Evidence Adoption Centre

East of England

The Effectiveness of Predictive Modelling Tools in Identifying Patients at High Risk of Using Secondary Care Resources

Can Predictive Modelling Tools Reduce Utilisation of Secondary Care Resources (e.g. Emergency Hospital Admissions) and Improve Quality of Care When Used at the Primary Care Level to Identify Subsets of High Risk Patients Most Likely to Benefit from Targeted Interventions?

A rapid review of the research literature

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1. Request

The Evidence Adoption Centre received a request from NHS Cambridgeshire PCT (Primary Care Trust) for a rapid literature review on the effectiveness of predictive modelling tools. The practical question is: 'Can these tools reduce utilisation of secondary care resources (e.g. emergency hospital admissions) and improve quality of care when used at the PCT level to identify subsets of high risk patients most likely to benefit from targeted interventions?'

2. Research question

Q1. What is the effectiveness of predictive modelling tools in identifying patients most likely to use future secondary care resources (e.g. emergency hospital admissions) in the UK?

Q1:
Problem: Increased use of secondary care resources by high risk patients in the UK
Intervention: Predictive modelling tools
Comparison: N/A
Outcome: Sensitivity, specificity and positive predictive value

Q2. Has using predictive modelling tools to help target interventions to high risk patients been shown to improve quality of care and reduce the use of secondary care resources in the UK?

Q2:
Problem: Increased use of secondary care resources by high risk patients in the UK
Intervention: Targeted interventions, for example. Case management (community matrons, polyclinics, virtual wards, health coaching etc) for high risk patients using predictive modelling tools.
Comparison: N/A
Outcome: secondary care resources (emergency hospital admissions), quality of care

3. Introduction

Over a million emergency admissions to hospital each year are accounted for by people being repeatedly admitted via Accident and Emergency.[2] The increase in the older population will result in a proportional increase in the number of long term conditions such as heart disease, chronic lung disease and diabetes, and an increase in emergency hospital admissions.[2] Patients with long term conditions are among the costliest to treat, and account for around a third of emergency admissions to NHS hospital beds in the over 65s.[25]

There has been an increase in emergency admissions with very short stays (0 days) and longer stays (7+ days), in the East of England.[4] Emergency admissions directly from Accident and Emergency (A&E) are rising, while admissions referred by GPs are falling.[4] Improving the services for high risk people, especially those with long term conditions, is an important constituent of the NHS agenda[1] and identification of people who are at risk of multiple hospital admissions is a key issue in implementing the strategy.[1]

A key issue for any health organisation is to identify patients who are at high risk of emergency hospital admissions and for whom targeted interventions will be more appropriate. The identification of high risk patients in the general population is termed as "case finding". The different approaches used for case-finding are threshold modelling, clinical modelling and predictive modelling.[6] The issue related to case finding that has been highlighted in the literature is that of changing risk profiles. Many case management programmes make the implicit assumption that an individual's level of risk and health service utilisation behaviour is sustained. However, figures from the US show the opposite. In one insurance company, the highest cost members represented 1% of members and accounted for 21% of total cost in 1998 but this same 1% of members accounted for just 7% of total cost in the following year without intervention.[32]

An indication of who is at risk of using future secondary care resources is useful as today's high cost patients will have lower costs in the future even without targeted intervention, a phenomenon called "regression to mean".[31] For example, patients who are high users of secondary care resources this year will most likely improve next year without any intervention.[6] This means targeted interventions (such as case management) can be more beneficial to the patients at risk of future hospitalisation, rather than being offered to patients who are currently using high levels of resources.[6] Predictive modelling is a process that identifies people at high risk of future utilisation of medical resources.[9]

In England, several predictive modelling tools are available but none are used systematically. The Department of Health and SHAs (Strategic Health Authorities) commissioned the King's Fund, Health Dialog and the New York University to develop the PARR (Patients At Risk of Re-admission) Model and Combined Predictive Model. The HUM (High-impact User Manager) tool was developed by Imperial College London, University College London and Dr. Foster Intelligence; and the RISC (Risk Information System for Cost) tool was developed by United Healthcare. The SPOKE (Sussex Predictor Of Key Events) and PEONY (Predicting

Emergency admissions Over the Next Year) tools are also used in the NHS. A brief summary of these predictive modelling tools can be found in the appendix 1.

The broad aim of targeted interventions (such as case management) is to develop cost-effective and efficient ways of coordinating services in order to improve quality of life and reduce use of secondary care resources.[25] Case management has been defined as "the process of planning, co-ordinating, managing and reviewing the care of an individual".[25] There is, albeit limited, evidence that targeted interventions (such as case management and self-management) can improve the quality of care in patient sub-group (for example, patients with long term conditions or elderly people)[26]. However, it is unclear whether targeted interventions can reduce emergency hospital admissions.

The literature review done by the King's Fund 2004,[25] found that there is limited evidence to suggest that case management for older people can reduce the use of health services. The evidence was drawn from studies of different populations of older people living in different settings and countries. The included studies discussing case management used different case finding tools such as threshold modelling, recent resource usage and population programmes.[25]

After becoming aware of the Evercare programme (a case management approach) success, that was developed for the US government in 1987, the Department of Health commissioned the United Health Group to undertake an evaluation of the Evercare programme in 9 sites across England. The Evercare programmes were intended to improve care for frail elderly patients for whom targeted interventions would be most appropriate and help in improving quality of care and reducing emergency admissions.[27] The Evercare evaluation found positive results on the quality of care for patients. Use of the programme also led to a fall in the rates of hospital admissions, however, much of this was reported due to the "regression to mean" phenomena.[27] Some Evercare project sites used threshold modelling for case-finding. Evidence suggests that threshold modelling has not shown good accuracy when applied to the general population.[6]

The first objective of this rapid review of the literature is to examine the effectiveness of these predictive modelling tools in identifying patients at high risk of future use of secondary care resources (e.g. Emergency hospital admissions). Because very little scientific evidence exists on the effectiveness of the predictive modelling tools used in the NHS, this report is limited to a description of the PARR and the Combined Predictive Models, as in these two cases, more detailed information was available from technical reports.

The second objective of this review is to assess whether using predictive modelling tools to help target interventions to high risk patients has been shown to improve the quality of care and reduce the use of secondary care resources. Because very little evidence exists on the effectiveness of the targeted interventions to high risk patients, using predictive modelling tools in the NHS, this report is limited to a description of the available targeted interventions currently commissioned by PCTs using predictive modelling tools.

4. Methodology

Other predictive modelling tools were not included in this document because of a lack of information regarding their use at PCT level in England. The studies reporting the validation of predictive modelling tools such as PARR, Combined Predictive Model and PEONY were conducted by the individuals who were involved in the development of the modelling tools.

a. Search Strategy

The literature search was performed on Medline, Pubmed, Embase, DARE, Cochrane databases and TRIP. Publications from The King Fund's were also reviewed. The combinations of key words used to conduct the search were: PARR, patients at risk of rehospitalisation, Combined Predictive Model, patients at risk of hospitalisation, patients at risk of readmission, patients at risk of admission, predictive model*, patient readmission, chronic disease, risk assessment, case management, models and forecasting.

b. Study selection

There were no independent scientific papers describing the effectiveness of the predictive modelling tools currently used in the NHS, England. As such, the authors relied on technical reports and information available on the tools' developers website to perform the analysis. The quality of included reports was not assessed and there was no need for inclusion, exclusion criteria. The findings in this review should be treated with caution as the reports analysing the sensitivity, specificity and positive predictive value of the tools were written by the organisations involved in the development of the tool.

5. Literature review

a. Development of the PARR and Combined Predictive Model

In 2005, Essex Strategic Health Authority commissioned The King's Fund to develop an algorithm to identify the population at risk of multiple hospital admissions on behalf of the Department of Health, the NHS Modernisation Agency and England's Strategic Health Authorities.[1] The project was divided into three phases. Phase one consisted in the literature review on the predictive risk tools. In phase two, software that could identify patients at risk of re-admission (PARR Model) was developed. Phase three built on the model developed in phase two to develop a model that could identify the wider population at risk of multiple admissions (Combined Predictive Model).[6]

The King's Fund worked with Health Dialog and the New York University to develop the Patients at Risk of Re-hospitalisation (PARR) tool (Phase two). In the PARR+ tool the user had a choice of two algorithms (PARR1 and PARR2). PARR1 was only triggered by an admission for a "reference condition", (For example, if you were admitted today for a fall, the tool will not pick you up). PARR1 was very focussed on people with current long term condition flare ups. PARR2 was much wider and was triggered by any admission, whatever the cause. Later on it turned out that not many people were using PARR1 as it identified very few people – often, the admitted patients did not have an accurate diagnosis or the reference condition had not occurred. The software was later updated and the latest version is PARR ++ (which uses the PARR2 algorithm) released in November 2007. PARR ++ uses inpatient data to identifying patients who are at risk of *re-admission* to a hospital within the next 12 months.[1]

In phase three the Combined Predictive Model was developed and released by The King's Fund in December 2006. The Combined Predictive Model selects inpatient, accident & emergency, outpatient, social services and GP data. The Combined Predictive Model identifies the population at risk of *admission* to hospital who might not be selected by the PARR++ software.[9]

b. Results of Phase One: literature review on predictive models

Evidence suggests that targeted interventions to high risk patients can improve health outcomes but some frequent users might not be appropriate for targeted interventions. Identification of high risk patients is an important aspect of targeting interventions to improve quality of care and reduce emergency hospital admissions.[6] "Case finding" is the term given to identifying high risk patients from a population. The literature review undertaken to produce the PARR and Combined Predictive Model tools identified three core methods for case findings.[6]

i. Threshold modelling

These models have been widely used in the UK in case-finding projects. They use a set of previously designed criteria which define or describe high risk patients. No statistical modelling is used in these models. Evidence suggests that these models have not yielded a high degree of accuracy within a general population. They were found to be more accurate when used within a specific clinical context, such as

identifying those at risk of coronary heart disease[6] but were inaccurate for predicting future risk in a general population. These models are predisposed to the negative effects of selection bias and regression to mean phenomena. Formal evaluation of these models is rare. It is suggested that these models are around half as accurate as other predictive models, therefore, they are no longer frequently used in the US for assessing risk.[6]

ii. Clinical Knowledge

These can only identify who is at risk now but are not able to accurately predict future high risk. For this approach, the clinicians use their instinct, knowledge and training to identify people who are at high risk and most suitable for an intervention. Using this technique to predict future risk in a large general population would be inefficient.[6]

iii. Predictive modelling

These establish relationships between a set of variables in order to predict future outcomes. They generally integrate formulae which allow users to interpret past data and make forecasts about the future and map associations and statistical relationships to specific targets. They then forecast potential events based on the identified associations.[29]

Predictive modelling tools can forecast future events. In contrast to the other methods, this approach is more likely to have good sensitivity and specificity. Numerous published studies, predominantly in the United States, have used statistical modelling to predict the future risk of hospital admissions in individual patients.[3] Routine hospital episode statistics can be used to identify patients at risk of multiple hospital admissions.[5]

Evidence suggests that predictive modelling has good projecting ability in identifying high risk patients, however, within the category of predictive modelling there is a variety of techniques used.[6] With regression models predictive power varies according to the data variables used.[6] There is no consensus amongst the papers as to which variables produce the highest predictive power, however, the majority of papers found that socio-demographic variables alone do not show high predictive power and that the inclusion of diagnostics and prior utilisation data to demographic variables increases power significantly.[6]

c. Description of the PARR Model and Combined Predictive Model

There were no scientific papers identified in the literature search analysing the effectiveness of PARR and the Combined Predictive Model in identifying high risk patients. The reports used in this literature review were produced by the individuals who were involved in the development of these tools.

PARR++ can only identify the higher risk group of the population. It uses data from individuals who already have had an emergency admission. It uses the past three years of an individual patient's data to provide a future twelve months prediction. Whereas the Combined Predictive Model does the segmentation of whole population in

different risk groups. The stratification done by the Combined Predictive Model can be explained by the Kaiser Permanente's risk triangle in figure 1.[15] The population breakdown done by the Combined Predictive Model divides the population into those at very high risk of admission and those at low risk of admission. The Combined Predictive Model gives the opportunity to tailor interventions according to the needs of the identified at risk groups. The patients in the top 0.5% predicted risk segment were 18.6% times more likely than the average patient to have an emergency admission in the year following prediction. The Combined Predictive Model helps the PCT commission and organise interventions according to the identified populations risk group. Different levels of interventions that can be provided to the risk groups are shown in figure 2.[15] This ability to apply interventions in a targeted fashion can increase efficiency.[15]

Figure 1 and Figure 2 shows the segmentation of the patient population using Combined Predictive Model and the stratification results derived from the Model.[15]

Figure 1

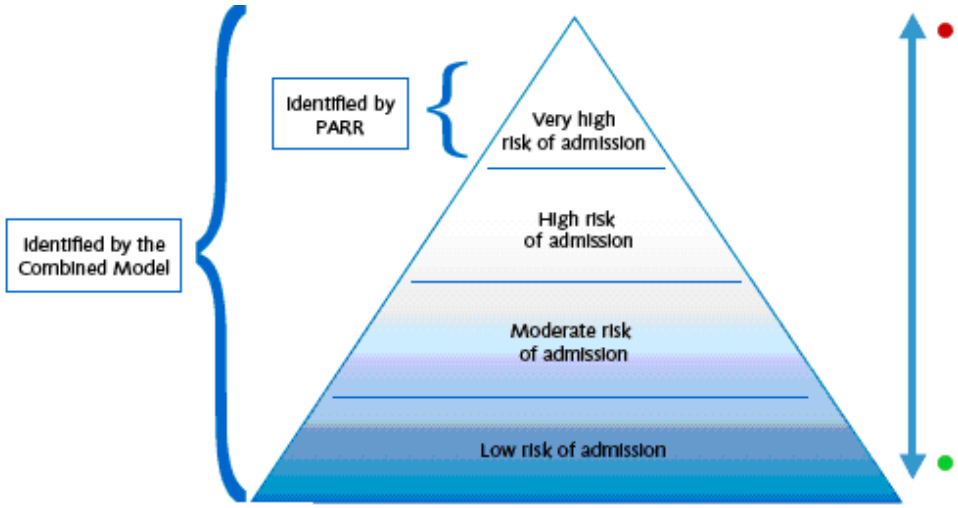


Figure 2

Relative Risk	Population%	Emergency admits	OP visits	A&E visits	Interventions
Very High Relative Risk	O.50%	18.6 X average	5.8 X average	8.5 X average	Case Management
High Relative Risk	0.5% - 5%	5.5 X average	3.8 X average	2.9 X average	Disease Management
Moderate Relative Risk	6% - 20%	1.7 X average	1.9 X average	1.4 X average	Supported Self Care
Low Relative Risk	21% - 100%	0.5 X average	0.6 X average	0.8 X average	Prevention & Promotion

The distinctive characteristics of PARR++ and the Combined Predictive Model are summarized in Figure 1. A more detailed table can be accessed in appendix 2.

Figure 3

Characteristics	PARR++ Model (same algorithm as PARR2)	Combined Predictive Model
Data Used	Only inpatient data used.(Patients who are admitted in hospital).[8]	Wider population data (Inpatient, accident & emergency, outpatient, social services, GP data) used.[9]
Population Identified	Can only identify patients who are at risk of **readmission**. (who had an admission earlier).[9]	Can identify patients at risk of hospital **admissions**. (even the ones which are not identified by PARR++).[9]
Limitations	Can not identify emerging risks. (Patients who have not been admitted previously).[9]	It is not a downloadable tool and can be implemented only in PCTs that are already (or are working towards) integrating storage of primary and secondary care data, such as through data warehousing.[14]
Cost	It's a free software that can be downloaded from the King's Fund website.	It's a free algorithm that can be downloaded from the King's Fund website. Software needs to be developed by individual PCTs with the help of either their in-house expertise or by the private companies. Prices widely vary in private companies.
Adoption of the Model	PARR++ is easy to adopt. The software is free. Download the software, install it, put in three years data and then add your SUS data every month. It takes about thirty minutes.	The Combined Model is difficult as there is no tool to download. It must be build locally or commissioned through a private company. PCT needs a programmer with intermediate skills and knowledge of SAS or SQL.[9]

It depends on the individual PCT how frequently they want to run either tool. PARR++ algorithms are designed for application in real time while the patient is still in hospital. However because obtaining information in real time can be difficult, the PARR++ can also be used using an archival approach. This approach involves analysis of archived hospitalisation data on a monthly or annual basis. The monthly approach is as effective as the real time approach in predicting risk of future admissions.[8] It is recommended that the PARR model is run monthly as Secondary Uses Service (SUS) data is updated on a monthly basis. The Combined Predictive Model can be run monthly or bimonthly. The frequency for running the Combined Predictive Model may depend on the availability of GP data.

d. Impactibility Models

Predictive modelling tools can be used to identify patients at high risk of unplanned hospital admissions, however, some of these identified high risk patients may not be suitable for preventive care. A recently published study by Dr. Geraint Lewis 2010,[24] explained the development of "impactibility models", which aim to identify the subset of high risk patients for whom targeted interventions might be more successful, however, it is not evidence based. A "predictive impactibility model" can be defined as one that,

"...predict[s] who will acquire a disease, an adverse event related to a disease, or change from one health (functioning) state to another, where these outcomes are

impactible with some specific intervention such as taking or stopping a medication, doing a test, reducing avoidable medical costs, making a behavioural change, or changing the person's environment."[30]

The study used semi-structured interviews with representatives from thirty American organisations that build, use, or appraise predictive models for health care. The study found that impactibiliy models may refine the output of predictive models by:

- Giving priority to patients who are most likely to benefit from targeted interventions.
- Excluding patients who are least likely to respond to targeted interventions.
- Showing the care most suitable to an individual patient's characteristics.

Dr. Geraint Lewis, a public health physician who developed and implemented the virtual wards project in Croydon PCT and during 2007-2008, explored the use of predictive modelling tools in the United States and stated that:

"By using predictive modelling tools, patients can be identified who are at high risk of unplanned hospital admission. However, some of these people may not have risks that can be mitigated. In order to distinguish those high-risk patients whose risk can be reduced versus those whose risks cannot be reduced, some organisations are developing "impactibility models". Impactibility models seek to identify the subset of high-risk patients whose risks can be mitigated."

"Impactibility models have the potential to make hospital-avoidance interventions more effective and cost effective. However, if used inappropriately, certain types of impactibility models could also increase health inequalities. For example, an impactibility model might recommend excluding people with a history of mental illness or alcohol misuse because they might be more difficult to work with."

e. Validity of the PARR and Combined Predictive Model

Sensitivity and specificity are the two most important criteria for assessing the performance of a case finding algorithm. The PARR model can help by assigning a risk score from 0.1 – 100 to individual patients. The higher the risk score, the higher will be the sensitivity and specificity.[3] For example, at a risk score of 50, the PARR model accurately predicts readmission of 66% of patients.[9]

The reference comparison of Positive Predictive Value (PPV) of the PARR and the Combined Predictive Model will be between PARR2 and the Combined Predictive Model (Evaluation reports mentioned PARR2 rather than PARR++ as PARR++ was not launched at the time of the report's publication. PARR++ has the same algorithm as PARR2 and almost the same Positive Predictive Value).

The Combined Predictive Model is capable of improved predictive accuracy in very high risk patients. It can stratify risk across all patients in a given health economy to help NHS organisations understand drivers of utilisations at all levels.[15] The Combined Predictive Model has added positive predictive value (PPV) as compared to the PARR model as it utilizes more datasets. Positive Predictive Value is defined as *"a reflection of the number of patients who actually had an emergency admission in*

the year following prediction out of all of the patients who were predicted to have an emergency admission within that segment".[15]

Inclusion of GP data has increased the Positive Predictive Value of the Combined Predictive Model. Figure 4[15] (appendix 3), shows that the Combined Predictive Model has more Positive Predictive Value as compared to the PARR model (73% instead of 65% in the top 250 patients). Figure 5[15] (appendix 3), shows the significant impact of GP data in the Combined Predictive Model. In the highest risk segments, the Combined Predictive Model improves predictive performance over the PARR model (i.e. PARR2)**.** For example, Croydon PCT and Devon PCT have been using the Combined Predictive Model to identify people at risk of admissions and they have found it highly effective in identifying high risk patients, however the comprehensive evaluation report was not available at the time of this review. Wandsworth PCT is also trying to adopt the Combined Predictive Model due to its wider application and high positive predictive value as compared to PARR++. They found that output from PARR++ does not identify the most appropriate cohort of patients for Community Matrons and Virtual Ward staff. Redbridge PCT has also adopted the Combined Predictive Model to identify people at high risk of admissions.

Dr. Lewis said: *"The health service can use predictive models to identify people at high risk of future unplanned hospital admission. In the United States, the Society of Actuaries*[36] *compares the predictive accuracy of different predictive models by providing competitors with two years' worth of population data. The models make predictions about what will happen in Year 3, and then the Society compares their predictor with what actually did happen in year 3. It then publishes the performance of the different models using metrics such as the r-squared and the area under the ROC curve."* NHS organisations might wish to use this method to evaluate the accuracy of tools provided by private companies.

A research project or an audit at regional or national level, to compare the accuracy of various predictive modelling tools could be beneficial for the commissioners. The accuracy of predictive modelling tools can be quantified using various measures according to its performance on sample populations. The metrics that can be used to analyse accuracy include sensitivity and specificity, positive and negative predictive values, the area under the Receiver Operating Characteristics curve (ROC curve) and the r-squared value.

f. Adoption of the PARR and Combined Predictive Model

The PARR model can easily be adopted. The software can be freely downloaded from the Kings Fund website. After installation, three years of data needs to be put in the software and then Secondary Uses Service (SUS) data can be added on a monthly basis. Due to ease of use, it has already been commissioned in several PCTs. Few PCTs are working to progress to the Combined Predictive Model despite its high predictive value compared to PARR++, due to the difficulties in adopting the model. (Lambeth PCT is doing a pilot on the Combined Predictive Model, and Wandsworth and Cornwall PCTs are also in the process of adopting the Combined Predictive Model).

The Combined Predictive Model is not a generic piece of software. Due to the complexity of using it, it has been commissioned by fewer PCTs (Croydon, Devon,

Oxfordshire, Redbridge, and Lambeth PCTs). In order to adopt this model the PCTs need a programmer with intermediate skills and knowledge of the statistical programmes, Structured Query Language (SQL) or Statistical Analysis System (SAS).[9] The other main difficulty in commissioning the Combined Predictive Model is the collection of GP data element which can be both politically and technically difficult. Croydon and Devon PCTs have developed their own software with their own in-house expertise. PCTs obtained permission from GP surgeries to set up Apollo software on their systems and extract data for the PCTs remotely. PCTs not having in-house expertise might need to commission software from other sources. PCTs should be aware that there is a huge variation in prices for this depending on the supplier. Commissioning the Combined Predictive Model for the whole region rather than a single PCT might be more cost efficient. For example, commissioners in London are commissioning the predictive modelling tool across the whole of London. PRISM (Predictive Modelling tool) has also being commissioned right across Wales. The perspectives of PCTs who are already using these models are mentioned in appendix 4.

g. Targeted interventions to high risk populations

There is good evidence that targeted interventions to people with long term conditions can improve quality of care.[28] But weak evidence that targeted interventions to people with long term conditions can reduce emergency hospital admissions.[25] The available evidence mainly discussed the role of targeted interventions (such as case management) for people with long term conditions using different case finding tools.

The literature search did not identify any high quality studies discussing the effect of targeting interventions to high risk patients using predictive modelling tools. This review describes a few of the many available targeted interventions that can be used to reduce usage of secondary care resources and improve the quality of care when using predictive modelling tools. The NIHR has recently commissioned a project to analyse if targeted interventions to high risk patients using predictive modelling tools can reduce usage of secondary care resources (emergency hospital admissions).[17]

The Kaiser Permanente risk triangle can help in stratifying the population and targeting interventions accordingly. It suggests that case management, disease management, supported self care and prevention should be provided to the population with respect to their risk groups, figure 2 and figure 3.[15] However, there is some debate as to whether targeting interventions to the top segment of the triangle is the most appropriate strategy.[6] It has been suggested that once an individual has reached this level of risk, an intervention is likely to be too late to prevent admissions. It may be of more value to target interventions to individuals in the lower strata of the triangle who are likely to move into the higher risk.[6] Further research will be needed to evaluate which risk group would most benefit from targeted interventions.

Multidisciplinary teams and GP practices need to be fully engaged in order to provide effective services to high risk individuals. The ability to tailor interventions to expected risk, based on stratification results, is critical. Practice-Based Commissioning and GP Commissioning will require that clinicians and managers use resources wisely, particularly given the current available supply of care management interventions.[15]

Targeted interventions that can be provided to the identified high risk population using predictive modelling tools through case management are: integrated social care, telephone health coaching, community matrons, primary care clinics for people with long term conditions, polyclinics and virtual wards. Multidisciplinary teams and GP practices need to be fully engaged to provide effective services to high risk individuals.

i. Case management

The Department of Health suggests that case management of people with long term conditions can effectively improve quality of life and outcomes, dramatically reducing hospital admissions and enable patients who are admitted to return home more quickly.[13] Nurse case managers have the potential to improve health outcomes for patients with long term conditions. A literature review published in 2009, found significant positive impacts of nurse managers on health outcomes such as "quality of life and functionality", "patient satisfaction", "adherence to treatment", "objective clinical measurements" and "self care and service use". The literature review focussed on people with diabetes, chronic obstructive pulmonary disease or coronary heart disease.[28] However the evidence is limited in terms of targeted interventions to high risk patients, reducing usage of secondary care resources.

Case management can be defined as "*A collaborative process which assesses, plans, implements, co-ordinates, monitors and evaluates the options and services required to meet an individuals health, care, educational and employment needs, using communication and available resources to promote quality cost effective outcomes.*"[11] Case management is also the first step to creating an effective delivery system and implementing the wider NHS and Social Care 'Long Term Conditions Model'.[13] The Department of health has recently published an evaluation report on Partnerships for Older People Projects (POPPs). The report suggested that targeting interventions to people with long term conditions can improve quality of life and it can be cost effective.[16]

There are six core elements of case management and any or all of them may be used in a particular setting.[25]

- Case finding
- Assessment
- Care planning
- Implementation/ management
- Monitoring
- Review

A literature review done by The Kings Fund 2004, found that there was weak evidence for the effectiveness of case managers in reducing emergency hospital admissions in elderly patients.[25] Eighteen studies reported emergency hospital admission as an outcome. Only two RCTs found a significant difference between the control and intervention groups. Of the studies reviewed, five demonstrated significant reductions in admissions, four found reductions in admissions that were not statistically significant, and seven studies found no difference. Two studies

included in the analysis showed non-significant increase in admissions. The findings of the review should be treated with caution as the included studies varied in terms of their geographical representation and the case finding tools used.

The evidence around case management programmes, reducing emergency hospital admissions is weak. The Evercare pilot programme evaluation suggested, that reported reductions in hospital admissions found in the analysis could be due to the "regression to mean" phenomena.[35] As discussed earlier, the Evercare pilot programmes used different case-finding tools for providing case management, which did not explicitly stratify patients as being at high risk of future emergency hospital admissions.

A recently published systematic review[33] analysing the effectiveness of case management for frail older people or those with chronic illnesses found that patient advocacy case management did not increase service use or costs in frail older people or people with chronic illness and there was some evidence of cost reductions. Eight RCTs were included in the review. Two RCTs were assessed as high quality, four as good and two as weak. The included studies were set in the USA, Canada and Europe. Although the review was well conducted, the findings were difficult to analyse due to heterogeneity between the included studies. There was no convincing evidence to support the author's conclusion that case management did not augment service use or costs. The authors' conclusions should be treated with caution due to lack of strong consistent evidence.

Case management for high risk patients identified using predictive modelling tools can be provided via community matrons, health-coaching, polyclinics and virtual wards etc. PCTs perspectives regarding using predictive modelling tools and providing targeted interventions to high risk populations are mentioned in appendix 4. This review provided the description of available interventions that can be provided to the high risk patients using predictive modelling tools.

1. Community matrons

The NHS Improvement Plan (2004) described an innovative clinical role for nurses in England, known as community matrons. These experienced, skilled nurses use case management techniques for patients who meet criteria denoting very high intensity of health care.[14, 34]

Case management work of community matrons and case managers is central to the government's policy for the management of people with long term conditions and who are at high risk of emergency hospital admissions.[14] Community matrons and case managers can support patients with long term conditions through an integrated care approach, support patients to remain at home, give support to care homes (e.g. improved care pathways for diarrhoea, vomiting and dehydration at care homes), work in A&E on weekends and effectively coordinate multi-disciplinary teams.[10] Community matrons and case managers can play a significant role in improving care for patients with long term conditions and in reducing emergency admissions.[14] However the evidence around a reduction in emergency hospital admissions is weak.

Introducing community matrons into PCTs can help people with long term conditions receive support at home and they can be contacted easily by the patients if required. This stops patients calling 999 and visiting emergency hospital department unnecessarily.[10] Community services and community matrons need to be engaged with GP services and other social care teams. Engaging these services effectively so that they can work as a team is a difficult task. PCTs will need individuals with outstanding leadership qualities for it to work effectively. Volunteers from different backgrounds can also be engaged to work in hospitals, community and residential homes. These volunteers can be trained by healthcare professionals to gain the maximum output.[10]

Community matrons are already in place in many PCTs looking after people at risk of multiple emergency hospital admissions and engaging between the patients, their GPs, their pharmacists, secondary care hospitals and care homes.[10] Lambeth and Redbridge PCT's provide support to targeted high risk patients using case managers and community matrons. A pilot is in progress in Lambeth PCT, based on the Combined Predictive Model to identify people at high risk of admissions and provide support using case managers and community matrons.

2. Polyclinics

Polyclinics have been commissioned by NHSR (NHS Redbridge PCT) to provide targeted interventions to high risk patients using identified using predictive modelling tools. The clinics in NHSR are used to improve engagement of primary care, secondary care and community services. These clinics engage with the population for the prevention of disease, treating patients with long term conditions and providing urgent care close to home.

There were no published evaluation reports available in the public domain that analysed the role of polyclinics in reducing the burden on secondary care. An evaluation at a later stage will be essential to assess how polyclinics help in reducing emergency hospital admissions and improving patient's quality of care following identification using predictive modelling tools.

3. Virtual wards

The concept of Virtual Wards has been recently introduced to PCTs and is already running in many PCTs. Virtual Wards are said to be virtual because there is no physical ward. Predictive modelling tools have been used to identify high risk populations and those populations are provided with the necessary support through Virtual Wards. There are three defining elements of the Virtual Ward model :[12]

1. Use of predictive risk modelling to select eligible patients. (Case finding)
2. Multidisciplinary case management of complex patients identified by the predictive modelling tools.
3. Provision of care in patients' own homes

Virtual Wards are mainly run by Community Matrons. The staff led by the Community Matron provide support to patients assisted by healthcare assistants, pharmacists, social workers, dieticians, occupational therapists, physiotherapists, voluntary sector helpers and ward clerks.[7] For Virtual Wards to be successful they need to be linked with GP surgeries.[7] Engagement between GP services, the community services and multi disciplinary teams is necessary for Virtual Wards to be effective. Two Virtual Wards were initially piloted in Croydon PCT using the Combined Predictive Model to assess risk. There are currently 10 permanent Virtual Wards working in Croydon PCT. The top 1000 patients (0.3% of Croydon's population) are admitted to Croydon Virtual Wards from the highest risk down, and provided with Case Management. Virtual Wards are also being piloted in Wandsworth PCT and Devon PCT and are still under evaluation so comprehensive results are not available yet. However, the anecdotal evidence is very positive, patient and professional feedback has been excellent.

An evaluation report produced by Croydon PCT, (2008) failed to construe any statistical significant association between Virtual Wards and emergency hospital admissions. However, clinical findings suggested some reduction in emergency bed days. The report concluded that Virtual Wards are a relatively new service in Croydon, so further evaluation is warranted at a later stage.[12] There is good evidence that case management improves quality of care for high risk patients, but weak evidence that it reduces emergency admissions or bed days.[12] Community services need to play a major role for targeted interventions to be effective and cost effective. Getting GP engagement with community services and multidisciplinary teams is crucial, and not easy. People with strong leadership qualities are required to run these services.

There is no high quality evidence stating that providing these interventions to high risk groups using predictive modelling tools can reduce emergency hospital admissions although it certainly can improve the quality of care. Virtual Wards can function better compared to independent community matrons as a specialist group. Virtual Wards can provide better support to high risk individuals and they can be more organised in dealing with high risk patients. For example, pharmacist and physiotherapist in Virtual Wards can provide better support to patients with respect to medicines or physiotherapy compared to individual community matrons.

ii. The NIHR project

In April 2010, the National Institute for Health Research (NIHR)[17] confirmed that it would fund a large scale study to evaluate Virtual Wards in Croydon, Devon and Wandsworth PCTs. The grant was awarded to a team of researchers from the Nuffield trust, New York University and the University of Auckland in New Zealand. The project started on 1st May 2010 and will run for approximately 18 months. The project will emphasise on establishing the costs and benefits of running Virtual Wards, especially in terms of any reductions in hospital admissions. The conclusions of the project should help councils and the NHS to decide whether to commission projects like Virtual Wards.

6. Limitations

The literature search did not find any independent scientific studies interpreting the effectiveness of PARR++ and the Combined Predictive Model in identifying people at risk of emeregncy hospital admissions in England.

There were no good quality scientific papers identified analysing if targeted interventions to high risk patients using predictive modelling tools could reduce usage of secondary care resources.

There are various projects in progress at different PCTs but no comprehensive report or internal evaluation is available yet.

The reports on PARR++ and the Combine Predictive Model discussing the positive predictive value were produced by the organisations who were involved in the development of those tools.

The comparison of these tools with other tools (High-impact User Management, SPOKE, PEONY and RISC tool) was not possible due to the lack of available information regarding the other tools and their varied functionality.

This rapid literature review did not cover all predictive modelling tools and available targeted interventions that could be provided to the identified high risk patients.

This rapid literature review did not discuss the load a case manager or a community matron could effectively manage.

The EAC literature search identified no published studies that considered the effectiveness of the PARR tool, the PARR ++ tool or the Combined predictive model tool. It would be necessary to undertake a quantitative study of effectiveness, in terms of quality of life improvements and/or reduced admissions, before a full economic analysis could be undertaken. At that point two questions could be asked: Is predictive modelling a good use of scarce NHS resources and, if so, are any of the existing predictive models dominated (i.e. are more costly and less effective) by one of the alternative models?

7. Need for further research

A research project or an audit at regional or national level, to compare the accuracy of various predictive modelling tools could be beneficial to primary care commissioners in the future.

There is a lack of evidence to suggest that targeting interventions to high risk populations using predictive modelling tools can reduce emergency hospital admissions. Further research would be required to analyse the efficacy of these tools in identifying populations at risk of multiple admissions and the effectiveness and cost effectiveness of targeted interventions provided to the population at risk (role of case management, community matrons, polyclinics, virtual wards, etc) using predictive modelling tools.

Further research is required to analyse which risk groups would most benefit from targeted interventions in the risk stratification triangle.

8. Conclusions

Predictive modelling tools:

- Predictive modelling tools cannot reduce emergency hospital admission by themselves.
- Predictive modelling tools show good projecting ability in identifying high risk patients in a general population,[6] However, there is no evidence that they can be helpful in reducing emergency hospital admissions through targeted interventions.
- Internal evaluation of available predictive modelling tools will be essential at local PCT level before implementation.
- Commissioners not having in-house expertise to commission predictive modelling tools will be required to learn from the experiences of other PCTs and compare prices from private companies as prices vary widely among suppliers. These variations in cost cannot be explained by differences in PCT demographics alone.

Targeted interventions:

- There is good evidence that targeted interventions to high risk patients can improve their quality of care, However, because the interventions studied to date were targeted using different case finding tools it is not possible to compare which one dominates in which setting

- There is a lack of evidence that interventions (role of community matrons, virtual wards, case management etc) targeted to high risk patients using predictive modelling tools can reduce emergency hospital admissions. Further research is needed to evaluate the full impact of predictive modelling tools on service utilisation.

9. Recommendations

Some PCTs have begun to use predictive modelling tools in an effort to focus resources more effectively. The case for using predictive modelling tools in primary care is stronger than it has been. Predictive modelling tools can help in stratifying the population with respect to their risk profile.

Targeting interventions to high risk patients can improve their quality of care, however, further research is required to assess if targeting interventions to identified high risk patients using predictive modelling tools can reduce emergency hospital admissions.

The recently funded 18 months project by the NIHR[17] would help NHS commissioners to decide whether commissioning projects such as virtual wards could be effective in reducing emergency hospital admissions.

10. Appendices

a. Appendix 1: Other Predictive modelling tools

High-impact User Manager (HUM) Tool[18]:
Dr. Foster Intelligence, in conjunction with Imperial College London and University College London, has developed the HUM system that enables primary care trusts and GP practices to access up-to-date information via the web and to conduct their own analyses to generate the list of potential high impact users of secondary care.

The high impact user has been defined as "Patient who has had at least three emergency admissions within a 12-month period. Any high-impact user with at least one of the qualifying admissions being for an Ambulatory Care Sensitive (ACS) condition." The details regarding the Ambulatory Care Sensitive can be accessed from their website.

The cost of the HUM tool is 15p per head of the population. There are no additional costs with the software. The addition support is provided free of cost to the PCTs. Access to the web-based systems can be via any computer with internet access either office or home-based. The data is stored on secure servers and cannot be accessed without knowing the URL, username and the password.

The limitation of the model is that it only stratifies the patients who have already been admitted at least three times in the last 12 months. It will only analyse the risk of emergency readmissions in the hospital, whereas, the new predictive models can stratify the risk of emergency admissions in the hospital.

Sussex Predictor of Key Events (SPOKE) tool[19]:
Spoke has been developed by the Sussex HIS. SPOKE is a predictive modelling tool, like PARR++ and the combined predictive model. SPOKE has been created using local data so it understands the local practices and coding. It calculates an admission from 0-100 % for each person in the Sussex population. The score created is the risk of chronic emergency admission in next 12 months. The primary care data is not currently used in the SPOKE model.

SPOKE has the ability to predict risk for specific conditions, for example, diabetes. It can be updated regularly so it reflects the latest healthcare activity delivery model. The SPOKE model as used in the East Sussex, provides predictive power comparable to the other national models (PARR++ and combined model). Sussex HIS will work with the Sussex PCTs to develop a generic, secure process for extracting the primary care data from the GP systems and incorporating this data into the SPOKE model, along with the other data sets.

SPOKE algorithm is available free of charge to the PCTS, provided Sussex HIS are acknowledged for the contribution. The Sussex HIS can provide support to run a pseudonymised population risk score calculation for any PCT population. The technical documentation can be used to analyse the predictive power of the model on other populations.

RISC tool[20]:
The RISC tool has been developed by the United Health Care[21]. RISC organises data about the patients to identify the risk factors and calculate a score that predicts the patients most likely to have an unplanned hospital admissions in the next 12 months. RISC reports provide excellent information for commissioners to analyse specific area pathways and target interventions accordingly. Free support and training is provided to the PCTs to fully appreciate the report outputs.

RISC identifies patients who are suitable for case management, disease management or self care programmes. RISC can provide a systematic look at the change in healthcare utilisation patterns for specific patients, helping to monitor and assess the success of various interventions. RISC data sources include census, registry data, A&E visits, consultant and GP visits and drug history etc.

RISC is currently used by the Somerset PCT. There are no internal evaluation reports available to analyse the RISC tool.

Predicting Emergency admissions Over the Next Year (PEONY) tool[22]:
PEONY has been build by Peter T. Donnan, Professor of Epidemiology and Biostatistics in the University of Dundee, Scotland. The tool has been commissioned in the NHS Tayside, Scotland. The key features of the model are that it includes people with and with no previous admissions. It includes everyone from the age of 40 years upwards. PEONY II will be developed at the later stage which will only use the primary care data and so does not require linkage with the secondary care data.

The PEONY model can be implemented at the individual patient level as well as family practice level to target case management. The key factors used in the model to identify the high risk patients are: demographic, history of hospital admission in previous three years, history of prescriptions in previous three years, number of prescriptions in previous three years etc. The sensitivity, specificity and Positive Predictive Value can be found in the figure 6 given below.

Figure 6[23]:

Table 4. Sensitivity, Specificity, Positive Predictive Value (PPV), Yield, and Likelihood Ratio for Different Cutoff Points for Predicted High Risk Expressed as a Percentage and Points System

Cutoff for Identification of High-Risk Patients, %	Cutoff in Terms of Clinical Scoring System, Points	No. of People 40 Years or Older Identified as Being High Risk in a Family Practice of 3000	Sensitivity, %	Specificity, %	PPV, %
≥60	>50	13	4.2	99.8	67.1
≥49[a]	>46	29	7.9	99.6	59.0
≥28	>37	154	27.1	96.8	40.6
≥18	>32	305	42.0	92.6	31.5
≥8[b]	>23	786	68.9	77.4	19.8
≥6	>20	1019	76.1	69.5	16.8

[a] Top percentile.
[b] Top quartile.

The copyright of the algorithm belongs to Professor Peter T. Donnan. The University of Dundee and Professor Peter T. Donan are working with a company so it may be possible to obtain software to run it in the near future.

b: Appendix 2: Figure 3: Characteristics of the PARR and Combined Predictive Model

Characteristics	PARR++ (same algorithm as PARR2)	Combine Predictive Model
Data Used	Only inpatient data used.(Patients who are admitted in hospital).[8]	Wider population data (Inpatient, accident & emergency, outpatient, social services, GP data) used.[9]
Population Identified	Can only identify patients who are at risk of **readmission**. (who had an admission earlier).[9]	Can identify patients at risk of hospital **admissions**. (even the ones which are not identified by PARR++).[9]
Ease Of Use	Can easily be used in PCTs. It is a free software available to NHS.[13]	Software needs to be developed to use Combine Predictive Model.[13]
Modelling Type	Predictive Modelling	Predictive Modelling
Positive Predictive Value (PPV)	PARR model can help in assigning a risk score from 0.1 – 100 to individual patients. It gives % risk of **readmission.** In the highest risk segment PPV of PARR model is less than Combined Predictive Model.[15] **For example**, 505 out of the top 1000 patients predicted by PARR model actually had an emergency admissions in the year following prediction.[15]	It can help in assigning a risk score from 0.1 – 100 to individual patients. It gives % risk of **admission.** In the highest risk segments, Combined Predictive Model improves predictive performance over the PARR2.[15] **For example**, 586 out of the top 1000 patients predicted by the Combined Model actually had an emergency admission in the year following prediction.[15] Combine Predictive Model can do the segmentation of patient population with respect to the risk of **admission.** **For example**, Patients in the top 0.5% predicted risk segment of CMP were 18.6 times more likely to have an emergency **admission** as compared to an average patient.[15]
Release Date	PARR++ (uses PARR2 algorithm) was released in November 2007 PARR+ was released in 2006. PARR was released in 2005.	Combine Predictive Model was released in December 2006
Limitations	Can not identify emerging risks. (Patients who have not been admitted previously).[9]	It is not a downloadable tool and can be implemented only in PCTs that are already (or are working towards) integrating storage of primary and secondary care data, such as through data warehousing.[14] CPM is based on Corydon's population where it was piloted, and it may need altering for other PCTs to implement it. This requires programming and analytic skills.[15]

Characteristics	PARR++ (same algorithm as PARR2)	Combine Predictive Model
Frequency of Use	PARR++ algorithms are designed for application in real time while the patient is still in hospital. However because obtaining information in real time can be difficult, PARR++ can also be used by means of archival approaches. These approaches involve analysis of archived hospitalization data on a monthly or annual basis. The monthly approach is as effective as real time approach in predicting risk of future admissions.[8]	It totally depends on ease of access to GP data and what the PCT wants to do with the result. For Example: It can be run monthly or bi-monthly.
Adoption of the Model	PARR++ is easy to adopt. Download it, install it, put in three years data and then add your SUS data every month. It takes about thirty minutes.	The Combined Model is difficult as there is no tool to download. It must be build locally using the technical documentation. This is because of the inconsistent nature of GP data. PCT needs a programmer with intermediate skills and knowledge of SAS or SQL.[9] Once it is built, the other challenge is accessing GP data. Some PCTs already do this but others have to set up the data flows. Few applications have been introduced in the market which automate the process (for example, Apollo which is used by the Croydon and Devon PCT)
Cost	It's a free software that can be downloaded from the King's Fund website.	It's a free algorithm that can be downloaded from the King's Fund website. Software needs to be developed by individual PCTs with the help of either their in-house expertise or by the private companies. The prices of private companies widely vary.
Places providing support in the development of the software in the PCT	-	Devon PCT BUPA Health Dialog UK http://www.bupahealthdialog.co.uk Health-Analytics http://www.health-analytics.co.uk/ The Computer Room, Nottingham http://www.tcr.i12.com/default.html Health intelligence limited http://www.healthintelligence.com/index.asp
Other Difficulties	-	Collection of the GP data element is both politically and technically difficult. Getting GP engagement is essential and not easy. The model has to use GP data and the information governance relating to GP data is a major issue.

c: Appendix 3: Figure 4[15] and Figure 5[15]

Figure 4[15] shows the Positive Predictive Values (PPVs)* for different cuts of population size identified by either the Combined Predictive Model or the PARR Model.

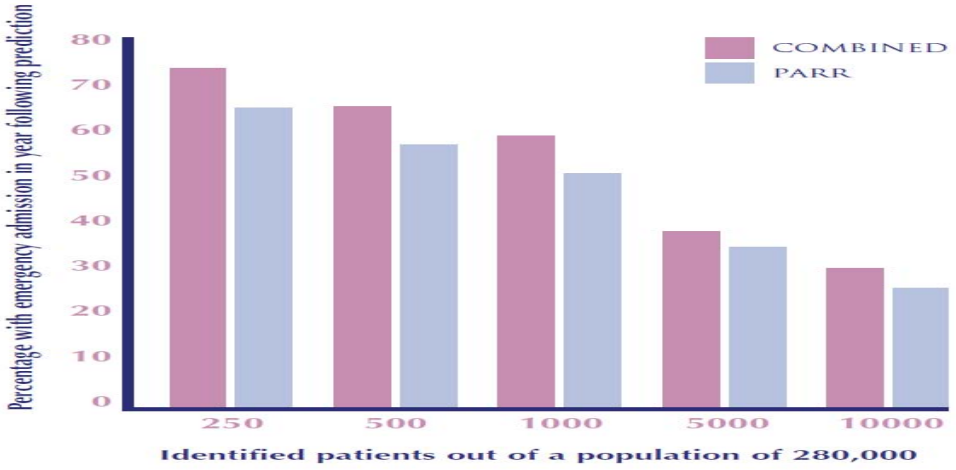
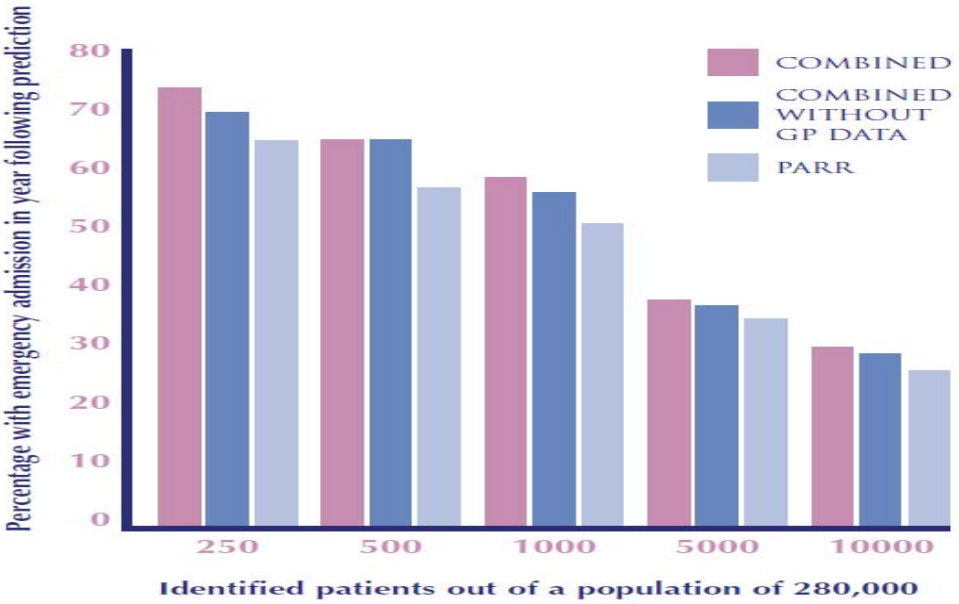


Figure 5[15]

Figure 5[15] shows the PPVs for different risk segments, for the Combined Predictive Model, with the Combine Predictive Model with GP variables separated (i.e., using inpatient, accident and emergency and outpatient data) and also compared to PARR Model.



d: Appendix 4: PCT's Perspectives

Croydon PCT:
Tool used: Combined Predictive Model (Developed by their in-house experts)
Interventions: Virtual Wards
NHS Croydon found the Combined Predictive Model to be effective in identifying the high risk patients. There is good evidence that case management improves quality of care for patients, but weak evidence that it reduce emergency hospital admissions.

Devon PCT:
Tool used: Combined Predictive Model (Developed by their in-house experts)
Interventions: Virtual Wards
NHS Devon found the Combined Predictive Model to be effective in identifying people at risk of hospital admissions and doing segmentation of the population. There is a lack of evidence to suggest that targeted interventions can reduce emergency hospital admissions. NHS Devon will be happy to share information with other PCTs looking to adopt the Combined Predictive Model.

Lambeth PCT:
Tool used: Combined Predictive Model (Developed by a private company)
Interventions: Case Managers and Community Matrons
A pilot project (based on the Combined Predictive Model) is in progress and no evaluation report is available. Previously found that the PARR++ was identifying patients who were already admitted in the hospital and was not stratifying the population.

Redbridge PCT:
Tool used: Combined Predictive Model (Developed by a private company)
Interventions: Community Services
It appears a key benefit of the Combined Predictive Model is the ability to focus resources more effectively. NHSR have compared the output to the work undertaken by the Long Term Conditions community support teams with the risk score generated by the system. The system runs in Redbridge PCT on a permanent basis. Getting GP engagement is essential and not easy. The model uses GP data and the Information Governance relating to GP data is a major issue. The GPs and community teams in the PCT are just starting to align their services and support in relation to the risk scores calculated for patients. The System also provides cost, regional and demographic data allowing polysystem to make informed commissioning decisions.

Wandsworth PCT:
Tool used: PARR++ (Planning to adopt the Combined Predictive Model)
Interventions: Virtual Wards
The output from PARR++ doesn't identify the most appropriate cohort of patients for our Community Matrons and Virtual Ward GPs. As an example some of the patients were beyond effective support from Case Managers. NHS Wandsworth found that what was needed was a caseload selection tool which would identify an appropriate

list. To this end, studies were made on how the Virtual Wards, GPs and Community Matrons actually selected their caseloads based upon available data sources such as GP Systems (EMIS) and Social Care/Intermediate Care as well as Acute (SUS).

The development of this tool is not yet finished. NHS Wandsworth is undertaking further analysis of selection criteria. So far this project has taken time from Community Matrons & GPs for case studies, informatics support for supplying/analysing data and management from public health senior mangers. NHS Wandsworth have not configured the combined model – instead NHS Wandsworth will continue to use PARR++ until the replacement is ready.

Note: The project of developing a Combined Predictive Model has stopped locally as the commissioners of London are proposing to supply a tool across the whole of London.

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