referrals. Alternatively, it may be that the virtual ward intervention led to a different, perhaps more considered, approach to discretionary elective care. These hypotheses would require further analysis to be explored in more detail.

Our findings are partly determined by the definition of 'usual care' for the matched control group, and are best interpreted as being relative to other hospital-avoidance measures being implemented elsewhere for similarly high-risk patients.

We were only able to analyse data from a certain proportion of the people who received the virtual ward interventions. Some virtual ward patients could not be linked to administrative data whilst other patients were not matched with a control, usually because they had no inpatient admission in the prior two years. However, such patients have limited scope for reduction in hospital admission rates in the short term since their expected rates are so low in any case. Overall, we do not believe that our exclusions biased the results away from finding a reduction in unplanned hospital admissions.

Although possible imbalances between cases and controls are a threat to the internal validity of our study, our ability to observe these interventions as they developed organically, rather than in a trial setting, may increase the generalisability of our findings. Furthermore, since we were able to analyse data for the vast majority of virtual ward patients with a hospital history, the probability of examining a biased sample is low.

We conclude that we found no evidence for a reduction in unplanned hospital admissions for the intervention (which was dominated by standard case management in Croydon), after controlling for a set of variables that is recognised as being predictive of such admissions. However we did observe reductions in outpatient and elective activity.

7.4 Costs

Our analysis of the costs elements of the virtual wards in the three study sites revealed considerable differences in the estimated costs of running the different interventions. These ranged from £3 to £17 per virtual ward patient per day. These differences reflect the differences in process underlying the operation of the virtual wards in the different sites, particularly the staff composition at each site. Most notably in Wandsworth, where the GP role incurred a relatively higher cost, the intervention appears to have delivered a more comprehensive service encompassing the entirety of primary care and community health services.

The costs of the virtual ward could in theory have been offset by changes in the costs of other health and social care services used by virtual ward patients. The analysis undertaken here gives a much more comprehensive view of the range of health and social care services used by NHS patients.

The changes we observed in health care and social care service use was insufficient to offset the costs of the intervention. In order to have broken even, the virtual wards would have needed to achieve a greater reduction in emergency admission rates in the first six months after starting the intervention. For the virtual wards with lower running costs, this could have been around a 10 per cent fall. In contrast, for the more costly models, the fall in emergency activity would have needed to be much greater – up to 100 per cent.

7.5 Limitations

There were a number of limitations to our study. These related to our methods for the local and national matching, the heterogeneous nature interventions under study, the limited range of outcomes we were able to measure - including the timescales over which we observed any differences, and the way in which we conducted our economic evaluation.

7.6 Local level matching

The major limitation in terms of local matching was the problem we encountered in finding suitably matched controls. This was partly because of the much smaller pool for selecting controls: there were fewer patients to choose from. As a result, a relatively large number of cases were not matched. Further, substantial differences existed between the groups after matching, for example in terms of the number of chronic conditions and post-intervention mortality. Perhaps more important was the potential danger that patients in the control pool had, for some unknown reason, been considered "unsuitable" for virtual ward care - in other words, that there was some crossover between cases and controls. The direction of bias that comes from this problem cannot be easily established. The lack of suitable controls simply means that our quasi-experimental design may not

have been valid, and therefore that differences in average outcomes for the intervention and control groups are likely to have been influenced by factors that we were unable to observe. For example, control patients might have had a higher probability of being rough sleepers or of being in receipt of palliative care. In both cases there is sometimes a perception that case management is somehow too "difficult", "inappropriate" or "unsuitable". Such excluded patients are likely to be systematically different in their hospital utilisation characteristics from their peers and so their potential inclusion as controls may have biased our findings.

Evidence for this limitation is seen in the contrast in cost profiles of matched control patients for the six months after the intervention. While the matched group had a much flatter profile after the intervention, the control group seems to have peaked at the time of the start of the intervention and then fell off sharply afterwards. This suggests that the control group were those people who had a sudden and unexpected acute exacerbation of a well-managed long term condition. Hence, whilst these patients might not have been deemed to be "suitable" for virtual ward admission, they appeared statistically similar by the propensity scoring algorithm and therefore were chosen as suitable controls. In this scenario, the control group would have had lower costs following the intervention when compared to the matched group, and we would expect to see a classic regression to the mean occurring.

7.7 National level matching

In our analysis of national data, the controls were drawn from matched areas of England. We were able to match over 95% of eligible participants. Differences between groups were smaller than in the local matching, although not zero. There was no significant difference in post-intervention mortality, although this comparison was restricted to hospital deaths. While we made efforts to ensure that these matched regions did not have a virtual ward intervention in place during the study period, our analysis shows that emergency admission rates were declining in these matched areas as well as in the intervention sites, having adjusted for the predicted risk scores and other characteristics of the individual patients concerned. This overall decline in admission rates suggests that there might have been interventions or initiatives underway in the matched areas at this time. It is therefore important to be cautious about interpreting the negative findings in our analysis suggesting that virtual wards did not reduce rates of unplanned admission since our findings reflect the relative reduction in hospital admission rates above what was occurring in the comparator areas.

The national analyses are also reliant on the quality and depth of diagnostic coding on routinely collected HES datasets. The danger is that differences in coding practice between areas may lead to poor matches. As a result the standardised differences between cases and controls will be larger where data quality issues impinge.

Finally, all retrospective matching studies must be wary of the possibility of hidden confounders, that is variables associated with the intervention group that were not recorded in the dataset used for matching.

7.8 Definition of a virtual ward

While the name virtual ward was used in all three sites, the interventions differed considerably in several important dimensions including the degree of GP involvement, type of clinical input, and multi-disciplinary case activity. More importantly, all sites differed markedly from what had been originally defined as the virtual ward. Therefore drawing inferences from these results as to the impact of the original concept of the virtual ward on unplanned admissions would not appear to be valid.

7.9 Limited range of outcome and output measures

This analysis deliberately sought to be pragmatic in its approach to exploiting existing datasets as much as possible. This limitation meant that our analyses were unable to examine the direct health consequences for patients or seek their perceptions of the experience of care or quality of life.

It is important to acknowledge that there will be other important dimensions of good quality care that we did not assess. These may well provide a suitable basis for justifying expenditure on new models of community care such as virtual wards. There may, for example, have been important benefits to patients in terms of continuity of care, patient safety or quality of life.

7.10 Timescales to observe change

In order to maximise our sample size, we chose to focus on a larger group of patients for a shorter time period, namely six months. Whilst we believe that changes in utilisation should have emerged within this time period, it is conceivable that at least some of the impacts of virtual wards might have appeared after this time.

7.11 Economic analysis

This work look at the direct costs of resources specifically linked to running the Virtual Wards, and service use costs for patients on the wards but it did not constitute a full analysis of economic effectiveness. Moreover the range of costs we were able to study was limited – for example we did not asses the costs to patients of care on the Virtual Ward versus usual care.

7.12 Implications for healthcare

Throughout the course of this analysis we have been aware of the growing interest in the idea of virtual wards and in the more general area of new approaches to managing people with complex chronic disease.

Our results did not find a reduction in emergency care within the cohort of patients who received the intervention in the three study sites. We did observe some reductions in outpatient and elective care activity that might be explained as a result of more coordinated care. But the evidence we looked at suggest that it was difficult to justify an economic case for virtual wards purely on the basis of a reduction in hospital activity.

Yet against this finding, there are some important factors that might temper the starkness of such a conclusion. We suggest that health service commissioners and providers should consider a number of factors:

- There were different 'forms' of virtual ward in this study and we suspect an even wider number of variants in other settings. Just as integrated care can mean many things[19] so it seems the label 'virtual ward' is now being applied to different forms of care. In these circumstances, we have to be cautious about the generalisability of the findings from this study. In particular, given that our analysis was dominated by the high volume model used on Croydon which in the main did not constitute multidisciplinary care, our findings are not representative of the 'original' model of virtual wards described by Lewis in 2006.[25]
- Our analyses have shown how patients being cared for on virtual wards included some people with serious complex illnesses that have important health service implications. These patient groups represent an important challenge for health services not just in terms of the costs of care but also in the quality of care that is offered. This included an effort to avoid institutionalization if services could help people live independently in their own home.
- Virtual wards are part of a generic approach to long term care which may be justified in other terms, for example as ways to improve the quality of communication between community health staff, the continuity of care, patient experience or safety.
- Though the evidence was not conclusive, the differential levels of service use in high risk patients suggested that these would provide more fertile ground for interventions aimed at reducing hospital use. Simple arithmetic shows that for patients at low predicted risk of unplanned hospital admission, reductions from this low baseline are unlikely to yield considerable savings.

It was not an intention of the study to identify specific recommendations for practice. In the revised text we have added the following table of suggestions, adapted from Lewis et al. (2012).[46]

Figure 22. Recommendations for practice regarding virtual wards

Domain	Recommendations For Practice (adapted from Lewis et al., 2012)
Patient selection	To ensure that virtual ward patients are truly at high risk of unplanned hospital admission, a predictive model should be used to identify the majority, if not all, virtual ward patients.
	The choice of predictive model should be based on a number of factors including the positive predictive value of the model for very high risk patients.[1]
	The use of an 'impactibility model' may be helpful in identifying high risk patients expected that are amenable to preventive care.[2]
Configuration	Virtual wards should be organized around groups of GP practices or equivalent
	VW catchment areas should be drawn to reflect the distribution of high-risk patients living in a local area (i.e. small catchment areas where there is a high proportion of high-risk patients and vice versa). This is to ensure that people at equal risk have equal access to preventive care, regardless of where they live.
Staff	The VW staff mix should reflect the needs of local high-risk patients. For example, in an area where there is a very high prevalence of mental illness amongst patients at high risk or hospitalization, the virtual ward staff should include one or more mental health professionals.
	The clinical team should include a ward clerk to act as a central point of contact for coordinating the VW

[1] Lewis G, Curry N, Bardsley M. Choosing a predictive risk model: a guide for commissioners in England. London: Nuffield Trust, 2011

[2] Lewis GH. "Impactibility models": identifying the subgroup of high-risk patients most amenable to hospital-avoidance programs. Milbank Q. 2010 Jun;88(2):240-55.

	Clear arrangements should be in place for providing care out of hours
VW processes	New VW patients should be screened for high-prevalence conditions (e.g. depression, cognitive impairment, alcohol misuse)
	A single electronic health record should be used, which enables VW staff to read and write in patient notes. The electronic health record should be accessible remotely.
	Alert systems should be place for informing VW staff if patients have had any contact with urgent care providers, such as attending local emergency departments or calling the out-of-hours GP service.
	Ward rounds should take place regularly, and arrangements should be put in place so that VW staff can attend the ward round remotely.
	There should be a clear policy in place for determining when VW patients should be discharged (e.g. fixed length of stay, clinical decision, or guided by reduction in predictive risk score).
	VW staff should be offered additional training in hospital-avoidance techniques such as motivational interviewing.
	Techniques such as 'Lean' should be considered for optimizing the efficiency of VW processes
Evaluation and monitoring	'Key Performance Indicators' should be used to monitor factors such as staff attendance at ward rounds and the turnover of VW patients etc.
	Any local evaluations should take account of regression to the mean? Simple pre/post evaluations may be misleading. Better alternatives are randomized controlled trials, prognostic score matching and regression discontinuity analysis.
	Attention should be paid to local hospitals, which may be expected to respond to any reduction in hospital admissions by VW patients by admitting lower-risk patients or by increasing the length of stay for hospital inpatients (known as "Roemer's Law").

Ultimately, for those in the health service who may be interested in developing models of care similar to virtual wards, we would suggest the following as important lessons from this study:

a. Be realistic about the scale of change that might be achievable in the short term, especially when seeking to have an impact on patterns of service use such as hospital admission rates.

There is a danger that in people's eagerness to introduce new models of care, they may be overly optimistic about the anticipated future savings. Better to to develop markers of progress that can be monitored and which change in the short term as part of the pursuit of a longer term goal.

b. Be realistic about the timescales for change to happen and to become embedded as the norm. The causal chain linking adaptations in service delivery to changed clinical behaviours - and ultimately patient health – can be surprisingly long.
c. Recognize that the ways in which we deliver health services are dynamic and can change over time. In some cases, this may mean that innovations in services may not be sustained without focused and prolonged effort and leadership.
d. Finally we would stress the importance of continuous monitoring and feedback in understanding where progress is being made the impact on different elements of the service.

7.13 Recommendations for research

A new study could be conducted on a prospective basis, and indeed the analysis presented here would be useful for establishing the required sample sizes. However, since the interventions were some way from showing a reduction in unplanned hospital use, there may be limited appetite in conducting such a trial. That said, we did observe reductions in elective admissions and outpatient use, and two of the sites did not adhere to the original model of VWs (most Wandsworth patients were not chosen according to predicted risk score, and in Croydon most patients did not receive multidisciplinary case management).

In Devon this analysis was able to use only a small number of patients – recruited within the time frame of this study. We know that since then the work in Devon has expanded and almost 4000 patients have now been admitted to the Virtual Ward. We suggest that this would be a suitable area to revisit with larger sample sizes.

We conducted this study in a challenging context, where the evaluation began a number of years after the first intervention started admitting patients. Although this is not an ideal situation for research, the need to analyse historic data arises not infrequently because perceptions of evaluation requirements can change over time. We believe that this study has provided some lessons for retrospective evaluation of complex interventions in the community where a change in hospital utilisation is a key outcome measure. In particular, the use of person-level data and matched control groups meant it was possible for us to take some account of the expected reduction in hospital admissions that occurs when high-risk cases are selected for an intervention, even where a predictive risk model is used. In the absence of a control group, a simple pre-post comparison of unplanned admissions would have suggested that there were reductions in hospitalization rates associated the virtual wards in all three sites.

Administrative data on hospital utilization has considerable practical advantages in that it is relatively inexpensive to collect; it is timely; and can be linked across time. However, the accuracy of the data must be borne in mind.[83,84]

Ideally, further research could also address some areas not covered in this study including a more comprehensive assessment of the quality of care and patient outcomes and experience.

Since approximately 2005, there has been a growing recognition in the United States that some patients at high predicted risk of unplanned hospital admission may not be amenable to preventive care. Disease management companies and predictive modelling vendors in the United States have since been developing "impactibility models," which aim to identify the subset of at-risk patients for whom preventive care is expected to be successful.

Broadly speaking, impactibility models may refine the output of predictive models by (1) giving priority to patients with diseases that are particularly amenable to preventive care, such as the ambulatory care sensitive conditions; (2) excluding patients who are least likely to respond to preventive care on the basis of personal characteristics such as alcohol misuse, mental illness or language barriers; (3) prioritising patients with suboptimal care - so-called "gap analysis"; or (4) identifying the form of preventive care best matched to each patient's characteristics.

Impactibility models could improve the efficiency of hospital-avoidance programs such as virtual wards, but those models which exclude patients on the basis of personal characteristics are likely to have important implications for equity and access.

Finally, the SDO might consider the use of prospective 'theory-based' evaluations in tandem with retrospective outcome studies in future, in order to better take account of the practical lessons for the implementation of complex interventions such as virtual wards.

7.14 Dissemination

The Nuffield Trust communications department has worked with us to develop a communications plan for this project, which includes the following elements:

7.15 Peer-reviewed publications

In addition to the peer-reviewed articles already accepted for publication,[46] we shall be submitting at least one more paper to a peer-reviewed journal and at least one abstract to an academic conference.

7.16 Other publications

In addition, with the permission of the NIHR-SDO programme, we hope to publish a version of this report on the Nuffield Trust website, together with a Nuffield Trust research summary, which we will launch at a Nuffield Trust seminar. We will also draft one or more articles for publication in the Health Service Journal or equivalent publication, and one or more blog posts for the Nuffield Trust website.

7.17 Peer-reviewed publications

The chief investigator presented the initial findings of the study at the SDO Network's Chief Executives Forum in October 2011.

We have also arranged local seminars at each of the three evaluation sites and we have arranged to hold seminars with NHS Midlands and East, as well as seminars for the SHA long term conditions leads and the national QIPP team.

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Before the study commenced, reviewers appointed by the NIHR SDO programme suggested a number of refinements to the research plan, but the research and the analyses were conducted by the authors and this report was prepared by the authors. External assessors appointed by the NIHR SDO reviewed an earlier draft and suggested changes, but the final decision on content was exclusively retained by the authors.

The views and opinions expressed here are those of the authors and do not necessarily reflect those of the SDO programme, NIHR, NHS or the Department of Health.

8.2 Contributions of authors

Martin Bardsley (Head of Research, Health Services Research) oversaw the work of the wider research team, provided supervision to the Nuffield Trust team and advice on analysis and prepared the results for publication

John Billings (Associate Professor, Health Policy and Public Service) advised on the application of predictive risk models in the modelling, analysed the matching results and prepared the results for publication

Ian Blunt (Senior Research Analyst, Health Services Research) led the work on costing care activity and prepared the results for publication

Xavier Chitnis (Information Manager, Health Services Research) undertook the national matching analysis and prepared the results for publication

Theo Georghiou (Senior Research Analyst, Health Services Research) led the work on data collection and preparation, creating the baseline datasets for local analysis and prepared the results for publication

Geraint Lewis (Chief Data Officer, Health Services Research) led the project as chief investigator, was the key liaison point for the study sites and the investigators, and prepared the results for publication

Adam Roberts (Research Analyst, Health Services Research) undertook the analysis of social care and primary care costs and prepared the results for publication

Adam Steventon (Senior Research Analyst, Health Services Research) led the work on local matching and analysis and prepared the results for publication

Lorraine Wright (Head of Nursing and Care Quality, Health Services Management) worked on the analysis of the operations of the Virtual Wards, liaised with the study sites and wrote the SDO Management Fellowship report in Appendix 1

Rhema Vaithianathan (Visiting Professor and Senior Research Fellow, Economics) conducted the economic analysis to estimate virtual ward costs, contributed to the synthesis of information between the two major components of the study, and prepared the results for publication

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Appendix 1 SDO Management Fellow's Report

This project was awarded supplementary resources by the SDO programme to second a practising health services manager – Lorraine Wright – to work with the research team. Prior to her appointment as the management fellow for this project, Lorraine was an Assistant Director for Programme Planning at NHS East Midlands, where she had responsibility for the implementation of the policy for the long term conditions programme.

In addition, the SDO funded the management fellow to undertake a study tour of three virtual ward projects in North America.

Box A1: Outline of Appendix A

A1 Aims and objectives of the management fellowship

The objectives of this fellowship were threefold:

1. to improve the quality and relevance of the funded research project through greater managerial involvement
2. to develop capacity in the managerial community for accessing, appraising and using research evidence
3. to encourage greater engagement, linkage and exchange between the Nuffield Trust and potential local research users within the NHS.

The specific aims of the fellowship were to:

- understand how virtual wards are functioning in each of the three evaluation sites by establishing relationships with commissioners, managers and clinicians.
- identify a research question related to virtual wards that was of particular pertinence to NHS managers.

- conduct a comprehensive literature review on this related topic
- develop a complementary qualitative research project on this topic.
- carry out knowledge mobilization activities relating both to the funded research project and the complementary study.
- Support the engagement, linkage and exchange of information between virtual ward sites in the NHS and between the Nuffield Trust and those sites.

The aims of the study tour of virtual ward sites in North America were to:

- spend a period of immersion at the virtual ward projects in New York, Toronto and Winnipeg.
- examine how each of these three virtual ward sites was configured
- publicise the pertinent findings from the study tour and share the lessons learnt with the research team and the NHS through workshops and blogs posted on the Nuffield Trust website.

A2 Research Engagement

The management fellowship was divided into three phases: fellowship initiation, complementary research and knowledge mobilization. Details of the study tour of North America are documented in the Section A4 of this appendix.

A2.1 Fellowship initiation

This initial phase of the fellowship involved spending time familiarising myself with the research project. This included an induction meeting with each member of the research team, with the local study leads from each site, and with our service/user representatives – however, I experienced difficulties engaging with patient and carer representatives because of the nature of the conditions that this group of patients experienced.

It was coupled with a preliminary review of the literature and a period of background reading about predictive modelling and case management in general, and virtual wards in particular.

The rest of this initial phase was spent designing and honing a research question, including research objectives and methodology. This was achieved through a series of conversations with managers at the three sites and other sites around the UK who were in the process of establishing virtual wards, as well as with qualitative researchers at the Nuffield Trust and in a number of universities. Finally, I completed the ethics and

Research & Development requirements for this complementary research, and set up my field work for phase two.

A2.1.1 Familiarisation

During my induction period I spent time with all members of the research team. In addition, I had induction sessions with other key members of the Nuffield Trust staff including the policy team, communications team and the Chief Economist to understand their roles in the organisation.

I arranged introductory meetings at all three of the study sites, where I met the frontline staff working on virtual wards (community matrons, ward clerks etc.) as well as commissioners and managers. All of the people I met seemed to be genuinely interested in the SDO Management Fellow role. I believe that my clinical background was beneficial at this stage as it enabled me to discuss and empathise with some of the challenges these NHS staff faced in delivering care to people with complex health and social care needs.

During my preliminary conversations at the sites, it soon became apparent that there was an unanswered research question of interest to clinicians, managers and commissioners alike – namely when should patients be discharged from virtual wards and indeed from case management more generally. On first meeting the community matrons in the evaluation sites and hearing about the work that they were doing, they told me that they felt that some patients did not seem to require intensive case management long term, and that therefore some patients might be suitable for "discharge" from a virtual ward after a period of time. It seemed to me that this research question was complementary to the funded study and to the NHS QIPP agenda in that the efficiency of a virtual ward may be influenced by its turnover of patients. However, the current Department of Health Policy on case management explicitly states that, "Nurses stay with the patient for life, involving themselves at all stages and in all care settings".

After discussion with our three site representatives, with the project advisory group and with other colleagues at the Nuffield Trust, we agreed that my complementary research would examine the issue of length of stay on a virtual ward. Specifically, I would investigate whether and when patients should be discharged from case management.

A2.1.2 Literature review

I conducted extensive background reading of the grey literature on this topic, followed by a comprehensive literature review conducted in conjunction with Rachel Posaner, who is the Library and Information

Services Manager, at the Health Services Management Centre library at the University of Birmingham. We searched five databases for the following search terms: case load, case management, case management administration, client discharge, community health care, community healthcare, community health nursing, community health nursing (organization & administration), community matron, community matron discharge, community matrons, community nurses, community nursing, district nurses, patient discharge, time factors, time management, virtual ward, work load.

This literature review has been submitted for peer-review to the International Journal of Nursing Studies.

A2.1.3 Design of research question

I discussed my research in a series of conversations with managers at the three study sites and at other sites around the UK who were in the process of establishing virtual wards. The commissioners of virtual wards in some of these areas had decided that a maximum 'length of stay' should be applied. Their rationale for this was to increase efficiency by ensuring a continuous throughput of patients. Elsewhere, the length of stay on a virtual ward seemed to be more flexible - often guided by clinical opinion and/or by changes in predicted risk score.

Some of the commissioners with whom I spoke expressed a concern that if every patient admitted to a virtual ward stayed there indefinitely then those virtual wards would have reduced ability to accept new patients. Some of these new patients would potentially be at a higher predicted risk than the patients who were being case managed on the virtual ward. The only option they could see to manage this tension was to 'discharge' virtual ward patients either after a set period of time or to assess patients for discharge on an individual basis. Interestingly, commissioners were unable to find any evidence to support such commissioning decisions and this concerned them.

My discussions with commissioners and clinicians about whether and when patients should be discharged from case management gave me an insight into some of the dilemmas they faced on a daily basis. A number of academics kindly helped me to refine the topic of my complementary research and to design a small qualitative research project. My specific research question was, "What are the processes for discharging patients from case management and is there an optimal time frame for a patient to be case managed?"

A2.1.4 Ethics and research logistics

I submitted a protocol amendment to the London-Surrey Borders research ethics committee on 26 May 2011 to conduct one focus group at each site with the clinicians working on the virtual wards. I received a favourable opinion letter dated 20 July 2011 (reference number 10/H0806/31) and I subsequently applied for and received NHS Research & Development approval to conduct this complementary study.

I then set up field work for phase two, scheduling the focus groups for August and September 2011.

A2.2 Complementary research

In this second phase of my fellowship, I spent a period of immersion at each of the three sites whilst awaiting ethical review of my complementary research study (one week each in Croydon, Devon and Wandsworth).

Once the ethics and NHS Research & Development permissions had been secured, I conducted my fieldwork focus groups at each site, followed by analysis and write-up.

A2.2.1 Immersion period

I spent a week at each of the study sites (see Table A1).

Table A1: Dates of the management fellow immersion period at the study sites

Study Site	Dates of immersion period
Croydon	9 May – 13 May 2011
Devon	23 May – 27 May 2011
Wandsworth	11 April – 15 April 2011

I divided my time during my immersion period at each site between meeting virtual ward staff and key stakeholders including commissioners, managers and social care staff. By spending a prolonged period of time on the ground in each of the sites, I was able to develop a good relationship with the community matrons, managers and commissioners. It also enabled me to gain an in-depth understanding of how the virtual wards were functioning in reality. In particular, it gave me insight on how the community matrons worked as part of the model in each of the evaluation sites. This provided some useful contextual information for the funded study.

A2.2.2 Fieldwork

I conducted three focus group discussions with clinicians working on the virtual wards: one at each of the participating sites. Although I invited a range of staff to participate in the focus groups, in fact only community matrons volunteered to participate. The topic guide for the three focus groups is given in Box A2.

Box A2: Topic guide for focus groups

1. Can you describe the model of the virtual ward as it works in practice?
    - How are patients selected? Is this the right approach? Do you agree with this approach? Should there be anything else?
    - Do you think you are reaching the right patients?
    - Are there any improvements that could be made? Are there any issues to be addressed around admission? What are these and what would you like to see in place?
2. In general terms, how are people managed on the virtual ward? Are there any guidelines or criteria for case management? Are there any guidelines or protocols locally for the management of people on the virtual ward? Are there any written or unwritten objectives to be achieved? If yes, are they helpful?
3. How are the caseloads weighted?
4. Is there ever a time when you need to consider whether a patient should be discharged or stepped down from the virtual ward?
    - What are the usual circumstances when this happens?
    - How is the decision made?
    - What criteria, if any, exist for discharging people out of the intensive care of a virtual ward? What do you think about these? Are they helpful?
    - Do you think there should be a maximum time for patients to be on the virtual ward?
    - How do you feel about discharging patients?
    - Have you experienced any problems with discharging patients? Any difficulties with patients or colleagues, readmissions, etc.?
    - What, if anything, is in place to facilitate a lower level of care following discharge from a virtual ward? In your view, is this the right service? If not, what would you like to see in its place? How does this affect your decision-making process to discharge patients?
    - Are there any issues to be addressed around discharge? What are these and what would you like to see in place?
    - Is there anything that you think needs to be in place to facilitate or support either admission to or discharge from the virtual ward?
5. How does communication work here to support care transitions in and out of the virtual ward and hospital?
    - Does this help or inhibit flexibility?
    - Could there be any improvements?
6. Do you consider you are working in the most effective model? Is there anything you

would want to change regarding discharge?

7. Do you think that people experience a better quality of life when they are cared for in the virtual ward?

In total, the number of participants in the three focus groups was 13.

As part of the consent process, participants were informed that their responses would only be reported in aggregate. With the participants' written consent, I made audio recordings of focus groups, which I then arranged to be transcribed ready for analysis.

A2.2.3 Analysis and write up

I analysed the transcripts of the focus groups to assess current practice and to generate recommendations from those who are involved in virtual ward projects.

This complementary research has helped me address a research question that is supplementary to the funded research study and which is pertinent to clinicians, managers and commissioners alike. I have been able to establish what the staff working on virtual wards believe are the factors that should be taken into account about when and how patients should be discharged from a virtual ward. I believe that the information gathered from this part of the study should be useful to commissioners who are considering developing a virtual ward or who wish to ensure that their virtual wards are operating efficiently and equitably.

I am currently finalising the first draft of the manuscript, with a view to submitting to the International Journal of Nursing Studies in the spring of 2012.

A2.3 Knowledge mobilization

In this third and final phase of my fellowship, I concentrated my efforts on developing capacity in the managerial community for accessing, appraising and using research evidence and on encouraging greater engagement, linkage and exchange between the Nuffield Trust and potential local research users within the NHS

Specifically, I worked with the Nuffield Trust communications team to revise the main communications plan for the project to ensure it addressed the needs of NHS managers, and I designed a communications plan for the complementary research I conducted in phase 2. I worked closely with the research team to ensure that the study report was relevant to a managerial

audience and I am developing materials to support the economic models that we will produce as part of the funded research. I have arranged local seminars at each of the three evaluation sites and regional seminars to include at least five additional sites that are establishing virtual wards. In addition, I shall be contributing to the Nuffield Trust seminars that we will be holding to disseminate the findings of the funded research project.

Because the results of the funded study were not finalised until near the end of my fellowship year, the research team and I felt it important that my knowledge mobilisation activities should continue into 2012. Accordingly, I have arranged to return to my substantive organisation for two days a week in December as planned, so I can carry over seven days to be used flexibly to deliver the workshops and other knowledge mobilisation activities in the spring of 2012.

A2.3.1 Communications

I held a series of meetings with the Chief Investigator, the Head of Communications and the Digital Communications Manager at the Nuffield Trust to ensure that the communications plan for the funded research met the requirements of the NHS managerial community, particularly in light of the current financial challenges facing the NHS and the restructuring of the health service.

Specific proactive communications activities included the following:

- **Mapping of virtual wards in England**. I kept a detailed log of information about the considerable number of virtual ward projects currently in place or under development across the UK. I compiled this information in the form of an "interactive map" for the Nuffield Trust website, where visitors to the website will be able to "mouse over" a particular site to learn more information about how the virtual wards are operating locally. The purpose of this map is to support the sharing of information across sites so that NHS managers can contact other areas that are developing the virtual ward model in particular ways. Many individuals and organisations contact the Nuffield Trust because they are considering developing a virtual ward model. The interactive map should hopefully encourage collaboration at clinical and managerial level between organisations in the NHS.

- **Risk Prediction**. The literature suggests that risk prediction is essential to identify patients who are at risk of future hospital admissions. Risk prediction tools are therefore a key component of virtual wards because they can help identify

which people in a population may benefit from admission to a virtual ward or from other forms of case management. In August 2011, the Department of Health announced that it would not be commissioning a national upgrade of existing predictive modelling tools used by the NHS. Instead, the new policy would be to promote an 'open market' in terms of suppliers of risk tools. Following this announcement, I was able to contribute to discussions about whether, in future, predictive models in England should best be procured or built at a local, regional or national level. I facilitated a dialogue between colleagues in Strategic Health Authorities, Primary Care Trusts, the Department of Health, the QIPP clinical lead for long term conditions and the Nuffield Trust. Colleagues at the Nuffield Trust published a blog on this topic and an article in the Health Service Journal, which I helped to publicise. I also contributed to a guide to commissioners now tasked with choosing a risk prediction tool for their population.

- **Blogs**. I have published a series of blogs for publication on the Nuffield Trust website on virtual wards. Each blog discusses an interesting feature of a particular virtual ward project and draws out a research-related issue, question or lesson aimed at encouraging greater engagement by the managerial community.

Other knowledge mobilisation activities I have undertaken during my fellowship year have included liaison with the following stakeholders:

- **Strategic Health Authority leads for long term conditions**. During the course of my fellowship year, I have retained my role as chair of the Strategic Health Authority long term conditions leads' group. By managing this meeting I have kept in close communication with colleagues in the SHAs. This, in turn, has ensured that I have kept in touch with developments in each of the ten SHAs on their implementation of Department of Health strategy and policy in this field. In return, I have provided regular updates on the funded research study to the ten Strategic Health Authority leads. The Nuffield Trust Head of Research attended a meeting of the group in June 2011 to share information on the work of the Nuffield Trust. The SHA leads were interested and were keen to hear of further research. They offered to provide ongoing support to the Trust and to act as a sounding board for future projects related to long term conditions. In September 2010, the Chief Investigator spoke to the group

about risk prediction and this provoked lengthy discussion regarding the importance of using predictive tools in the long term conditions programme which has continued throughout this year. Partly thanks to this fellowship opportunity, there is now a great deal of interest in this group on bridging the divide between the NHS and researchers and I will be holding a seminar with this group on the evaluation of the virtual ward on either 15 March or 17 July 2012

- **National NHS organisations**. Many organisations have expressed an interest in the results of the funded research study, including NHS Nottinghamshire and NHS Tower Hamlets. I have been able to provide information and support to the representatives who have made enquiries, informing them of the progress of the research and raising awareness of the research methods being used.

- **European organisations**. I have received enquiries from several European countries including Spain, Sweden and the Netherlands on the implementation of virtual wards. I have provided information and support, and facilitated communication with NHS organisations and researchers by means of a virtual wards email group which I co-administer with the Chief Investigator.

- **North American organisations**. Whilst on my study tour of virtual wards in Canada and the United States, I found myself sharing knowledge about different virtual ward models in the UK. This was particularly the case in Winnipeg where the virtual ward was in very early stages of development. The health system in Winnipeg is very medically dominated so the Wandsworth model of using virtual ward GPs seemed to be of particular interest.

- **Australian organisations**. Nurses from the Emergency department and short-stay unit at Ballarat Health Services in Victoria, Australia have been in frequent contact with me regarding the implementation of a post-discharge virtual ward similar to the Toronto model I visited in September 2011. I have shared much information with them, and they are now planning a study tour to visit Toronto to learn more.

- **Department of Health** Throughout my fellowship year I have had frequent conversations with colleagues in the Department of Health, particularly with members of the QIPP team and the long term conditions policy team. Department of Health officials have been interested in the implementation of the virtual ward in the UK and overseas.

- **Long term conditions conference**. I was invited to chair a session at the Managing Long Term Conditions 2011 conference in Harrogate – the largest conference and exhibition of its kind in the UK. I chaired a question and answer session on integrated care which included a discussion about virtual wards. This was a very energetic and interactive session, which the conference evaluations show was well received. Later in the day, I gave a joint presentation with a colleague from Wandsworth on the implementation of the virtual ward in practice.

- **Nottingham & Nottinghamshire PCT**. I have supported the development of the Nottingham & Nottinghamshire Long Term Conditions strategy. As the East Midlands SHA lead for long term conditions, the knowledge I have gained through this fellowship of the virtual ward model helped me to support a merged PCT as they developed their strategy for long term conditions.

- **Nuffield Trust**. Colleagues at the Nuffield Trust hold regular lunchtime seminars to discuss and share information, and to plan future projects. I have personally gained from attending these sessions: it has been useful to hear about the other projects to gain an understanding of the Trust's work with the NHS from the researchers' perspectives. My input to the discussions seems to have been valued because I have been able to contribute to the discussion by offering an NHS perspective. I have received comments such as, 'It was useful to have the NHS viewpoint', and, 'It has been useful to be able to access your NHS knowledge.'

- **SDO Management Fellows**. Since June 2011, I have co-ordinated the SDO Management Fellows' meetings at the NHS Confederation. The outcome of this work is that the Management Fellows themselves are planning to work more collaboratively together to share information about the role and knowledge mobilisation strategies. We are working

towards having a dedicated area on the NHS Confederation website to facilitate this sharing. There is also a plan to develop an alumni organisation for Management Fellows that we hope will support the development of future SDO projects where NHS involvement would be useful. In addition, I have facilitated an online conversation with the current Management Fellows regarding the importance of patient and public involvement and the possibility of working with an independent consultant to facilitate this development.

- **Nottinghamshire CLARHC.** During my fellowship year I have established links with the Nottinghamshire Collaboration for Leadership in Applied Health Research and Care (CLAHRC).

- **East Midlands Research Design Service**. I have established a link with the East Midlands Research Design service and offered them my support as an NHS link where this would be useful in the future.

A2.3.1 Contributing to the funded research project

Throughout the year, I attended the project team meetings as well as the research team meetings. This gave me the opportunity to contribute to and comment on the progress of the research, and to engage on behalf of the NHS with the funded study. I helped develop the agenda for the two Nuffield Trust workshops were held for the study sites, and I attended all of the advisory group meetings. At each of these meetings I presented an update on the work being carried out as part of my fellowship.

Other ways in which I directly contributed to the funded research project included:

- Data extractions. On a number of occasions during the course of my fellowship year, the researchers encountered some difficulties with the sites sending pseudonymous data to the Nuffield Trust ready for analysis. On these occasions, I was able to mediate and support the data delivery ensuring that it was delivered in an agreed format by a specified date.
- During my immersion weeks in each site, I was able to inform NHS staff about the interviews, questionnaires and diaries that the research team would be asking them to complete as part of the economic evaluation of the funded study. I was able to discuss the importance of completing the

questionnaires and diaries and to address any questions they had.

- I worked with two members of the research team to write a peer-reviewed paper "Multidisciplinary Case Management for Patients at High Risk of Hospitalization: Comparison of Virtual Ward Models in the UK, USA and Canada". This article was accepted for publication in the American journal 'Population Health Management'.

A2.3.1 Developing materials

I am working with Rhema Vaithianathan to develop materials to support the economic models that we will produce as part of the main research.

A2.3.1 Running local seminars

In early 2012 I shall be running local seminars at each of the three sites. In addition I have arranged the following seminars. I have invited representatives of several sites that are establishing virtual wards to attend one of these seminars. I have arranged to hold seminars with NHS Midlands and East, the SHA long term conditions leads and the national QIPP team (the latter seminar being held via Webex seminar).

A2.3.1 Contributing to the Nuffield Trust seminars

I will contribute to a Nuffield Trust seminar scheduled for in which the research team will disseminate the findings of the funded research project.

A3 North America Study Tour

Following my immersion periods at the three study sites, the Chief Investigator suggested I might find it valuable to undertake a study tour of the virtual wards in Toronto, Winnipeg and New York. He was aware that, since its original introduction in Croydon in 2006, the virtual ward model had been adopted by several sites in North America. Each of these three sites is configured slightly differently from the other and from the virtual wards in the UK, and he believed that these subtle differences held potentially important lessons for the NHS.

I applied to the SDO for additional funding for this study tour and was awarded £5,898 which covered my travel, accommodation and subsistence costs. My study tour took between 26th September and 12th October 2011

and my findings have been published as a series of blog posts on the Nuffield Trust website.

A3.1 Toronto

I visited the virtual ward in Toronto between 26 September and 29 September 2011. The virtual ward in Toronto identifies patients who are at a high risk of readmission to hospital within 30 days of discharge from hospital. Patients are identified using the LACE predictive model. Patients with a high LACE score, who are at high risk of death or readmission within 30 days after discharge from hospital, are offered admission to the virtual ward. As with other virtual wards, these patients are cared for in their own homes by an interdisciplinary team. In Toronto, the team shares a common set of notes, has a single point of contact, and has 24-hour direct access to a hospital physician who co-ordinates care in the hospital and supports the care coordinators with any medical concerns for several weeks after hospital discharge. During my visit, I was able to spend time with care co-ordinators in the hospital and the community, and with the ward clerk and pharmacist. A randomised control trial is currently taking place to evaluate this model and I spent time with members of the research team.

A3.2 Winnipeg

I visited the virtual ward in Winnipeg between 30 September and 5 October 2011. The virtual ward in Winnipeg opened in August 2011. The Winnipeg virtual ward model is similar to those in the UK, but they have an additional focus on patients that require ongoing institutional care. The Winnipeg virtual ward identifies patients who seek care in A&E and are admitted to hospital because the required care in the community is not available, or who experience delays in being discharged from hospital because alternative care is not forthcoming. The evaluation of the Winnipeg virtual ward should therefore help to identify what services are missing in the community.

Whilst in Winnipeg I attended a number of strategic developmental meetings. The meetings were devised to support knowledge-sharing and learning from each other. The meetings took place in the Regional Health Authority, where I met the chief executive, director of nursing, director of primary care and many other senior colleagues.

A3.3 New York

I visited the virtual ward in New York City between 6 October and 11 October 2011. The virtual ward in New York is called "Hospital2home". It uses a variant of the PARR model to identify Medicaid patients at high risk of future admission to a New York public hospital. Many of the patients identified by this model are homeless and so the make-up of the virtual

ward team reflects this by including a number of housing officers. Patients are risk-stratified in the Emergency Department using the predictive model, and high-risk patients are offered a co-ordinated service in the community through the virtual ward. Hospital2home is currently being evaluated with a cluster randomised controlled trial.

I was able to spend a considerable amount of time with the care co-ordinators, visiting patients in refuges, shelters and on the hospital wards. I also met with the senior social worker the primary care doctor and home nursing service.

A3.4 Reflections on the study tour

The main 'take home' lessons of my study tour for the NHS were as follows:

Toronto

- It was great to see the level of collaboration that took place between different professionals that were working together for the benefit of the patients. There were few referral pathways in place for these patients so if a patients needed for example physiotherapy or meals on wheels this could be accessed very quickly.
- I was able to see the pharmacist working very closely with the team providing advice and support regarding the best medications and discussing any interactions that should be considered. The pharmacist was accessible and available which did prove to be really useful as you could see the added value of this role for the multidisciplinary team.
- I could see the value of case managers visiting patients within 24 hours of discharge from hospital because they were able to make an assessment of the patient's ability to cope. Often people are still not very well when they are discharged and the first few days are often difficult until they start to feel a bit better. I could see that the assessment at this stage does reduce the possibility of a readmission occurring, because the right services to prevent this can be mobilised quite quickly.
- I was very interested to learn that the case managers were not nurses as in the UK. In Toronto they can be from a nursing, social care, physiotherapy or Occupational Therapy background. I observed care coordinators with a social care background. It is difficult to know how much this influenced the approach but it was much less clinical than the similar role in the UK.

Winnipeg

- In Winnipeg the virtual ward was much less developed than I had expected. There was a pilot project providing intensive case management to 10 patients who had been identified as people who would benefit from this level of input. These 10 patients were already on the case manager's case load along with 100 other patients. The benefit of this pilot was that extra resource, advice and support was provided by having the involvement of a Medical Director whose role was to work across primary and secondary care. This medical director was able to support the diversion of resource to support patients remaining at home rather than experiencing repeated admissions unnecessarily. I saw that there was a very medically dominated health system in Winnipeg that meant advanced nurse practitioners needed to seek permission from doctors before carrying out any advanced clinical procedures. I was also surprised to learn that as many as 70% of the population were not registered with a primary care doctor. These patients were described as orphan patients, with no medical home. I was able to help with the thinking on developing primary and community care services in Winnipeg.

New York

- This model identifies high risk Medicaid patients in the City of New York. The high risk patients that the risk prediction tool identifies frequently have very difficult social circumstances, they may have tenuous housing and use harmful substances.
- I was interested to learn that there had been a huge amount of development prior to launching this service in New York that entailed building good networks with the organisations that exist to help the patients that are homeless e.g. soup kitchens and hostels. There is a senior advocate in each of these organisations across the whole of New York so that when an identified person at risk of hospital admissions appears there is a good communication/alert system in place. The NHS could learn from this. A governance structure has been set up that responds to any issues raised regarding confidentiality or other concerns so that information can be shared.
- Clients are seen as equal partners in providing the service and actions are agreed before being taken forward. Care co-ordinators are not necessarily well received by some clients. A certain level of trust can take some time to develop - the care co-ordinator will remain in touch with clients and provide support on their terms.
- This service requires extensive mental health support as well as housing and other services to work effectively together for the benefit of clients.

Overall

1. The level of collaboration that takes place at the operational level in New York and Toronto in particular was better than any seen in the UK, this had a positive impact on the efficiency of the service delivery for clients.
2. People were not seen as patients or service users, they were clients and therefore equal partners in deciding on how their care will be managed and agreeing to the services that will be delivered to them.
3. The assessment processes in New York and Toronto were very different but equally comprehensive. These are repeated at a later stage as a measure of effectiveness, we should consider introducing this in the UK.
4. Case managers were not nurses as in the UK, the benefits of this should be explored much more as there appeared to be benefits to having a less clinical approach than the UK model.

A3.5 Knowledge mobilisation following the study tour

Shortly after returning to the UK, I shared the principal lessons from my study tour with NHS and Nuffield Trust colleagues and at a workshop held at the Nuffield Trust for the three virtual wards study sites. I also presented my findings at the SHA Long Term Conditions leads' meeting, and I am also planning to share them more broadly with NHS colleagues on via a Webex conference being organised by the Department of Health Long Term Conditions QIPP team. I have written a series of blogs on my study tour for the Nuffield Trust website, and further sharing of information will also take place on my return to the strategic health authority in 2012.

A4 Reflections on the Management Fellowship role

I found it interesting to work in a think tank such as the Nuffield Trust. This relatively small organisation plays a major role in conducting health services research and policy analysis, and is often instrumental in influencing policy development at the highest levels. I had the opportunity to attend a wide range of Nuffield Trust events during the course of my fellowship year, including the 2011 Annual Health Strategy Summit, the Nuffield Trust Risk Adjustment Conference as well as a large number of smaller workshops and events. These opportunities allowed me to listen and contribute to discussions between attendees that expanded my thinking on the NHS. I found it fascinating to participate in discussions based on evidence and analysis. I know from experience that much of the information being debated rarely comes to the attention of NHS managers. I now understand how the work conducted by the Nuffield Trust and similar organisations such

as the King's Fund can influence policy development and help to set the direction for the NHS. The Fellowship year has enabled me to look at the NHS from the outside for a period and to reflect on this.

I found it rather daunting at first to be working in a team that has such a focus on quantitative research. Initially, I was unfamiliar with much of the language and terms being used but I have now learned more about quantitative research and the processes involved in conducting the funded study. Prior to starting my Fellowship, I had for some time been aware of the importance of risk prediction and why organisations need to use such tools. However, spending time at the Nuffield Trust made me more aware of the technicalities involved and the importance of offering preventive interventions to the patients identified as being at high risk. I have read a good deal of the relevant research evidence in this field and now have a greater understanding of this area. Indeed, the opportunity this Fellowship gave me to read more health-related literature has improved my knowledge considerably. I have read many papers on the role of the community matron, case management, risk prediction, integrated care, care transitions, Nuffield Trust papers and many more papers on related subjects – all of which are of direct relevance to the NHS.

I have also spent time with the qualitative researchers at the Nuffield Trust and elsewhere to learn about their work. I purchased a number of books during the year to extend my research knowledge and I used this newly acquired information in my complementary study. For this complementary study, I was required to submit a project variation to a research ethics committee. This provided me with a researcher's perspective on the requirements and procedures involved in obtaining ethics and Research & Development permissions. It also provided me with opportunities to write and publish in a number of different styles, ranging from academic papers to blog posts for the Nuffield Trust website.

One of the biggest surprises during my fellowship year was that the Long Term Conditions policy that I was responsible for four years ago, and that I believed had been reasonably well delivered, was not actually implemented in practice as I had expected it to be. Reading Michael Lipsky's book 'Street level bureaucracy' shed a new light for me on how policy is typically re-interpreted at each level by constraints that may not be visible to those devising the policy from above. This insight will be useful as I return to a strategic post in the NHS, and I intend to spend more time in future learning from practitioners on the front line (so-called "management by walking around").

Somewhat paradoxically given that my Management Fellowship involved spending a year working outside the NHS, one of the most useful experiences was the close contact I had with community matrons, provider managers and commissioners. This provided me with refreshed knowledge

on how community services are currently organised and managed to deliver care to patients with long term conditions. My insights will be invaluable when I return to the SHA, especially if I retain a responsibility for people with long term conditions and other patients with complex needs. It is unclear at this stage what exactly my new role will be. However much of the learning I gained during my fellowship last year will be applicable to other areas of future work.

A5 Acknowledgements

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Appendix 2 Site Descriptions

This appendix provides a detailed description of these differences between the three study sites, based on the taxonomy used by Boaden and colleagues in the final report of the UK Evercare pilots.[11]

Croydon

Overview	**Distinguishing features**	"Original" virtual wards Nurse-led programme Clinical oversight provided by a nurse consultant in long term conditions Strict adherence to predictive model
	Policy background	Public service agreement to reduce unplanned admission rates and to appoint community matrons Along with South Warwickshire, Croydon was one of two PCTs that provided data for the development of the NHS Combined Model. A "diary exercise", where patients with long term conditions were asked to keep a reflective diary of their experience of the health service showed that patients valued the feeling of "safety" when on a hospital ward.
	External support	No external funding for the project
	Timing	First patient was admitted in May 2006. Additional 8 virtual wards were opened in March 2007.
	Commissioner	Croydon PCT
Organisational Structure	**Project name**	Virtual community ward (VCW)
	Total number of virtual wards	Two pilot virtual wards opened in May 2006 and August 2006. Increased to ten virtual wards in May 2007. Since October 2010 there have been eight virtual wards.
	Number of virtual wards under study	2 then 8
	Funding	Croydon PCT
	Commissioner	Croydon PCT
	Number of full-time staff (core team)	The two "pilot" community virtual wards (CVWs) each had a community matron [1 x full time and 1 x 0.75 full time equivalent], plus a full-time ward administrator (ward clerk). In May 2007, a further eight CVWs were opened in Croydon. Of the additional community matrons

		employed at that time, three full-time community matrons have since left and were not replaced: one in August 2010, another in October 2010 and a third in August 2011. Community matrons work in isolation, based in health clinics.
	Number of part-time staff (wider team)	The two "pilot" community virtual wards were each supported by a named pharmacist, physiotherapist, occupational therapist and health visitor for older people who attended weekly ward rounds. A member of Croydon Voluntary Action (an umbrella group for voluntary groups in Croydon) was also assigned to each CVW. However, with the opening of the additional CVWs, the intervention ceased to be multidisciplinary. Instead, community matron, supported by a ward clerk, delivered one-to-one case management, referring to all other agencies as required.
	Line-management structure	The five ward administrators were originally managed by the Head of Community Nursing. Then, in March 2009 line management was devolved to five community matrons on a 1:1 ratio. Community Matrons managed by Head of community nursing from inception; transferred to assistant director of adult nursing in 2009 and then back to new head of adult community nursing services in March 2010.
	Mentoring arrangements	Community matrons receive clinical supervision from the nurse consultant in long term conditions, as well as 1:1 meetings with their line manager and peer support in the multidisciplinary mortality and morbidity meetings. Community matrons provide mentoring for district nurse students and for medical students.
	Administrative support	5 administrators (ward clerks) Administrators are based in a central location (i.e. they are not co-located with the community matron)
	IT arrangements	The EPEX system is used for recording contacts with virtual ward patients. This is the system used by all community health staff. In some sites, virtual ward staff have limited access to blood test results but not to the GP clinical record. Paper-based notes are also used: the main notes are held at a central location and contact details are held in each patient's home.
	Training	Higher education courses are provided by local affiliated universities, including courses on advanced clinical assessment and independent prescribing.
Target populatio	**Patient identification**	During the study period, virtual ward care was only ever offered to patients selected according to the output of the Combined Model. has been run on a quarterly basis.
	Predictive model	Combined predictive model

	"Filtering" of predictive model output	Community matrons sometimes reject "inappropriate" high risk score patients. Patients may be rejected if • the patient is already being case managed by another professional • the GP states that they do not think case management will be effective for an individual patient; • addiction/ dependency issues; • known severe mental health diagnosis; • known risk to a lone worker (staff may try to see them in a clinic setting). • Where there is a language or social barrier that prevents the patient from engaging with the community matron.
	Patient characteristics	Perceived high proportion of patients with • Low socioeconomic status • Language barriers • Black and minority ethnic • Psychological issues
Virtual wards	**Caseload**	The original aim was for a caseload of 100 patients. Typical caseload however is 50 – 70 patients.
	Ward rounds	With the exception of the pilot phase, when weekly ward rounds were held, there have been no ward rounds held. Instead, all communication is *ad hoc* between the ward clerks and the community matrons. District nurses and the mental health team etc. have no dedicated time to spend on virtual ward activities or with virtual ward patients. All communication between community matrons and other staff is ad hoc and the usual referral process is in place.
	Assessment and care plans	The Single Assessment Process (SAP) is used, and care plans are available on the EPEX system.
	Monitoring of patients	The frequency with which patients are reviewed varies on a case by case basis. No tele-health devices were used as part of the virtual wards during the study period.
	Deterioration	Community matrons are seldom informed if a patient is admitted to hospital, and communication on discharge from hospital does not always occur. During the study period, automatic alert systems were not in place for informing virtual ward staff when one of their patients attended A&E. During office hours, patients may contact the virtual ward using a single telephone number. Outside these times, patients are required to contact the GP out-of-hours service, which as limited information about virtual ward patients.
W o	**Intermediate care**	Community matrons may refer virtual ward patients to

		the intermediate care service using the standard referral process.
	Other types of bed	Virtual ward patients can access rehabilitation beds via the intermediate care team.
	OT and physiotherapy	There is no dedicated time for physiotherapists and occupational therapists (OT) to spend on virtual ward activities. All communication with OT and physiotherapy is ad hoc and the usual referral process is in place.
	Social services	There is no dedicated time for social workers to spend on VW activities. There are no social care workers attached to the VWs. All communication with social workers is ad hoc and the usual referral process is in place.
	Specialist nurses	There is no dedicated time for specialists nurses (e.g. nurse consultant in heart failure) to spend on VW activities. All communication with specialist nurses is ad hoc and the usual referral process is in place.
	Pharmacists	There is no dedicated time for pharmacists to spend on VW activities. GPs are encouraged by the community matrons to conduct medication reviews.
	Mental health	There is no dedicated time for the VW allocated to district nurses, nor the mental health team. All communication is ad hoc and the usual referral process is in place.
	Voluntary sector	Croydon Council and Croydon PCT supported voluntary community sector through the (now defunct) Health and Social Care Forum to provide an advice, support and liaison service; and by encouraging and developing community involvement in the management of Long Term Conditions (LTCs). This involved Patient and Public Involvement training sessions for community nurses; increased voluntary sector representation on LTC working groups; working with community matrons to devise a feedback event from patients who utilised the virtual wards service; and setting up a user group forum for patients who utilised the virtual ward. Twelve self-help groups were established, with discussions held online at Talk2Croydon (http://www.talk2croydon.co.uk/)
	Secondary care	The ward clerk has access to hospital patient administration system (PAS) system and can view if a patient has been admitted to hospital. Community matron requests for consultant advice may or may not be acceptable by individual consultants. Send patients to A&E for consultant advice Send patients to A&E for imaging Virtual ward staff do not have direct access to outpatient clinics but can always visit patients in hospital if they are

		admitted there.
Exit	**Decision to discharge**	A falling risk score prompts the community matron to consider discharging a patient. Ultimately, the decision to discharge is clinical and takes into account whether the patient is "compliant/engaged" with virtual ward staff.
	Arrangements post discharge	At the time of discharge from a virtual ward, a discharge letter is sent to the patient's GP detailing the treatment and care plan, together with the reason for discharge.
Impacts	**Intended outcomes**	Principal aim was to reduce unplanned hospital admissions Secondary aims included reducing health care inequalities, reducing outpatient attendances, reducing A&E attendances, reducing duplication, improving quality of care.
	Legacy	Since September 2011 VWs are also accepting clinical referrals from GPs. Since 2009 there has been an end-of-life multidisciplinary team meeting, which community matrons attend as part of the Gold Standards Framework.

Devon

Overview	**Distinguishing features**	Rural Practice-based GP champion
	Policy background	Based around Complex Care Teams (CCTs), which are integrated health and social care teams that were developed following a Partnerships for Older People Pilots (POPP) project. The initial pilot was developed under a Practice Based Commissioning (PBC) initiative to integrate Virtual Wards, CCTs and predictive modelling
	External support	No external funding for the project
	Timing	First patient was admitted in October 2008
	Commissioner	NHS Devon
Organisational Structure	**Project name**	*Virtual ward (VW)*
	Total number of virtual wards	South Molton and Chulmleigh VW opened in October 2008 Increased to 23 virtual wards following pan-Devon rollout commencing in July 2009, however only the South Molton and Chulmleigh VW was evaluated in this study.
	Number of virtual wards under study	1
	Funding	NHS Devon and Devon County Council
	Commissioner	Devon PCT
	Number of full-time staff (core team)	*Community Matron and Complex Care Team administrator (ward clerk)*
	Number of part-time staff (wider team)	*Adult care services social workers, community psychiatric nurse (CPN), CPN for older people, staff grade elderly care doctor, physical therapist, occupational therapist, voluntary sector representative, district nurses, GP, complex care team manager (joint Health and Social Care appointment)*
	Line-management structure	The community matron was line-managed by the CCT manager At the start of the project, the administrator was managed by the 3 local GP practices. Over the pilot duration this role merged with the CCT co-ordinator role as a combined function, and then came under CCT line-management.
	Mentoring arrangements	The community matrons and CCT co-ordinators both attend role-specific support and education groups. The GP lead for the project also provided clinical support and mentoring throughout the project.
	Administrative support	1 *complex care team administrator (ward clerk)* The ward clerk was co-located with the community matron at a GP practice but is now based at South Molton community hospital with the community matron.

	IT arrangements	The community matron and the co-ordinator had direct or remote access to the three GP practice clinical systems. They also had access to the Devon County Council social care records system, an electronic Single Assessment Process (SAP) system and the acute trust patient administration system (PAS). Work is underway to provide unified access and interoperability of these systems.
	Training	The community matron undertook a nurse prescribers' course
Target population	**Patient identification**	Between October 2008 and Winter 2009, patients were solely identified as referrals from GPs. From Winter 2009 onwards, approximately 85% of patients were identified by a predictive risk model with the remainder of patients being clinical referral. Between Winter 2009 and March 2011, the Combined Model was used; and from March 2011 onwards, the Devon Combined Model was used (a local version of the Combined Model, weighted for Devon data). Both models were run on a monthly basis.
	Predictive model	Combined Predictive Model / Devon Combined Model
	"Filtering" of predictive model output	Community matrons would sometimes reject "inappropriate" patients. Patients may be rejected if they were referred by a clinician but were low risk on the DPM score the community matron or GP felt the patient might benefit more from an alternative service (e.g. a young person)
	Patient characteristics	Perceived that a high proportion of patients were Elderly, rural with multiple LTCs, poor self-management, often high anxiety or lack of extended family, isolated.
Virtual wards	**Caseload**	The original aim was for a caseload of 50 patients. Typical caseload however is now 100
	Ward rounds	There is daily communication between the ward clerks and the community matrons. In addition, there is a weekly ward round of the wider multidisciplinary team.
	Assessment and care plans	Integrated assessment process using standard forms including BICA (initial assessment) and FACE (contact assessments). These were shared via an electronic system.
	Monitoring of patients	Dependent on need and care plan, discussed weekly and RAG (Red/Amber/Green) status used. After discharge, the patient can be seen as a scheduled appointment (so-called 'out-patient' of the virtual ward).
	Deterioration	Patients can contact the ward clerk during office hours. Outside office hours, GPs working for the out-of-hours service are able to access a summary and basic care-plan for virtual ward patients.
Working with other services	**Intermediate care**	The rapid response team is able to respond in urgent situations and mobilise resources. During office hours, this is the CCT team itself. In twilight hours and during the daytime at weekends, this is provided by the Pathfinder service.
	Other types of bed	The virtual ward team have access to GP beds in the local community hospital and have the ability to go through a rapid response process to

		spot-purchase residential or nursing home beds for up to 6 weeks.
	OT and physiotherapy	There is a named occupational therapist and physiotherapist attached to the virtual ward, who have dedicated time to attend the weekly ward round. Their roles include working with any complex patient if requested by the community matron. They do not require separate referral once they are known to the CCT.
	Social services	Social workers have dedicated time to attend the weekly ward round. Their role includes working with any complex patient if requested by the community matron.
	Specialist nurses	All communication with specialist nurses is *ad hoc* and the usual referral process is in place.
	Pharmacists	There is currently no dedicated time for pharmacists to spend on VW activities although starting in January 2012 a community pharmacists will be allocated to work with each of the virtual wards / CCTs
	Mental health	Mental health nurses have dedicated time to attend the weekly ward round. There is a named mental health nurse and 'older people mental health' nurse attached to the VW. They provide advice and guidance only and require a separate referral form the GP if further review is required and the patient is not already known to them.
	Voluntary sector	A voluntary sector representative attends the weekly ward round and can signpost patients to relevant voluntary sector resources. They can link in with the two other voluntary services of the Red Cross home-from-hospital service and the voluntary sector co-ordinators who cover the non-complex patients in the local population
	Secondary care	The staff of the virtual ward / CCT are employed by the local acute trust and Devon County Council. They therefore have access to all the acute PAS systems and to consultant support when required.
Exit	**Decision to discharge**	The locally enhanced service (LES) for GP practices requires 85 per cent of virtual ward patients to be in the 'high risk' or 'very high risk' categories on the DPM. So a falling risk score prompts the community matron to consider discharging a patient. Ultimately, the decision to discharge is made by the multidisciplinary team at the time of a ward round. A review of the patient's initial goals is also used to guide this decision.
	Arrangements post discharge	After discharge, the patient will be monitored by their GP and the VW staff will arrange a follow-up review (called an 'out-patient' review) by the VW staff at an appropriate time thereafter.
Impacts	**Intended outcomes**	The principal aim was to reduce unplanned hospital admissions. Secondary aims included reducing health care inequalities, reducing outpatient attendances, reducing A&E attendances, reducing duplication, improving the quality of care, improving access, improving equality in service provision, and reducing length of stay in hospital.
	Legacy	The aim of the pilot was to focus a proactive approach to care on the right group of patients and improve the management of this high risk group of individuals. The roll-out of virtual wards to other areas of Devon should hopefully cement this proactive approach across the county and provide a foundation to build up other disease-specific services and so on. The main legacy will be in the change in attitudes towards more population-focussed care.

Wandsworth

Overview	**Distinguishing features**	Virtual ward GPs (VWGPs)
	Policy background	Based on Croydon virtual wards (VWs) Public service agreement to reduce unplanned admission rates and to appoint community matrons
	External support	No external funding for the project
	Timing	The project started on 18 November 2008. However, the first VW did not open until 1 March 2009.
	Commissioner	Wandsworth PCT
Organisational Structure	**Project name**	*Virtual ward (VW)*
	Total number of virtual wards	4 The first patients were admitted to the VWs on 1 March 2009 (Battersea), 25 March 2009 (Wandle), 13 May 2009 (South Wandsworth),and 15 May 2009 (Roehampton).
	Number of virtual wards under study	4
	Funding	Wandsworth PCT and Wandsworth Council
	Commissioner	Wandsworth PCT
	Number of full-time staff (core team)	*VWGP, Community matron and ward clerk*
	Number of part-time staff (wider team)	*Social worker, district nurse, physical therapist, occupational therapist, pharmacist, drug & alcohol therapist.* *Plus access to specialist nurses (heart failure, diabetes, palliative care, COPD, tissue viability), social worker, community mental health team, and a dietician*
	Line-management structure	Community Matrons lined managed through established nursing structure: reporting to Clinical Team Leaders as line managers. Ward clerks line managed by VWGPs. VWGPs line managed by the Project Lead.
	Mentoring arrangements	Some clinical support provided to Community Matrons by local Consultant in Elderly Care through weekly teaching programme and clinical case discussions.
	Administrative support	4 *ward clerks* Ward clerk is co-located with the VWGP at a GP practice or local health clinic
	IT arrangements	GP practice systems (EMIS) are used for recording contacts with virtual ward patients and remote access to these systems (EMIS) set up. Access to St George's Hospital electronic patient record (EPR) system to access patient test results.

		All four virtual wards can access a shared drive for saving document, as well as a shared calendar and a shared task list. Access to system (Adastra) used by out-of-hours providers enabled VWGPs and community matrons to enter special notes about VW patients. 5. Access to Framework-i (the social services database)
	Training	Ward Clerks had training for 'telephone triage' from NHS direct. VWGPs held weekly teaching for community matrons and other VWGPs where, in addition to presentation on pre-arranged topic, difficult cases were also discussed.
Target population	**Patient identification**	Initially, predictive tool data was limited and the majority of referrals came from clinicians only. From March 2009 onwards, the PARR++ model has been used to identify patients, which is run every two to six months. In addition to patients identified by the model, approximately 75% of patients are referred by clinicians. It is important to note why 75% of patients were included in the VW that were not appearing on the risk prediction list. The core team were being made aware of patients from GP practices who were very unwell. The VWGP and community matron accepted these referrals and provided a "hospital at home service." This was because the core team believed that these patients should have previously been on the risk list and as they hadn't appeared in the past, so the list was missing patients that they should have been caring for.
	Predictive model	PARR++
	"Filtering" of predictive model output	Occasionally the VWGP and community matrons reject "inappropriate" high risk score patients, for example if a patient refused consent to be cared for by the VW team. Another example would be patient with a high PARR score due to a recent transplant: such patient might have frequent but necessary hospital admissions and would need care from more specialist resources than the VW could provide.
	Patient characteristics	There was a perception that a high proportion of patients seen were elderly, socially isolated, and with concurrent chronic diseases (e.g. COPD, heart failure) with exacerbations of at least one of these. For many patients, the regimen of medications they were taking had not been optimised and often their concordance with medication was low.
Virtual wards	**Caseload**	The original aim was for a caseload of 50 patients. Typical caseload however is [45]
	Ward rounds	There is daily communication between the VWGP, ward clerks and the community matrons, however this is *ad hoc* rather than at a specific time of day. In addition, there is a weekly ward round of the wider multidisciplinary team .
	Assessment and care plans	VWs use the following tools: Continuing Care or Higher Funded Nursing Care assessment Individual Clinical Management Plans with goals etc PHQ9 for depression
	Monitoring of	Patients with chronic conditions are reviewed on a daily, weekly

	patients	or monthly basis according to need. Any acute illness would prompt a review, since VWGPs take over all GP care whilst the patient is being cared for on a VW. A log is kept to ensure that patients are at MDT meetings at appropriate time intervals. Teleheath is used to monitor patients – usually for those who require daily monitoring
	Deterioration	Patients can contact the ward clerk during office hours. Outside office hours, patients call the local out-of-hours service. This service is aware of which patients are on each VW and clinicians can see the entries in the notes that the VWGP or community matron has made. This contains useful information such as baseline observations so that a doctor who has not seen the patient before is aware of what 'normal' is for that patient. The out-of-office doctor can fax VW the next day if a visit or review is required. When patient attends St George's Hospital A&E department, a flag appears on the front charge sheet to alert the staff that this patient is cared for by the VW and can be contacted for information and early discharge. This alert system is maintained by sending a weekly list to A&E. Patients are issued with a credit card sized card that alerts any health care staff that this patient is cared for by the VW. The card contains the contact numbers and names of the patient's VWGP and community matron. The "pot-in-fridge" scheme has been implemented – this alerts ambulance staff that the patient is cared for by a VW, and alerts them to baseline observations so that they are aware of what 'normal' is for that patient. Occasionally, ambulance staff would telephone the VW from patient's home if admission might be inappropriate or could be averted.
Working with other services	**Intermediate care**	Liaison occurs with the intermediate care team (ICT) when extra input is required (e.g. overnight or at the weekend)
	Other types of bed	A local hospital had some rehabilitation beds that were for patients who required less than full hospital care. These are used for patients who required extra support through an acute illness e.g. UTI. The hospital doctors look after the patients but not as time-intensive as an acute hospital bed. ICT had some rehabilitation beds that they could admit to for intensive rehabilitation.
	OT and physiotherapy	Physiotherapists and occupational therapists have dedicated time to attend the weekly ward round. However, they do not have additional time assigned to see VW patients and instead, they still require formal referrals to see patients.
	Social services	Social Workers attended the weekly MDT meetings every week or every fortnight. This was not a named social worker as they used a rota system. Referrals were made to social care in the usual way. Since mid 2011 (after the end of the study period) there has been a dedicated full time SW for each ward.

	Specialist nurses	Specialists nurses (e.g. nurse consultant in heart failure) were not allocated dedicated time to spend on VW activities. Instead, the usual referral process was in place.
	Pharmacists	Each ward had a dedicated named pharmacist for half day per week. They could be contacted at other times on an ad-hoc basis. They carried out medication reviews on all patients admitted to the VW and attended weekly MDT meetings.
	Mental health	One or more members of the mental health team would attend the weekly MDT meeting if a patient of theirs was being cared for on the VW. They required formal referrals.
	Voluntary sector	No representative of the voluntary sector attended the weekly ward round, nor was there a named voluntary sector representative who could signpost patients to relevant voluntary sector resources.
	Secondary care	There was no direct access to clinics and there were no special arrangements in place for requesting x-rays and other imaging. However, VWGPs did visit VW patients when they were admitted to hospital so as to facilitate early discharge and VW staff were able to access the hospital's electronic patient record system to obtain test results.
Exit	**Decision to discharge**	A falling risk score prompted the VWGP and community matron to consider discharging a patient. For patient not identified according to the risk tool, discharge would occur when clinical goals had been met.
	Arrangements post discharge	At the time of discharge, the VWGP would write a letter written to the patient's own GP to explain follow-up needs, and the community matron would hand over to the district nurses and specialist nurses as required.
Impacts	**Intended outcomes**	The principal aim was to reduce the rate of unplanned hospital admissions. Secondary aims included reducing health care inequalities, reducing outpatient attendances, reducing A&E attendances, reducing duplication, improving quality of care, improve team working for community staff and promote, peer support.
	Legacy	

Appendix 3 Members of the Advisory Group

Richard Grieve, Senior Lecturer in Health Economics, London School of Hygiene and Tropical Medicine

Claire Jones, Head of Adult Community Nursing Services, Croydon Health Services NHS Trust

Paul Lovell, General Practitioner, East Street Surgery, South Molton

David Osborne, Senior Public Health Information Analyst, Croydon Public Health Intelligence Team, NHS South West London

Sarah Purdy, Consultant Senior Lecturer and MRC Clinician Scientist, University of Bristol

Seth Rankin, General Practitioner, Wandsworth Medical Centre, London

In addition, two service user representatives attended one meeting of the advisory group[3]

[3] We made a concerted effort at each of the three study sites to encourage the participation of user representatives on the project advisory group. As well as sending repeated requests for representatives via lead collaborator at each site, we also approached local research networks and local patient and service user advocacy groups. During her immersion weeks at each of the study sites, the SDO Management Fellow made additional attempts to engage with service user representatives. We suspect our difficulty in recruiting service user representatives to the advisory group from all study sites may reflect the complex needs of patients being cared for on the virtual wards."

Appendix 4 Interview Schedules

The interview topic guides for the finance, managerial and frontline staff were as follows:

Finance

Topics for discussion at your interview:

1. Discussion of your answers to the questionnaire to your organization and costs to the patients of running a Virtual Ward.
2. Cost of setting up a Virtual Ward.
3. Potential ways in which the efficiency and effectiveness of Virtual Wards might be improved.

Managerial

Topics for discussion at your interview:

1. Discussion of your answers to the questionnaire
2. Costs to your organization and costs to the patients of running a Virtual Ward.
3. Cost of setting up a Virtual Ward.
4. Potential ways in which the efficiency and effectiveness of Virtual Wards might be improved.

Frontline

Topics for discussion at your interview

1. Discussion of your answers to the questionnaire
2. Your work diary
3. Time spent with patients
4. Travel costs

   Referrals