COMBINED PREDICTIVE MODEL

FINAL REPORT

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CONTENTS

IDENTIFYING RISK ALONG THE CONTINUUM

To meet national goals for reductions in emergency bed days and effective administration of practice-based commissioning, National Health Service (NHS) organisations have highlighted the need for tools to assess patient needs across the continuum of care. A risk stratification tool called the Combined Predictive Model (the Combined Model) has been developed to provide a rich segmentation of patients at each section of the continuum. The model is based on a comprehensive dataset of patient information, including inpatient (IP), outpatient (OP), and accident & emergency (A&E) data from secondary care sources as well as general practice (GP) electronic medical records.

Stratification results derived from the Combined Model are shown in Figure 1. The model was developed on a 50% random sample of data from two Primary Care Trusts (PCTs) and validated on the other 50% random sample.* All patients in the validation sample were ranked based on their risk for emergency admission and placed into segments. Relative utilisation rates are shown for patients in each segment for the ***year following prediction*** compared to average utilisation rates across the entire population. For example, 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.

Through identifying relative risk along the continuum, the Combined Model allows NHS organisations to develop and tailor intervention intensity to match the expected 'returns'.

Through identifying relative risk along the continuum, the Combined Model allows NHS organisations to develop and tailor intervention intensity to match the expected 'returns'. Previously, this level of detail and stratification were unavailable to the NHS, but the Combined Model allows for development and implementation of these strategies across patient segments.

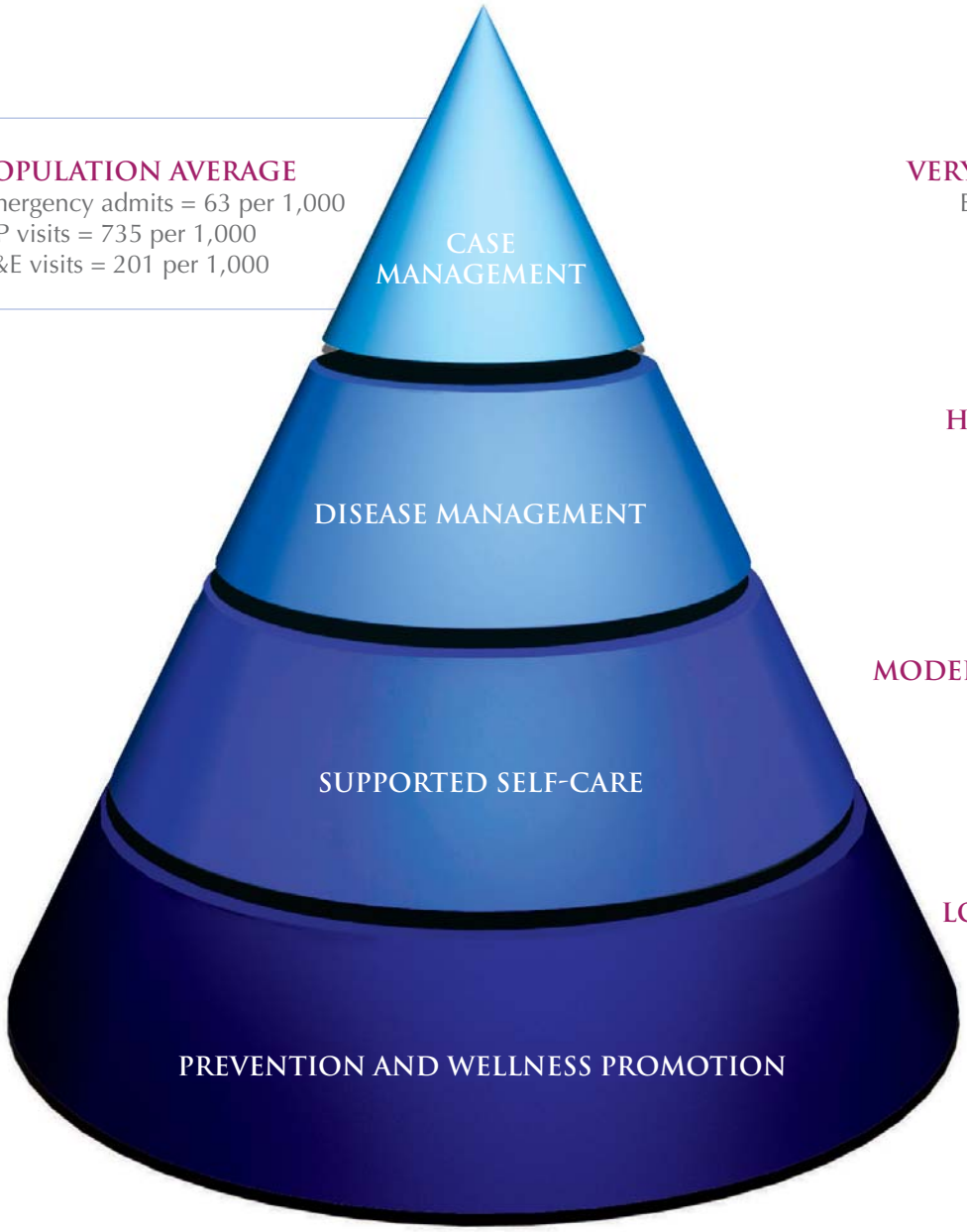
The ability to tailor interventions to expected risk based on stratification results such as these is critical for three reasons. First, Practice-based Commissioning will require that clinicians and managers use resources wisely, particularly given available supply of care management interventions. Second, while much of the current intervention focus is on the tip of the pyramid, need is distributed along the continuum. Third and most important, we recognize that more care is not always necessarily wanted or needed. A generic intervention model applied to all patients within a practice would likely increase utilisation among those at the bottom of the pyramid.[1-3]

*Analyses in the Final Report are based on validation of the Combined Model on a random 50% sample of the total population of the two PCTs which provided data for its development. The validation analyses were based on the time period of 1 April 2002-31 March 2004 to predict emergency admissions in the following 12 months of 1 April 2004-31 March 2005. More information on methodology is included in Appendix A.

FIGURE 1

SEGMENTATION OF PATIENT POPULATION USING COMBINED MODEL

POPULATION AVERAGE
Emergency admits = 63 per 1,000
OP visits = 735 per 1,000
A&E visits = 201 per 1,000



VERY HIGH RELATIVE RISK 0.5%
Emergency admits = 18.6 x average
OP visits = 5.8 x average
A&E visits = 8.5 x average

HIGH RELATIVE RISK 0.5 - 5%
Emergency admits = 5.5 x average
OP visits = 3.8 x average
A&E visits = 2.9 x average

MODERATE RELATIVE RISK 6 - 20%
Emergency admits = 1.7 x average
OP visits = 1.9 x average
A&E visits = 1.4 x average

LOW RELATIVE RISK 21 - 100%
Emergency admits = 0.5 x average
OP visits = 0.6 x average
A&E visits = 0.8 x average

Source - Health Dialog UK

BACKGROUND

THE NEED FOR PREDICTIVE CASE FINDING

The development of long term conditions management, including case management, is becoming established across England. These efforts have been 'encouraged' by the release of various national strategic papers; a national Public Service Agreement target has been set to improve outcomes for people with long term conditions. This agreement calls for a personalised care plan for vulnerable people most at risk, and includes as a goal the reduction of emergency bed days by 5% by March 2008.

Case finding is essential for effective long term conditions management. Predicting who is most at risk of emergency admissions is a critical function of case finding.

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To address this need, a package of predictive case finding algorithms has been commissioned by the Department of Health (DH)/Essex Strategic Health Authority from a consortium of the King's Fund, New York University and Health Dialog. This consortium has developed three tools. The first two are aimed at identifying Patients At Risk for Re-hospitalisation *(PARR1 and PARR2)*. PARR1 uses data on prior hospitalisations for certain 'reference conditions' to predict risk of re-hospitalisation while PARR2 uses data on any prior hospitalisation to predict risk of re-hospitalisation. The third tool is aimed at identifying risk along the continuum (the *Combined Model*). The PARR models use IP data only, while the Combined Model supplements these data with OP, A&E and GP data. The Combined Model was developed with two PCTs which supplied the data for its development.

THE PATIENTS AT RISK FOR RE-HOSPITALISATION (PARR) MODEL AND CASE MANAGEMENT

PARR1 and PARR2, tools that identify very high risk patients, have been previously released. Both use inpatient data to produce a 'risk score' showing a patient's likelihood of re-hospitalisation within the next 12 months. Risk scores range from 0 – 100, with 100 being the highest risk.

Since their release in Autumn 2005, the PARR algorithms have been widely distributed and shown to be effective in identifying patients with high utilisation of secondary care services[4]. These patients are being targeted for intervention by Community Matrons, Virtual Wards and other similar case management approaches. Given the limited data set used to identify these patients and the resulting narrow population targeted when looking only at re-admissions, the need for additional tools exists to identify patients across a broader spectrum of care needs and levels of intervention.

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THE COMBINED MODEL

THE COMBINED MODEL AND SEGMENTATION STRATEGIES

To meet this broader need and to determine whether the addition of further data sets improves predictive accuracy, a third algorithm has been developed which combines secondary care data with GP electronic records. This Combined Model is able to:

- **Improve predictive accuracy for very high risk patients**
- **Predict risk of hospital admission for those patients who have not experienced a recent emergency admission**
- **Stratify risk across all patients in a given health economy to help NHS organisations understand drivers of utilisation at all levels**

The ability to identify emerging risk patients will enable NHS organisations to take a more strategic approach to their care management interventions. For example, PCTs will be able to design and implement interventions and care pathways along the continuum of risk, ranging from:

- **Prevention and wellness promotion for relatively low risk patients**
- **Supported self-care interventions for moderate risk patients**
- **Early intervention care management for patients with emerging risk**
- **Intensive case management for very high risk patients**

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The broad application of the Combined Model will allow segmentation of an entire population into relative risk segments and facilitate matching the intensity of outreach and intervention with the risk of unwarranted secondary care utilisation. The ability to apply the intervention in a targeted fashion increases the likelihood that patients will receive the care they want (and nothing more) and the care they need (and nothing less).

WHAT DOES THE COMBINED MODEL DO?

The aim of the Combined Model is to use a broader and more comprehensive set of data to identify patients who may become frequent users of secondary care services. Through prospectively identifying these patients, the appropriate levels of outreach and intervention can be applied; from helping patients at lower risk to manage their conditions with information and self-management support, to providing intensive case management support for patients at the highest levels of risk.

The Combined Model was developed using a split sample methodology on data from two PCTs with a total population of 560,000. Details of the development methodology and population can be found in Appendix A. The model takes primary and secondary care data for an entire patient population and stratifies those patients based upon their risk of emergency admission in the next 12 months. With access to this broader set of data beyond just inpatient data, the Combined Model is not limited to identification of very high risk patients based solely on past admissions. The Combined Model offers a tool to help design, commission and implement an overall long term conditions programme strategy.

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THE COMBINED MODEL

THE COMBINED MODEL ENHANCES PREDICTIVE ACCURACY

In addition to stratifying an entire patient population and identifying emerging risk, the Combined Model is also effective in identifying patients in the very high and high risk segments of the population. In the sections below, we discuss the clinical and utilisation profiles of patients who fall into these segments, highlighting the opportunities for impact. In the highest risk segments where the most intensive outreach will be targeted, such as case management interventions, the Combined Model improves predictive performance over the PARR (i.e., PARR2) model for the same populations. Figure 2 below shows the Positive Predictive Value (PPV)* for different cuts of population size identified by either the Combined or the PARR model.

*PPV is 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. For example, 586 out of the top 1000 patients predicted by the Combined Model actually had an emergency admission in the year following prediction as compared with 505 out of the top 1000 PARR patients.

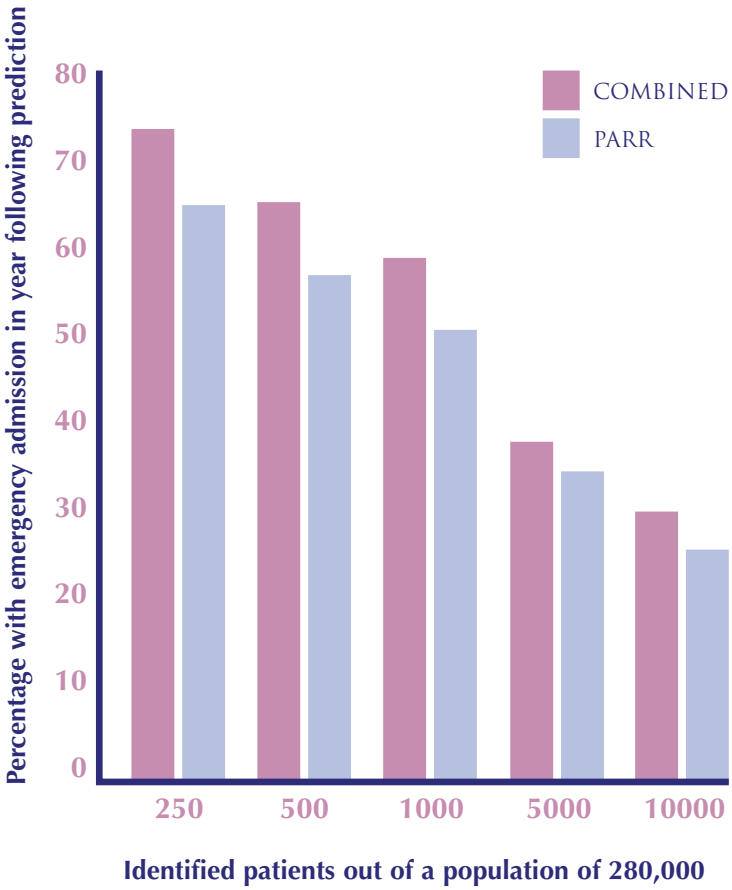


FIGURE 2

POSITIVE PREDICTIVE VALUE FOR COMBINED MODEL VS. PARR

GENERAL PRACTICE DATA ADD TO THE PREDICTIVE ACCURACY

The Combined Model was also developed to determine whether GP practice data add to predictive accuracy compared to the PARR model and against models that might include outpatient attendances and A&E data but not GP data. Figure 3 below shows the PPVs for different risk segments, still within the very high and high risk categories, for the Combined Model compared to the Combined Model with GP variables removed (i.e., using IP, A&E, and OP data only) and also compared to the PARR model. Comparing the full Combined Model against the Combined Model without the GP data included in the prediction allows one comparison of the relative impact of including GP data.

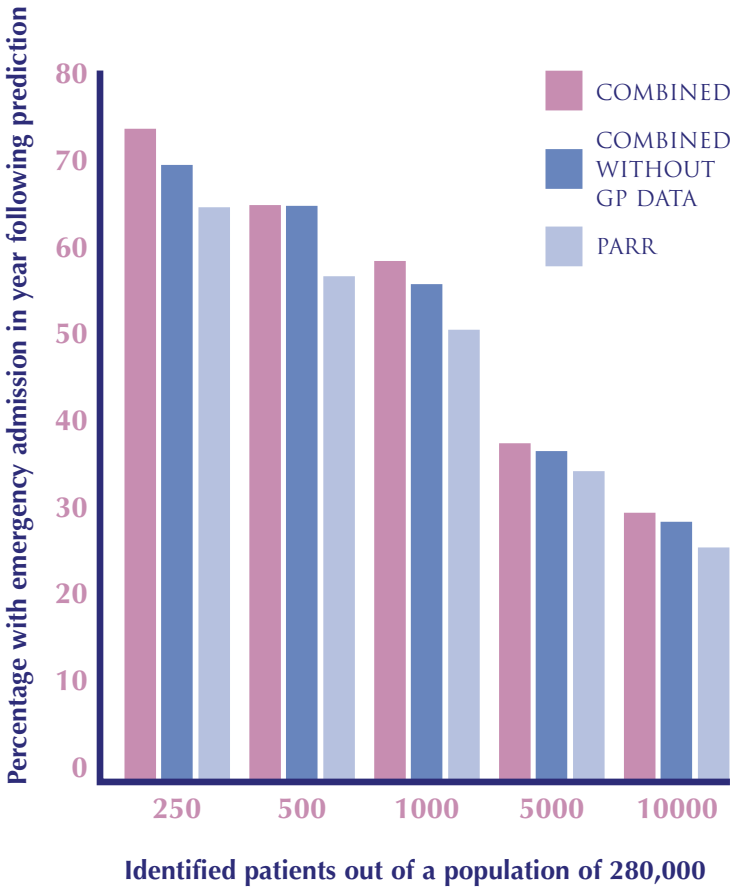


FIGURE 3

PPV FOR COMBINED MODEL WITH AND WITHOUT GP DATA VS. PARR

THE COMBINED MODEL

As highlighted on page 11, Figure 3 shows that a more inclusive model using inpatient, outpatient, and A&E data alone outperforms PARR, and the full Combined Model which also includes GP data outperforms both models at almost all risk segments.

With the additional predictive accuracy achieved by introducing the OP, A&E, and GP data sets, the 'break even' analysis of the potential cost savings that can be achieved is enhanced when compared with PARR, particularly when identifying very high risk patients. Figure 4 below shows scenarios built by running the Combined Model and PARR2 on the validation sample and focusing only on the segments where case management interventions might be most suitable. An intervention cost of £500 per patient and intervention impact of 20% is assumed. The additional predictive accuracy of the Combined Model allows PCTs to design interventions with greater potential for net cost savings.

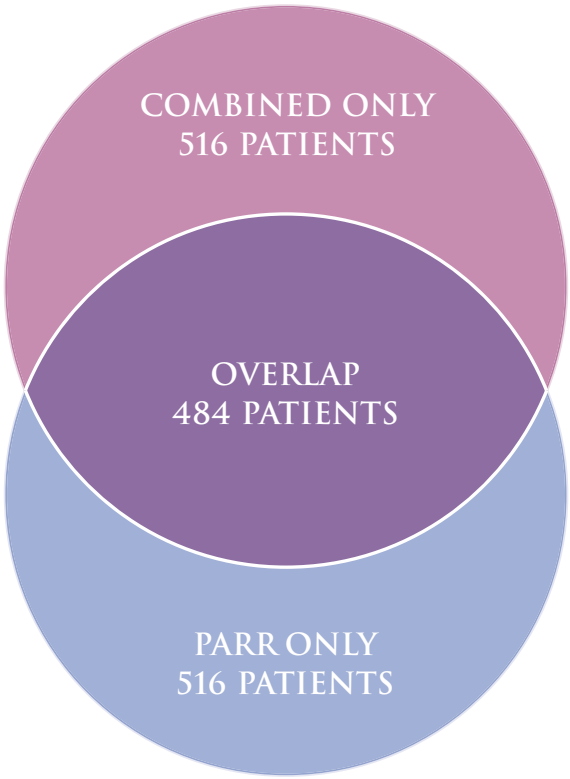
FIGURE 4

BREAK-EVEN FOR VERY HIGH RISK PATIENTS

Risk Score Cut-off		Number of true positives	Number of false positives	Cost per patient	Total intervention cost	Emergency admissions within 12 months per true positive	Estimated impact of intervention	Estimated cost per admission	Total intervention savings	Net savings or loss
Top 250	Combined Model	184	66	£500	£125,000	2.85	20%	£2,100	£220,248	£95,248
	PARR	163	87	£500	£125,000	2.75	20%	£2,100	£188,265	£63,265
Top 500	Combined Model	327	173	£500	£250,000	2.54	20%	£2,100	£348,844	£98,844
	PARR	285	215	£500	£250,000	2.71	20%	£2,100	£324,387	£74,387
Top 1000	Combined Model	586	414	£500	£500,000	2.33	20%	£2,100	£573,460	£73,460
	PARR	505	495	£500	£500,000	2.44	20%	£2,100	£517,524	£17,524

THE COMBINED MODEL INTRODUCES A NEW PATIENT POPULATION

The PARR and Combined Models identify different patients, even at the highest risk levels. The Venn diagram in Figure 5a below demonstrates the overlap between the PARR and Combined Models using the top 1,000 patients as an example: those patients who are identified in PARR only, those identified in the Combined Model only, and those identified in both models.



With the additional predictive accuracy achieved by introducing the OP, A&E, and GP data sets, the 'break even' analysis of the potential cost savings that can be achieved is enhanced when compared with PARR, particularly when identifying very high risk patients (as shown in Figure 4 on page 12).

FIGURE 5A

VENN DIAGRAM OF PARR AND COMBINED MODEL PATIENT POPULATIONS OUT OF TOP 1,000 IDENTIFIED

THE COMBINED MODEL

Figure 5b below shows the Combined Model patients at different cut points stratified into emerging risk patients, including both patients who have no prior inpatient admission history (light blue), as well as patients who have an admission history but a lower risk score from the PARR model (dark blue) and those identified by PARR (purple). For example, out of the 1000 highest risk patients identified in the Combined Model sample, approximately 48% of them would also have been identified in the top 1000 patients using PARR in the same sample. Forty seven percent of the top 1000 would have been identified in PARR but would have a relatively lower risk score. A further 5% would not have been identified at all using PARR.

The addition of patients who would have been missed by PARR altogether, due to lack of prior inpatient admissions, and patients who would have been identified at much lower risk levels by PARR, due to its reliance on inpatient data only, is significant. The Combined Model's use of richer data sets allows for risk stratification at levels conducive to more effective early intervention as it identifies patients before they have deteriorated to the point of multiple inpatient admissions.

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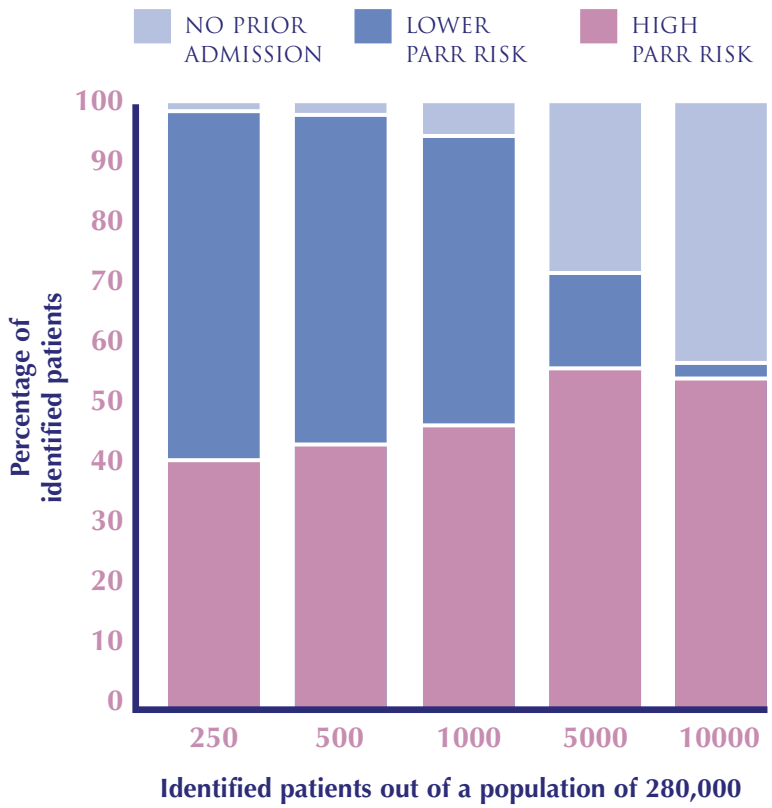


FIGURE 5B

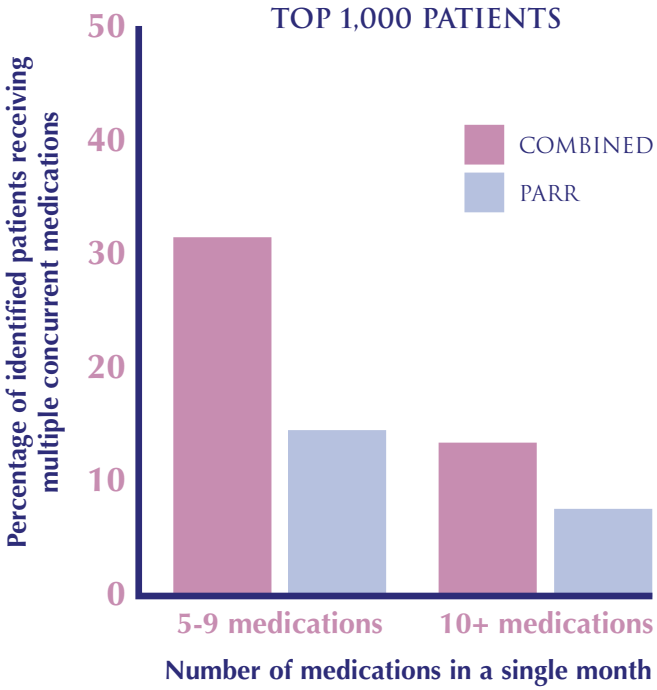
OVERLAP OF PATIENTS IDENTIFIED BY COMBINED MODEL AND PARR

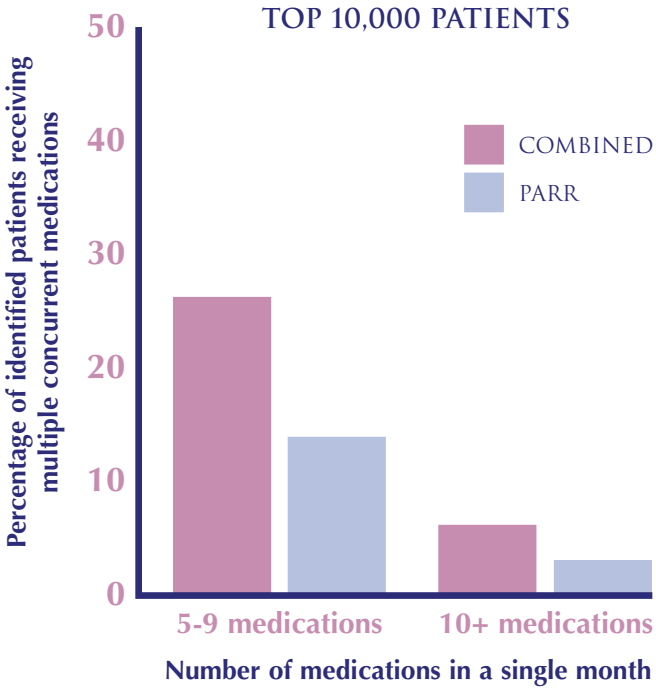
THE COMBINED MODEL IDENTIFIES PATIENTS WITH RICH CLINICAL PROFILES AND OPPORTUNITIES TO IMPACT FUTURE UTILISATION AND CLINICAL CARE

The addition of GP, OP, and A&E data sources in the Combined Model gives further clinical insights into the status of identified patients and the factors that are contributing significant risk for emergency admission. In addition, the clinical profile that emerges from creating the input data required to implement the Combined Model provides a much more descriptive clinical roadmap of how to tailor the intervention to the needs of the patients identified.

FIGURES 6A & 6B

POLYPHARMACY UTILISATION AMONG PATIENTS IDENTIFIED BY COMBINED MODEL AND PARR





Across a number of different measures, the high risk patient population being identified by the Combined Model is rich in opportunities for impact. For example, Figures 6a and 6b above show the percentage of patients in the top 1,000 and top 10,000 identified in the Combined Model and PARR that are taking between five and nine and 10 or more different prescription drugs in a single month.

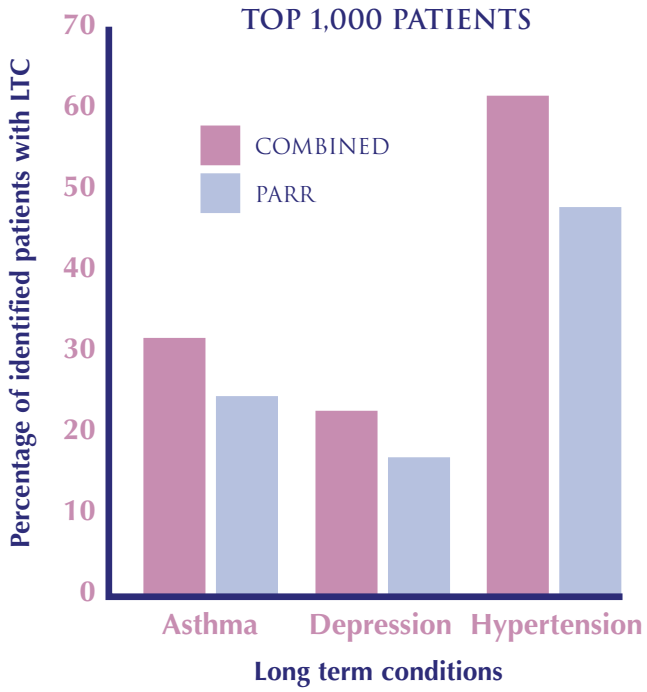
THE COMBINED MODEL

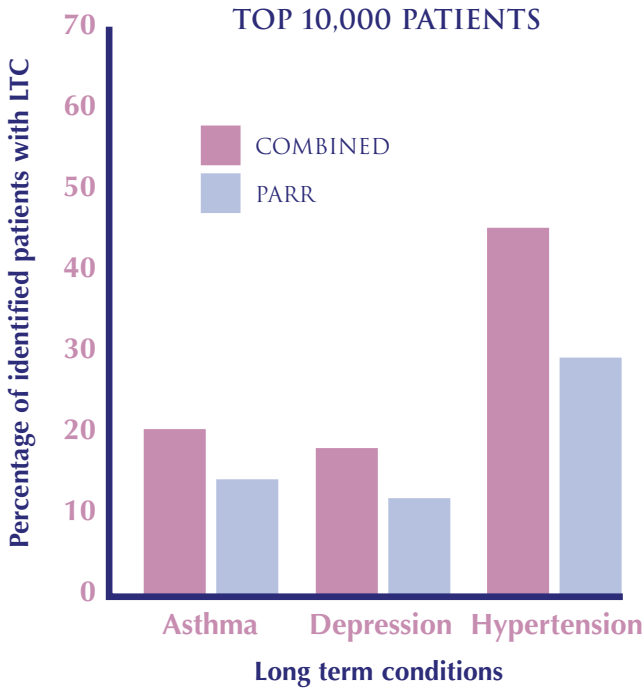
Polypharmacy issues are a significant area of focus for high intensity and/or telephonic interventions; the Combined Model identifies a set of patients with higher rates of polypharmacy-related concerns than the PARR model. This clinical information, only available through the linking of the different data sets, will have a direct impact on the type and intensity of intervention design planned, such as the use of pharmacy experts to look at polypharmacy issues and how to manage those for improved outcomes and lower cost.

Figures 7a and 7b below look at the prevalence of key chronic diseases in the top 1,000 and top 10,000 patients (a summary of clinical profile variables across cutpoints is shown in Appendix B). The prevalence of impactable conditions such as asthma, depression, and hypertension is higher in the top 1,000 Combined Model patients than the top 1,000 PARR patients.

FIGURES 7A & 7B

LONG TERM CONDITION PREVALENCE AMONG PATIENTS IDENTIFIED BY COMBINED MODEL AND PARR





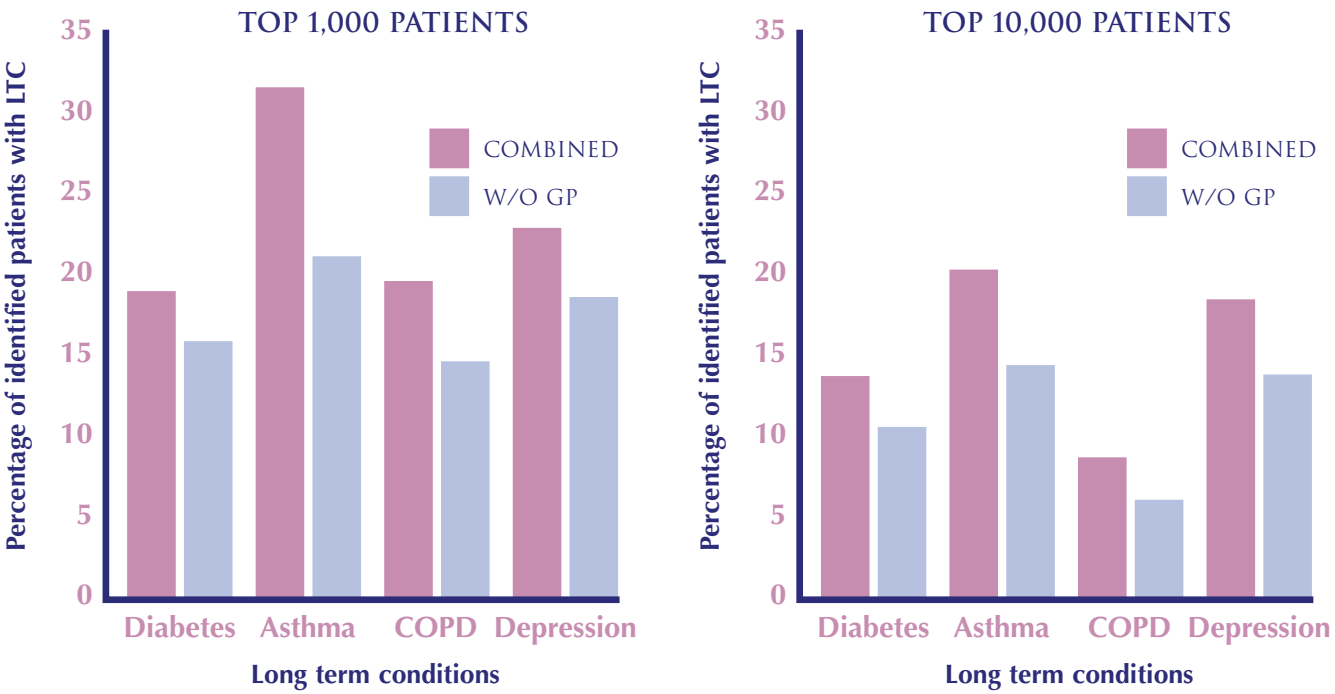
This is consistent with the different patient population being introduced using the more comprehensive data set and the ability to identify emerging risk patients. Similarly, for the top 10,000 patients, the Combined Model is consistently identifying patients with higher long term condition prevalence and more impactable opportunities across all conditions (as shown in Appendix B).

GENERAL PRACTICE DATA HELPS IDENTIFY PATIENTS WITH IMPACTABLE CONDITIONS

Including GP practice data, in addition to the secondary care data, significantly enhances the opportunity to identify patients with long term conditions and the overall richness of the clinical opportunities for intervention. Figures 8a and 8b below show the prevalence of diabetes, asthma, chronic obstructive pulmonary disease (COPD) and depression within both the top 1,000 and top 10,000 patient segments when comparing the Combined Model with and without GP variables. Adding GP data enhances the ability of the model to identify more patients with impactable long term conditions.

FIGURE 8A & 8B

LONG TERM CONDITIONS IN COMBINED MODEL AND COMBINED MODEL EXCLUDING GP VARIABLES



As the true goal of these segmentation efforts is to reduce the risk rather than describe it, the additional clinically relevant information in the GP practice data is essential for carrying out interventions across patient segments. Additional clinical profile information for the Combined Model and Combined Model excluding GP variables is included in Appendix B.

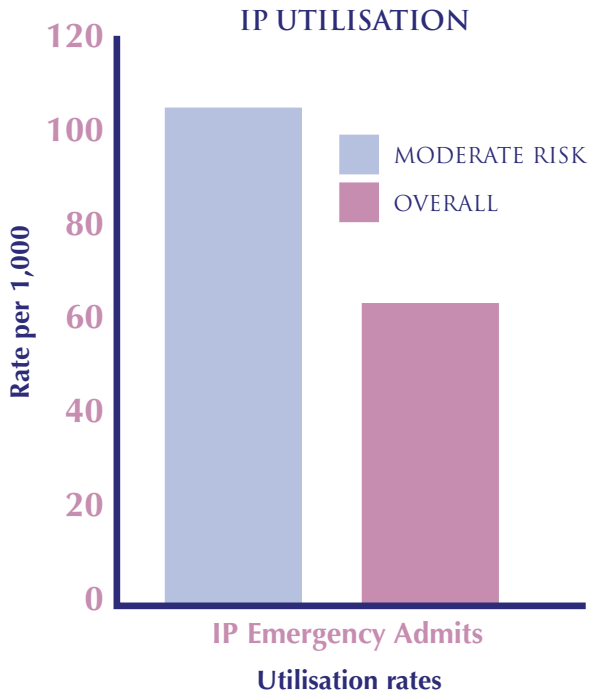
THE COMBINED MODEL

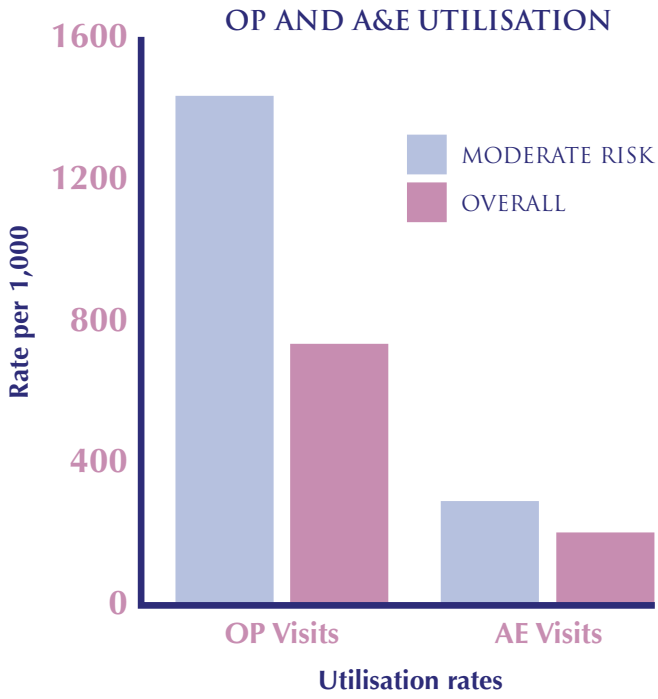
THE COMBINED MODEL OFFERS THE ABILITY TO IDENTIFY OPPORTUNITIES IN OTHER SEGMENTS OF THE RISK PYRAMID

As discussed earlier, the Combined Model identifies patients across the continuum of risk. This allows NHS organisations to tailor targeted outreach and intervention to the relative risk of individual patients in each segment of the risk pyramid (shown on page 5). Most of this document focuses on those in the very high and high risk segments where case management and disease management interventions involving direct interaction with patients may be warranted. However, there are also opportunities to design lower intensity strategies for supported self-care for patients in the moderate risk segment (6-20%) such as support via telephone, mail, internet, text messaging and/or email.

FIGURES 9A & 9B

UTILISATION OF MODERATE RISK PATIENTS IN RISK PYRAMID





As Figures 9a and 9b above demonstrate, there is ample secondary care utilisation driving cost within this segment of more than 40,000 patients that could be addressed using lower-intensity interventions. Patients in the moderate risk segment have nearly twice as many outpatient attendances, 70% more emergency admissions, and 40% more A&E attendances when compared with the average person in the population.

Figure 10 below demonstrates that there is also significant clinical opportunity within the moderate risk group. For example, compared with population averages, patients in the moderate risk segment are more than twice as likely to have polypharmacy utilisation of between five and nine different drugs in a single month. In addition, there is relatively high prevalence of impactable long term conditions in this segment which, if unmanaged, may lead to patients progressing up the pyramid. For example, hypertension prevalence in this group is 18% compared with 9% in the overall population.

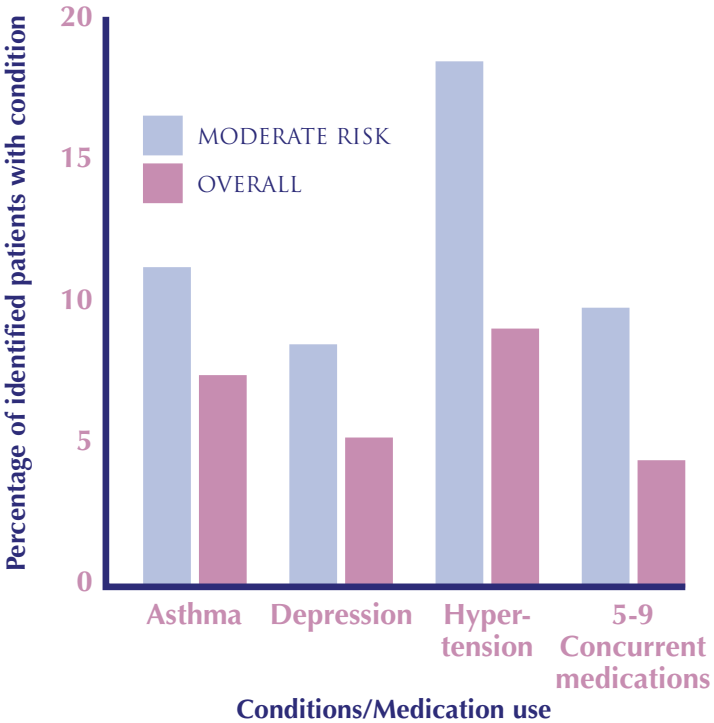


FIGURE 10

CLINICAL PROFILE OF MODERATE RISK PATIENTS IN RISK PYRAMID

CONCLUSION

The Combined Model significantly extends the range of opportunities for the NHS and clinicians interested in long term condition interventions. The ability to stratify the entire population allows PCTs to develop intervention strategies aimed at reducing immediate, intermediate and longer term risk. Further, the addition of rich, clinical detail allows PCTs to not only segment populations, but also begin to assemble the clinical interventions for each of the different segments.

The Combined Model offers an increase in predictive power for the highest risk patients, and also facilitates the identification of a much broader population with emerging risk.

The findings from the Combined Model show that it holds significant potential value for NHS organisations seeking to develop population-based strategies for utilisation reduction and quality improvement. Whilst the PARR model has offered the NHS a nationwide tool that allows for quick identification of the very highest risk patients, it has been limited to identifying only those individuals at the highest end of the risk pyramid. The Combined Model offers an increase in predictive power for the highest risk patients, and also facilitates the identification of a much broader population with emerging risk. An integrated approach, using both tools, which matches interventions of varying intensity to population needs across the continuum of risk levels will be an essential component of PCTs' care management strategies, and the Combined Model offers an important set of tools for PCTs to design and implement these strategies.

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APPENDIX A

SUMMARY OF DATA SOURCES AND METHODOLOGY

The Combined Model was developed on a total population of 560,000 patients from two PCTs using three years of hospital data (April 2002 – March 2005), including inpatient (IP), outpatient (OP), and accident and emergency (A&E) attendance data. Additionally, primary care data for the same time period were included from the two PCTs, including lab, diagnosis, and encounter information from general practices within those PCTs. Unfortunately, pharmacy data were only included for one of the two PCTs that supplied the primary care data. In addition, social services data were requested from the PCTs participating in the Combined Model development work. Health Dialog was able to link the social services information to the clinical data supplied for only one of the PCTs and only in a very small percentage of patients due to complications with the data. This proportion of linked social and clinical service records at the patient-level was not sufficient for inclusion in the Combined Model.

The model was developed using logistic regression on a random selection of 50% of the available data (known as the 'development sample'). Data for the period of April 2002 through March 2004 were mined for predictor variables associated with risk of admission during the time period of April 2004 through March 2005. The model was validated by applying the variable beta weights resulting from the logistic regression analyses to the remaining 50% of data (known as the 'validation sample'). All Combined Model results shown in the Final Report are for this validation sample only and are compared with PARR scores for patients from the same validation sample and same time period.

In development, more than 850 variables were considered for inclusion. These variables included a combination of values from administrative records and derivations from those values. Derived variables included proxy variables for long-term conditions (drawn from GP and IP encounters), polypharmacy (drawn from Read codes evaluated on a monthly basis), and changes in lab values (derived from GP encounters). Each variable was also coded into five mutually exclusive time periods to account for recency of occurrence and patterns of recurrence. Each variable was assessed independently for its relationship with inpatient emergency admission before being included in a multivariate model.

APPENDIX B

CLINICAL PROFILE A

CLINICAL PROFILE INFORMATION FOR PATIENTS IDENTIFIED AT DIFFERENT RISK SEGMENTS USING THE COMBINED MODEL VERSUS PATIENTS IDENTIFIED AT THE SAME RISK SEGMENTS USING THE PARR MODEL

		LONG TERM CONDITION											
Identified patients	Model	Asthma	COPD	Depression	Diabetes	Hypertension	Cancer	CHD	CHF	Avg. age	5 - 9 Medications	10+ Medications	Avg. length of stay*
10,000	Combined	20.1	8.2	17.9	13.7	45.2	14.9	15.5	6.5	67.3	26.0	6.0	11.4
	PARR	14.3	5.1	11.8	9.3	29.0	9.4	12.0	4.6	55.4	14.1	3.0	10.4
5,000	Combined	23.3	11.0	20.6	16.2	51.4	15.3	18.5	9.4	69.7	29.5	8.6	11.5
	PARR	16.6	8.8	13.7	12.9	38.7	15.1	18.8	8.3	66.2	17.6	4.3	11.0
1,000	Combined	31.4	19.6	22.7	18.8	61.2	16.4	24.5	15.9	71.6	31.5	13.4	10.3
	PARR	24.3	20.6	16.9	19.9	47.7	20.0	24.8	19.2	69.5	14.6	7.4	9.9
500	Combined	34.0	22.6	25.2	19.2	63.2	16.4	28.8	19.4	70.7	30.6	14.6	9.8
	PARR	28.4	24.6	16.4	23.0	49.0	21.0	28.8	24.4	69.1	14.8	8.6	9.4
250	Combined	40.8	28.4	24.4	21.2	62.8	17.6	29.6	23.2	69.5	32.0	18.0	8.9
	PARR	30.8	26.8	20.0	22.8	52.4	20.8	30.8	29.2	68.8	14.4	10.0	9.8

* per emergency admission

CLINICAL PROFILE B

CLINICAL PROFILE INFORMATION FOR PATIENTS IDENTIFIED AT DIFFERENT RISK SEGMENTS USING THE COMBINED MODEL VERSUS PATIENTS IDENTIFIED AT THE SAME RISK SEGMENTS USING THE COMBINED MODEL BUT WITH GP VARIABLES EXCLUDED (FROM PREDICTION)

		LONG TERM CONDITION											
Identified patients	Model	Asthma	COPD	Depression	Diabetes	Hypertension	Cancer	CHD	CHF	Avg. age	5 - 9 Medications	10+ Medications	Avg. length of stay*
10,000	Combined	20.1	8.2	17.9	13.7	45.2	14.9	15.5	6.5	67.3	26.0	6.0	11.4
	w/o GP	14.1	6.2	13.8	10.5	34.6	14.6	13.5	6.0	67.2	17.3	4.0	11.3
5,000	Combined	23.3	11.0	20.6	16.2	51.4	15.3	18.5	9.4	69.7	29.5	8.6	11.5
	w/o GP	15.8	8.0	15.4	12.5	40.0	15.1	15.9	8.4	69.6	19.6	5.3	11.3
1,000	Combined	31.4	19.6	22.7	18.8	61.2	16.4	24.5	15.9	71.6	31.5	13.4	10.3
	w/o GP	21.0	14.5	18.2	15.7	49.1	17.6	22.4	16.0	71.7	20.9	8.2	10.5
500	Combined	34.0	22.6	25.2	19.2	63.2	16.4	28.8	19.4	70.7	30.6	14.6	9.8
	w/o GP	25.8	18.0	20.6	17.4	55.6	17.0	26.6	19.6	71.7	22.6	10.6	10.3
250	Combined	40.8	28.4	24.4	21.2	62.8	17.6	29.6	23.2	69.5	32.0	18.0	8.9
	w/o GP	27.2	21.6	20.0	18.4	56.8	19.2	28.0	24.4	70.9	22.4	11.6	8.8

* per emergency admission

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Health Dialog UK Limited

Health Dialog is a leading provider of care management services, including disease management. It is one of the fastest growing privately held firms in the US, with a subsidiary company headquartered in Cambridge, UK. The firm's services include analytic services and telephonic care management support for individuals. Health Dialog helps individuals become more actively engaged in their healthcare and have more effective relationships with their clinicians.

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