Refereed paper

Estimating the value of information in strategies for identifying patients at high risk of cardiovascular disease

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ABSTRACT

Background There are many different potential strategies for identification of patients eligible for primary prevention of cardiovascular disease. The ability to use a more efficient strategy has a value. This paper models the costs and benefits of a number of identification strategies and estimates the additional value of an information-based strategy.

Design Modelling study.

Methods Ten-year Framingham cardiovascular risk was calculated for each individual in a population of 4471 persons aged 35–74 drawn from the Health Survey for England (equivalent to a total practice population of 12 000). Estimated Framingham risk was calculated using limited risk factor information and default risk factors. Costs of risk factor assessment were calculated using standard NHS costs. The outcomes of risk factor assessment were the total number of patients identified as eligible for treatment and the total burden of cardiovascular disease in eligible patients. Several strategies for prioritising patients for assessment

were defined: opportunistic, diabetics and treated hypertensives first, ranked by estimated cardiovascular risk. The costs and outcomes of assessing increasing numbers of patients under each strategy were presented in graphical form.

Results To identify 70% of the burden of cardiovascular disease in this population opportunistically costs £82 102; under a 'diabetics and hypertensives first' strategy it costs £72 916; under a strategy prioritising by estimated cardiovascular risk, £27 795. The value of information in this scenario is therefore at least £45 121.

Conclusions Because strategies prioritising patients by estimated cardiovascular risk dominate alternative strategies, it is possible to estimate the value of information in terms of reduced resources to achieve the same results. These resource savings largely represent savings in staff time.

Keywords: cardiovascular disease, cost-effectiveness, patient identification, screening

Introduction

Primary prevention of cardiovascular disease (CVD) requires identification of patients at high risk, and treatment of eligible patients. To date, the Framingham risk equation remains the best predictor of cardiovascular risk, and its guidance is used to determine treatment eligibility. UK guidelines recommend:

- statins for all patients whose 10-year Framingham CVD risk exceeds 20%

- antihypertensive treatment for all those above this risk level whose blood pressures exceed 140/90 mmHg
- aspirin for all those above this risk level who are aged over 50 (once blood pressure has been controlled).[1]

Estimating CVD risk requires clinicians to determine a patient's risk factor status: age, gender, diabetic status, smoking status, blood pressure and lipid levels. However, some of these risk factors are already known. In

primary care, electronic medical databases have records of every patient's age and gender; whether a patient is on the cardiovascular disease register is known, diabetic status is also known, and prescribing records are generally comprehensive. Further risk factor information can be acquired, but at a cost. Determining a patient's smoking status requires a clinical consultation. Each blood pressure or cholesterol measurement requires a clinic visit. Because measured blood pressure shows considerable variation from one clinic visit to the next, guidelines advise clinicians to measure blood pressure at least twice.[2] Total cholesterol and HDL cholesterol levels also show considerable variation. Although previous guidance has recommended they should be measured three times, it is assumed that cholesterol levels are measured twice.[3] This means that estimating blood pressure and cholesterol levels requires two clinic visits.

Assessing a patient's CVD risk can be seen as an investment of healthcare resources. In some patients it is found that they are eligible for treatment, and the investment therefore offers the potential of improved health. Because risk of CVD predicts the benefits of treatment, in those at higher risk of CVD the benefit is greater. In many the investment is not beneficial because the patient is not eligible for treatment.

A practice undertaking primary prevention of CVD must decide on a strategy to identify patients for CVD risk assessment. If it decides to screen all adult patients, it makes little difference which strategy it follows, since all patients will be assessed. However, most practices seek to prioritise some patients for CVD risk assessment.

Multiple risk factor measurements increase the accuracy of estimated CVD risk, increasing the number of persons correctly identified as eligible for treatment. This means that patients at higher CVD risk are identified, and therefore the burden of CVD among those identified – the sum of their CVD risks – is higher. Multiple risk factor measurements also have costs: clinician time, patient inconvenience and laboratory costs. Data collection, therefore, has both costs and benefits. There are two sources of data available to the practice: data collected from individual patients when they consult; and data that has previously been collected and is available in the primary care database. It is well-recognised that previously collected data has a value in describing the epidemiology and service use associated with CVD.[4] It is widely accepted that there are considerable benefits from creating primary care databases.[5] However, there is little information on the relationship between costs and benefits of data collection in primary care. This paper uses modelling to analyse the costs and benefits of using increasing cardiovascular risk factor information to identify patients eligible for treatments to prevent CVD.

Methods

The model population

The study population was obtained from the Health Survey for England of 2003.[6] Patients with an existing diagnosis of CVD were excluded from the population, leaving a dataset of 4471 persons aged 35–74 with complete cardiovascular risk factor information.

Clinically measured blood pressure and clinically measured cholesterol level

Clinically measured blood pressure is not identical to true mean blood pressure, and therefore diagnosis based on the average of a number of clinically measured blood pressures is subject to a degree of misclassification.[7] To reflect chance variation in measured blood pressure, two measured blood pressures are generated for each individual in the model population. The measured blood pressures are generated using a previously described methodology that adjusts the patient's true blood pressure (the survey blood pressure) by an error term:

Measured BP = True BP × (1 + Error Term)

A series of normally distributed error terms are generated in Microsoft Excel[TM] as random numbers with a mean of zero and a standard deviation equal to the coefficient of variation of between-visit, measured blood pressure. This between-visit coefficient of variation is derived from meta-analysis.[8]

A similar process is carried out to reflect chance variation in clinically measured cholesterol levels. Two measured cholesterol levels are also generated for each individual in the model population. These measured cholesterol levels incorporate an error term that is based on the coefficient of variation derived from published studies: 7.2% for total cholesterol and 7.5% for HDL cholesterol.[9]

Default risk factor values

When an individual's risk factor status is not known a best estimate of their risk factor status is substituted. Because non-smokers outnumber smokers, individuals are assumed to be non-smokers if their smoking status is unknown. If blood pressure or cholesterol levels are unknown, the average blood pressure or cholesterol level for a person of their age, gender, diabetic status and smoking status is substituted. This follows a previously described methodology.[10] Default

risk factor values are derived from the Health Survey for England of 1998.[11]

Estimated cardiovascular risk

Data are entered into Excel[TM] and individual 10-year CVD risks are calculated for each individual using the risk factor values in the survey and the Framingham risk equation.[12] This is taken to be each individual's 'gold standard' or true 10-year CVD risk.

Five further estimates of CVD risk are calculated. The first estimate is based on age, gender and diabetic status alone; the second estimate is based on age, gender, diabetic and smoking status; the third adds one clinically measured blood pressure measurement; the fourth adds one clinically measured blood pressure and one clinically measured cholesterol; the fifth adds two blood pressure and cholesterol measurements. For each of these five estimates, any unmeasured risk factors are replaced by default risk factor values.

Eligibility for treatment

Treatment eligibility criteria are determined using the most recent UK guidelines. These recommend antihypertensive treatment for those whose blood pressures exceed 160/100 mmHg, or with blood pressures exceeding 140/90 mmHg and 10-year CVD risk over 20%.[1] They also recommend aspirin for those with more than 20% 10-year CVD risk who are aged over 50, and statins for those with more than 20% 10-year CVD risk or with familial hyperlipidaemia (defined here as total to HDL cholesterol ratio ≥ 8).[3]

Treatment eligibility criteria are written as logical functions in Excel[TM]. For example, the logical function below determines whether a patient is eligible for antihypertensive treatment (1 = eligible):

=IF(OR("SystBP">=160,"DiastBP">=100),1,IF(AND
(OR("SystBP">=140,"DiastBP">=90),OR("10-year
CVD Risk">0.2,"CVD History"=TRUE,"Diabetes"=
TRUE)),1,0))

These are then used to determine each patient's eligibility for treatment with aspirin, antihypertensive or statin. Treatment eligibility status is determined from complete risk factor data including the means of each of two blood pressure and two cholesterol measurements. Under some identification strategies not all patients undergo full risk factor assessment, either because initial assessment suggested they are at low risk, or because they are a low priority for assessment. This means that slightly different numbers of patients are identified as eligible for treatment under different identification strategies.

Patient identification strategies

Practices know the age, gender, diabetic status and antihypertensive drug treatment status of all of their patients. Additional risk factor data must be collected and therefore has a cost. Information only has a value if it influences the way in which the practice seeks to identify patients for cardiovascular disease prevention. Three different categories of patient identification strategies are therefore modelled: full assessment of all patients; limited assessment of all patients followed by full assessment of a limited number; limited assessment of all patients, using this information to prioritise patients for full assessment.

1 Full assessment of all patients

Patients undergo full assessment on the first occasion that they are seen by the clinician: blood pressure and cholesterol levels are measured at two separate clinic visits. Within this category, the order in which patients are assessed can vary. One option is to assess patients opportunistically (in random order). A second (following National Service Framework recommendations) is to assess diabetics on antihypertensive treatment first, diabetics second, those on antihypertensives third, and finally all other patients.[3] A third (previously described) option is to prioritise patients by an estimate of their 10-year CVD risk.[10] This risk estimate is calculated from their age, gender, diabetic status and antihypertensive treatment status.

2 Limited assessment of patients followed by full assessment of high-risk patients

Patients undergo limited risk factor assessment on the first occasion that they are seen. The order in which patients undergo this limited assessment can be opportunistic (random), following the National Service Framework recommendations, or by using the prioritisation method described above. If on first assessment a patient's blood pressure exceeds 135/85 mmHg or their estimated 10-year CVD risk exceeds 20% or their cholesterol exceeds 5.0 mmol/l, they undergo full risk factor assessment. This follows published recommendations.[1,3] There are several variations of the limited risk factor assessment in this strategy: in the first, smoking status alone is determined; in the second, a single blood pressure is added; in the third, a single cholesterol level is added.

3 Limited assessment of all patients followed by full assessment of all patients

All patients undergo limited risk factor assessment. Patients are then ranked in order of their cardiovascular

risk and undergo full cardiovascular risk assessment in descending risk order.

Costs

Costs are considered from the perspective of the primary care provider. Obtaining risk factor information on individual patients has a cost. A smoking history requires at least one 10-minute consultation with a practice nurse (£32 per hour): a cost of £5.33.[13] Blood pressure should be measured with the patient seated and at rest for five minutes.[3] Failure to allow sufficient rest period leads to systematic overestimation of blood pressure.[14] Blood pressure measurement therefore takes 10 minutes of practice nurse time: cost £5.33. Smoking history can be ascertained at the same visit, and therefore has no additional cost when blood pressure is measured.

Cholesterol measurement takes 10 minutes of staff time plus the laboratory cost of a lipid profile (£5.67)*: a total of £11.00 if carried out by a practice nurse. Cholesterol and blood pressure measurement at the same visit takes 15 minutes of staff time: a total of £13.67 if carried out by a practice nurse.

In a pilot study, extracting risk factor information from the practice database and importing into an Excel[TM] template to calculate CVD risk took two hours of clinician time. General practitioner time costs £118 per hour.[13] This process therefore costs £236 for a practice.

The total cost of each strategy is the sum of the costs of any initial risk factor assessment, the costs of ranking patients and the costs of full risk factor assessment.

Effectiveness of patient identification strategies

The effectiveness of each patient identification strategy is first measured as the number of patients correctly identified as eligible for treatment. Effectiveness is also measured as the total burden of CVD risk in patients correctly identified as eligible for treatment: this gives an indication of the total burden of preventable CVD in identified patients. Because the method by which patients are identified does not influence the effectiveness of treatments, it is not necessary to calculate effectiveness in terms of CVD prevented.

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* Source: Reinhold Grün, London School of Hygiene and Tropical Medicine, 1996, and adjusted for inflation.

Cost-effectiveness

As the resources used under any chosen strategy increase, the number of patients identified (and the total burden of CVD) also increases. We are interested in the relationship between resource use and effectiveness within each strategy and how this compares across different strategies. The cost-effectiveness of each identification strategy can therefore be expressed graphically: the total cost of the strategy on the horizontal axis and the effectiveness of the strategy on the vertical axis.

Results

In this population 1143 patients (23.6%, 95% CI: 22.4% to 24.9%) are eligible for at least one treatment: 1066 of these (93.3%, 95% CI: 91.8% to 94.8%) are aged 45 or over. If treatment eligibility status is determined from two clinical cholesterol and two blood pressure measurements, 25.6% (95% CI: 24.3% to 26.8%) are categorised as eligible for treatment. If all patients are assessed in this way, clinical diagnosis of treatment eligibility has a sensitivity of 87.8%, a specificity of 93.7% and a positive predictive value of 81.2%.

Numbers of high-risk patients identified

The relationship between resources allocated to patient identification and number of patients identified as eligible for treatment is shown in Figure 1. The equivalent relationship for burden of cardiovascular disease is shown in Figure 2.

1 Full assessment of all patients

To identify 800 patients eligible for treatment (70% of the total) costs £82 293 under an opportunistic strategy; £75 898 under a strategy prioritising diabetics and treated hypertensives; £42 541 under a strategy prioritising by cardiovascular risk. The 800 patients identified have a total 10-year cardiovascular risk of 191 under an opportunistic strategy, 194 under a strategy prioritising diabetics and treated hypertensives, and 223 under a strategy prioritising by cardiovascular risk. These are shown as strategies 1A, 1B and 1C in Figure 1 and Figure 2.
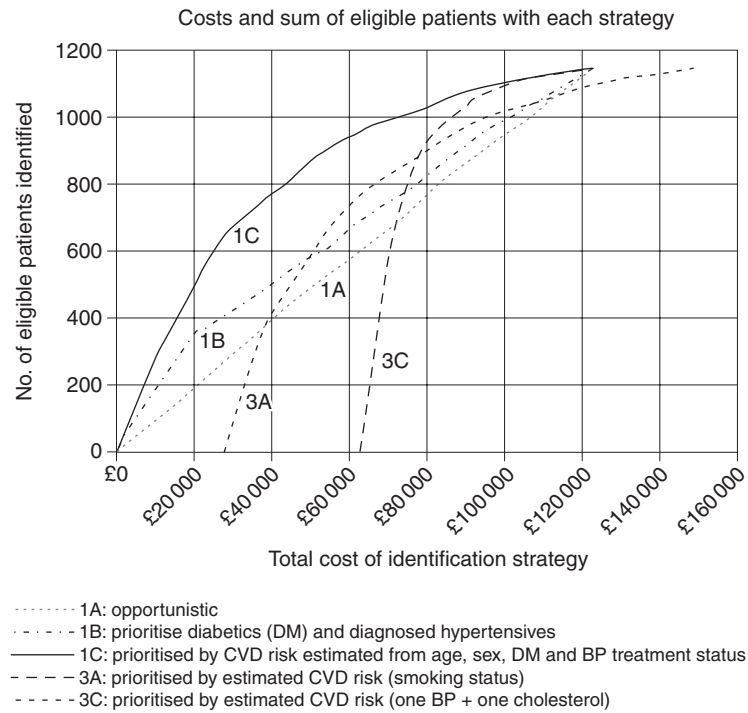
Costs and sum of eligible patients with each strategy

Figure 1 Relationship between numbers of patients identified as eligible for at least one treatment and costs with each identification strategy
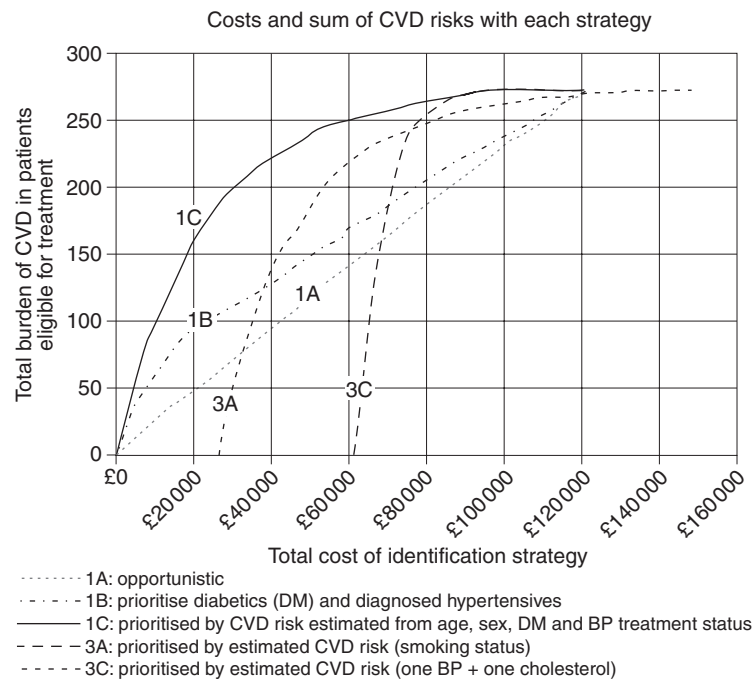

Figure 2 Relationship between burden of cardiovascular disease (sum of 10-year cardiovascular risks) in patients identified as eligible for at least one treatment and costs with each identification strategy

2 Limited assessment of patients followed by full assessment of high-risk patients

If patients are prioritised by an estimate of CVD risk, it costs £38 218 to identify 800 patients eligible for treatment under a strategy of only undertaking full assessment in patients who meet certain criteria on limited assessment. The 800 identified patients have a total 10-year cardiovascular risk of 226. Overall the results of this type of strategy are very similar to the results of full assessment at first visit. In both cases, prioritising patients by their cardiovascular risk allows more patients and a greater burden of cardiovascular disease to be identified within available resources. The curves are not included in Figure 1 and Figure 2 because they are almost indistinguishable from curves 1A, 1B and 1C.

3 Limited assessment of all patients followed by full assessment of all patients

Strategies that collect risk factor information on all patients and then prioritise patients for full assessment are clearly much less efficient. Before a single patient is identified, £26 500 of staff resources are needed to ascertain smoking status, or £61 400 to check blood pressure and cholesterol levels on all patients. These are shown as strategies 3A and 3C in Figure 1 and Figure 2.

The incremental value of a prioritised prevention strategy

There are clearly very great differences in the efficiency of different strategies for identifying high-risk patients. Strategies that advocate collecting risk factor data on all registered patients are very inefficient because many patients do not need treatment. Strategies that advocate opportunistic risk factor assessment, or that use categorical variables (diabetic status, antihypertensive drug treatment status) to prioritise patients for treatment, are less efficient than strategies that prioritise patients based on an estimate of their cardiovascular risk.

A strategy based on estimated cardiovascular risk requires fewer resources to identify a given burden of preventable cardiovascular disease. We can therefore estimate the savings that result from implementing such a strategy. For a practice with 4471 eligible patients (equivalent to a registered population of 12 000), to identify treatable patients with a burden of 190 preventable cardiovascular events (70% of the total), will cost £25 416 under a prioritised strategy, compared with £82 102 and £72 916 under opportunistic or 'diabetics and antihypertensive treatment first' strategies. The value of the prioritisation strategy is therefore at least £45 121 (see Table 1).

The savings are greater in practices intending to identify more of their burden of cardiovascular disease and less in those intending to identify less. However,

Table 1 Costs of identifying an equal burden of preventable CVD under different identification strategies

Percentage of total CVD events	Total CVD events	Strategy 1 Opportunistic	Strategy 2 Diabetics & BP treatment first	Strategy 3 Prioritised by CVD risk	Value of ability to prioritise by CVD risk
10	27	£11 319	£3445	£2423	£1022
20	54	£22 993	£9706	£4911	£4795
30	81	£34 776	£16 185	£7919	£8267
40	108	£46 341	£28 598	£11 609	£16 988
50	135	£57 387	£43 443	£16 066	£27 377
60	162	£70 182	£58 234	£21 042	£37 192
70	190	£82 102	£72 916	£27 795	£45 121
80	217	£95 006	£87 625	£39 004	£48 621
90	244	£109 251	£104 603	£55 764	£48 839
100	271	£122 237	£122 237	£122 473	−£236

by using the prioritised strategy, even a practice intending to identify only 20% of its burden of cardiovascular disease can achieve the same results at a cost £4795 lower. Over half of the cost savings are accounted for by a reduction in nurse time needed to undertake risk factor assessment. The remaining savings are accounted for by a reduced number of lipid profiles.

Discussion

The method described permits analysis of the efficiency of several different strategies for identifying high-risk patients. It also demonstrates the incremental cost savings that accrue from using one strategy rather than another. This is important as it indicates the potential value of software and training that allows risk factor data to be turned into information and an identification strategy.

The analytic method does not calculate the amount of cardiovascular disease prevented, the number of quality-adjusted life years gained, the costs of treatment, or the costs avoided as a result of treatment in identified patients. This analysis is unnecessary because the method by which a patient is identified is unlikely to affect the future costs or effectiveness of their treatment. Both future costs and future effectiveness are dependent only on the cardiovascular risk of identified patients.[15]

The prioritised strategy requires only that patients' age, gender and diabetic status are known. Clearly, many practices have additional risk factor data on many patients.[16] A prioritised strategy is therefore even more efficient than has been illustrated here.

The analysis only includes costs from the perspective of the primary care provider. Including patient costs – travel costs and indirect costs – increases the cost of each clinic visit. This considerably increases the cost per identified patient of strategies that do not prioritise patients prior to assessment. It also ignores additional time that might be required to counsel patients after their cardiovascular risk has been calculated. If this additional staff time is included, the resource savings are greater. The analysis assumes that the costs of extracting data from the primary care database are relatively high. However, with appropriate software the costs of data extraction are negligible, and in many practices in the UK such software (MIQUEST[17]) is available. Finally, it assumes that only nurse time is used for cardiovascular risk assessment. If general practitioner time is also used for cardiovascular risk assessment, the resource implications of inefficient strategies are greater and the savings with efficient strategies considerably larger.

Conclusion

Existing data in practice databases can be used to inform more efficient strategies for identifying patients at high risk of CVD. In effect, this means that data can be converted into knowledge. This knowledge has a quantifiable value. Appropriate information technology could calculate estimated cardiovascular risks on all patients in a practice database and identify those most likely to benefit from assessment. Such a tool would greatly facilitate the development of registers of high-risk patients.

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CONFLICTS OF INTEREST

The author is providing advice to iSoft on the development of software to identify patients at high risk of coronary heart disease from the Torex medical information system. This work is unpaid.

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