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The prevention of progression of arterial disease and diabetes (POPADAD) trial: factorial randomised placebo controlled trial of aspirin and antioxidants in patients with diabetes and asymptomatic peripheral arterial disease

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ABSTRACT

Objective To determine whether aspirin and antioxidant therapy, combined or alone, are more effective than placebo in reducing the development of cardiovascular events in patients with diabetes mellitus and asymptomatic peripheral arterial disease.

Design Multicentre, randomised, double blind, 2×2 factorial, placebo controlled trial.

Setting 16 hospital centres in Scotland, supported by 188 primary care groups.

Participants 1276 adults aged 40 or more with type 1 or type 2 diabetes and an ankle brachial pressure index of 0.99 or less but no symptomatic cardiovascular disease.

Interventions Daily, 100 mg aspirin tablet plus antioxidant capsule (n=320), aspirin tablet plus placebo capsule (n=318), placebo tablet plus antioxidant capsule (n=320), or placebo tablet plus placebo capsule (n=318).

Main outcome measures Two hierarchical composite primary end points of death from coronary heart disease or stroke, non-fatal myocardial infarction or stroke, or amputation above the ankle for critical limb ischaemia; and death from coronary heart disease or stroke.

Results No evidence was found of any interaction between aspirin and antioxidant. Overall, 116 of 638 primary events occurred in the aspirin groups compared with 117 of 638 in the no aspirin groups (18.2% *v* 18.3%): hazard ratio 0.98 (95% confidence interval 0.76 to 1.26). Forty three deaths from coronary heart disease or stroke occurred in the aspirin groups compared with 35 in the no aspirin groups (6.7% *v* 5.5%): 1.23 (0.79 to 1.93). Among the antioxidant groups 117 of 640 (18.3%) primary events occurred compared with 116 of 636 (18.2%) in the no antioxidant groups (1.03, 0.79 to 1.33). Forty two (6.6%) deaths from coronary heart disease or stroke occurred in the antioxidant groups compared with 36 (5.7%) in the no antioxidant groups (1.21, 0.78 to 1.89).

Conclusion This trial does not provide evidence to support the use of aspirin or antioxidants in primary prevention of cardiovascular events and mortality in the population with diabetes studied.

Trial registration Current Controlled Trials ISRCTN53295293.

INTRODUCTION

Cardiovascular disease is the major cause of morbidity and mortality in patients with diabetes. Peripheral arterial disease is also a powerful indicator of systemic atheroma. Regardless of whether symptoms are evident,[1] patients with peripheral arterial disease have an increased risk of myocardial infarction and stroke and are six times more likely to die from cardiovascular disease within 10 years than patients without peripheral arterial disease.[2]

The use of antiplatelet agents is known to reduce secondary cardiovascular events in patients with both diabetes and cardiovascular disease[3 4] and in those with peripheral arterial disease.[3 5] The strength of the evidence for use of antiplatelets as secondary prevention in these groups[6-9] has, however, led to the suggestion that aspirin might be useful for primary prevention in patients with both diabetes and asymptomatic peripheral arterial disease. These recommendations have been incorporated into several guidelines.[10-14] despite evidence from a meta-analysis[3] showing no such benefit from antiplatelet therapy in people with diabetes.

A meta-analysis[15] of four randomised controlled trials of aspirin as primary prophylaxis against cardiovascular events showed that although aspirin decreased the risk of myocardial infarction it did not reduce total mortality and might increase the risk of stroke and of major bleeding. That meta-analysis and another study[16] concluded that on the basis of evidence

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from randomised controlled trials aspirin should not be given to all people with diabetes but only to specific subgroups.

Links between platelet aggregation and the increase in oxidative stress in people with diabetes[17] and in those with peripheral arterial disease[18] have also been studied. Free radicals have been shown to increase platelet aggregation, with antioxidants decreasing aggregation.[19] Defence against free radical attack is provided in part by the body's antioxidants. We determined whether aspirin and antioxidant therapy, combined or alone, are more effective than placebo in reducing the development of cardiovascular events in patients with diabetes and asymptomatic peripheral arterial disease.

METHODS

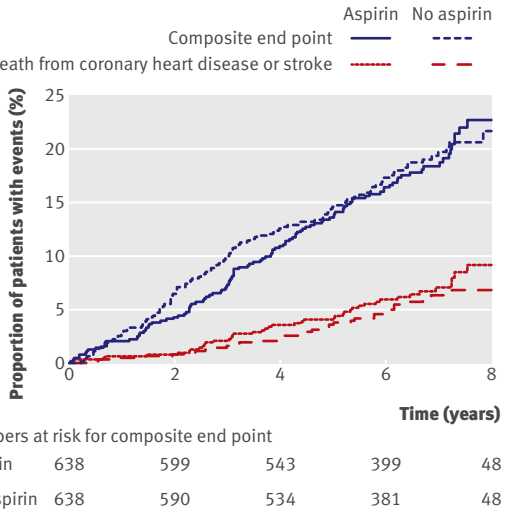
The prevention of progression of arterial disease and diabetes (POPADAD) trial was a multicentre, randomised, double blind, placebo controlled trial. We used a 2×2 factorial design[20] to examine the efficacy and safety of aspirin plus antioxidant compared with aspirin alone, antioxidant alone, and placebo. The interventions were daily aspirin 100 mg or placebo tablet, plus antioxidant or placebo capsule. Placebo tablets and capsules were identical in appearance to active tablets and capsules.

Sixteen hospital centres in Scotland participated in the trial, supported by 188 primary care groups. Participants had to be aged 40 or more with type 1 or type 2 diabetes and have asymptomatic peripheral arterial disease (lower than normal ankle brachial pressure index ≤0.99).

Patients were randomly assigned to either aspirin plus antioxidant, aspirin plus placebo, antioxidant plus placebo, or double placebo. To ensure allocation concealment an independent pharmacist packaged the drugs into numbered containers. Recruiting nurses dispensed the drugs on the day of randomisation. The participants, research nurses, and staff involved in providing care were blinded to group assignment.

Follow-up evaluations were done every six months. At these visits we recorded outcome events, adverse events, and interventions. The results of electrocardiography were recorded at the baseline visit and annually thereafter. The electrocardiograms were reviewed manually for evidence of silent myocardial infarction using criteria from the Minnesota code. Primary and secondary end points were adjudicated on a blinded basis by a committee.

We used two composite primary end points: death from coronary heart disease or stroke, non-fatal myocardial infarction or stroke, or above ankle amputation for critical limb ischaemia; and death from coronary heart disease or stroke. The main secondary end points were all cause mortality, non-fatal myocardial infarction, and occurrence of other vascular events (see bmj.com).



Numbers at risk for composite end point

Aspirin	638	599	543	399	48
No aspirin	638	590	534	381	48

Fig 1 | Kaplan-Meier estimates in aspirin and no aspirin groups of proportion of patients who experienced the composite end point of death from coronary heart disease or stroke, non-fatal myocardial infarction or stroke, or above ankle amputation for critical limb ischaemia; and death from coronary heart disease or stroke

Power calculations and statistical analysis

Overall, 1276 patients were recruited; if follow-up continued until June 2006 then 256 events would be expected to occur during the trial. This would give 73% power to detect a 25% relative reduction in event rate and 89% power to detect a 30% reduction in event rate if only one treatment was effective.

The end points were measures of survival. We used a Cox proportional hazards model as the primary method of analysis. We assessed the interventions by fitting terms corresponding to aspirin, antioxidants, and the interaction between these treatments. As there was no evidence of interaction we dropped this term, allowing the overall effect of each intervention to be assessed. We assessed the assumption of proportionality of hazards and we used Kaplan-Meier plots for the survival experience by treatment group. Specific adverse events were assessed using logistic regression with terms corresponding to aspirin, antioxidants, and the interaction between these treatments. As we found no evidence of interaction we dropped this term. All analyses were done on an intention to treat basis, with two tailed tests of significance used throughout. Research nurses collected the data, which were entered and analysed at the University of Edinburgh.

RESULTS

Adults aged 40 or more with diabetes were screened between November 1997 and July 2001. Overall, 1276 of 1670 (76.4%) were randomised; 320 to aspirin tablets plus antioxidant capsules, 318 to aspirin tablets plus placebo capsules, 320 to placebo tablets plus antioxidant capsules, and 318 to placebo tablets plus placebo capsules. The groups were similar for baseline characteristics (see bmj.com). The median length of

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follow-up was 6.7 years and a total of 8127 patient years of follow-up were completed.

Overall, 233 participants experienced the composite primary end point: overall event rate 2.9 per 100 patient years (see bmj.com). Seventy eight participants died from coronary heart disease or stroke: event rate 1.0 per 100 patient years.

The interaction between the aspirin and antioxidant treatments was not statistically significant either for the composite end point (P=0.88) or for death from coronary heart disease or stroke (P=0.95). In addition, the interaction between the two treatments was statistically significant for only two of the secondary end points—claudication (P=0.032) and death from stroke (P=0.004). No evidence was found of an interaction for the specific adverse events. Because there was no evidence of an interaction between aspirin and antioxidant, patients in the groups randomised to aspirin were compared with those in the groups randomised to placebo tablets (no aspirin), and patients in the groups randomised to antioxidant were compared with those in the groups randomised to placebo capsules (no antioxidant).

Figure 1 shows the cumulative percentages of patients over time with each of the primary end points. The differences between these two groups were not statistically significant for either of the end points.

No statistically significant differences were found between the aspirin and no aspirin groups for any of the secondary end points. Specific adverse event rates were not statistically significantly different between the aspirin and no aspirin groups (see bmj.com).

Figure 2 shows the cumulative percentages of patients over time with each of the primary end points. No statistically significant differences were found between these two groups for either of the end points.

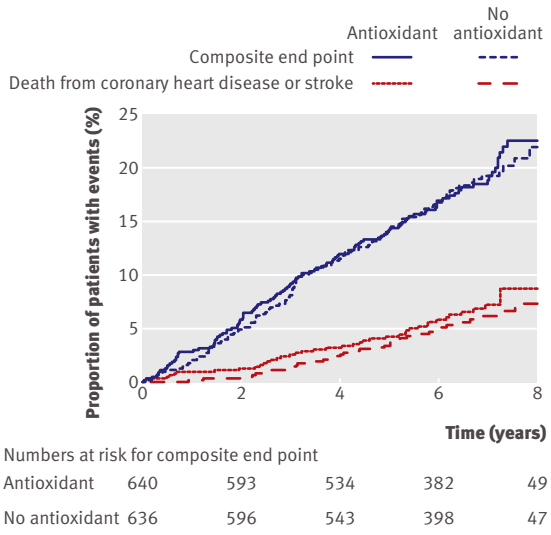

Fig 2 | Kaplan-Meier estimates for antioxidant and no antioxidant groups of proportion of patients who experienced the composite end point of death from coronary heart disease or stroke, non-fatal myocardial infarction or stroke, or above ankle amputation for critical limb ischaemia; and death from coronary heart disease or stroke

The increase in numbers of deaths from any cause in the antioxidant group compared with the no antioxidant group was statistically significant (P=0.006; see bmj.com). This difference in all cause mortality seems to be partly due to a relative deficiency of deaths in the no antioxidant group compared with an age and sex matched Scottish population and partly due to a relative excess of deaths in the antioxidant group. No statistically significant differences were found between the antioxidant and no antioxidant groups for any of the other secondary end points.

Specific adverse event rates were not statistically significantly different in the antioxidant and no antioxidant groups, except for gastrointestinal symptoms including dyspepsia (P=0.015), which were reported by more patients in the no antioxidant groups.

More deaths occurred in the antioxidant groups than no antioxidant groups for all the categories except other coronary heart disease (see bmj.com).

The difference in treatment effect between the subgroups by age, sex, and ankle brachial pressure index was not statistically significant for any of the three characteristics (see bmj.com).

DISCUSSION

We evaluated the effect of aspirin or antioxidant on cardiovascular events and mortality in a large cohort of people with diabetes mellitus with asymptomatic peripheral arterial disease. These two clinical criteria were selected for study as guidelines[10-13] were being published, without evidential support, recommending aspirin use as primary prevention of cardiovascular disease in patients with diabetes and with asymptomatic peripheral arterial disease. We found no evidence of benefit from either aspirin or antioxidant treatment on the composite hierarchical primary end points of cardiovascular events and cardiovascular mortality. The lower 95% confidence limits for these primary end points, however, only just excluded a 25% benefit for aspirin and a 23% benefit for antioxidant, whereas the upper 95% confidence limits only just excluded a 27% increase in cardiovascular events for aspirin and a 34% increase for antioxidant.

In examining why aspirin may have been ineffective the question was asked as to whether these patients were at sufficient risk, in terms of peripheral arterial disease, as the cut-off point of an ankle brachial pressure index of 0.99 or less is higher than that used to define peripheral arterial disease in the population (<0.9).[21] A subgroup analyses did not, however, find evidence of a difference in effect of aspirin between those with an index of 0.91-0.99 or less. Furthermore, one of the current major interventions in the specialty of diabetes mellitus is statin therapy. As aspirin was the first drug to have an evidence base for secondary prevention of cardiovascular disease it is always given to patients in subsequent trials and it might be asked if aspirin does indeed provide additional benefit when statins are used to good effect.

The importance of the neutral effect of aspirin on cardiovascular events is that this drug is not without

WHAT IS ALREADY KNOWN ON THIS TOPIC

Aspirin is effective in the secondary prevention of cardiovascular events in patients with symptomatic peripheral arterial disease and with or without diabetes

Aspirin is responsible for significant gastrointestinal morbidity

No large intervention trial has shown any reduction of events with antioxidant intervention

WHAT THIS STUDY ADDS

Aspirin was not effective in the primary prevention of cardiovascular events in patients with asymptomatic peripheral arterial disease and diabetes

Antioxidants showed no benefit on cardiovascular events in this population

side effects.[22] Aspirin is the most commonly prescribed drug in Scotland, with about 544 438 person years exposure per year in 2002. The number of prescriptions is increasing. Gastrointestinal bleeding is associated with general use of non-steroidal anti-inflammatory drugs in over 80% of reported adverse drug events, and 87% of that use is associated with aspirin, either alone or with other non-steroidal anti-inflammatory drugs.[23] The risk of a bleeding event increases with age and also continuous exposure.[22] Although the calculated risk of major bleeding is relatively small,[24] the number of people taking aspirin is relatively large and therefore in population terms aspirin induced bleeding is a major problem.

Of concern was the fact that there was a tendency to harm in the antioxidant group. The increase in number of deaths in the antioxidant groups, however, seems to partly reflect better survival than expected of the groups who did not receive antioxidants, rather than just an obvious negative effect of the antioxidants. Thus this may at least in part be a difference achieved by chance.

We found no evidence to support the use of either aspirin or antioxidants in the primary prevention of cardiovascular events and mortality in people with diabetes. Aspirin should still be given for secondary prevention of cardiovascular disease in people with diabetes, when the evidence base is convincing, and the results of this study must not detract from this important standard of care.

We thank Bayer for donating the aspirin and placebo tablets, Scotia Pharmaceuticals (formerly Cardinal) for the anitioxidant capsules and matching placebo, and the study nurse team of the prevention of progression of arterial disease and diabetes trial. Members of the Prevention of Progression of Arterial Disease and Diabetes Study Group. Medical Research Council steering committee: JBel (principal investigator), IC, SC, AMacC (chair), RT, and representatives of the Medical Research Council (various). Data and safety monitoring committee: Keith Fox, Desmond G Johnston, Gordon Murray, and JS (chair). End points committee: PM (chair), SMcE, JMcK, SP, RMacW, JBan, and Mairi Stirling. Contributing centres: Dundee—GL, RJ, AM, and Ray Newton (Ninewells Hospital); Dunfermline—AJ (Queen Margaret Hospital); Edinburgh West—JMcK (Western General Hospital); Falkirk—J Doig and NP (Falkirk and District Royal Infirmary); Glasgow—CS (Southern General Hospital), DG (Stobhill), Colin Kesson (Victoria Infirmary), and JP (Royal Infirmary); East Kilbride—Susan Benbow (Hairmyres and Stonehouse); Kirkcaldy—IC (Royal Victoria Hospital); Livingstone—Stuart Gray (St John's Hospital); Perth—AC (Perth Royal Infirmary); Monklands—DM (Monklands Hospital); Motherwell and Wishaw—IO'B (Wishaw General); Stirling—Sheila Reith and CK (Stirling Royal Infirmary). Nursing staff: JBan (senior research nurse). Royal College of Physicians Edinburgh Diabetes Registry Group, and West of Scotland clinicians: JBel, IC, John Chalmers, Joycelin Chalmers, AC, John Doig, David Fraser, Stuart Gray, Victor Hawthorne, RJ, RL (study statistician), GL, Susan Lewis, Derreck McCullough, SMcE, Margaret MacLeod, John McKnight, David Matthews, Andrew Morris, Ray Newton, NP, RP (study statistician), Sheila Reit, Mary Scott, Tanya Siann, Alan Smith, and James Walker.

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Foot orthoses and physiotherapy in the treatment of patellofemoral pain syndrome: randomised clinical trial

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ABSTRACT

Objective To compare the clinical efficacy of foot orthoses in the management of patellofemoral pain syndrome with flat inserts or physiotherapy, and to investigate the effectiveness of foot orthoses plus physiotherapy.

Design Prospective, single blind, randomised clinical trial.

Setting Single centre trial within a community setting in Brisbane, Australia.

Participants 179 participants (100 women) aged 18 to 40 years, with a clinical diagnosis of patellofemoral pain syndrome of greater than six weeks' duration, who had no previous treatment with foot orthoses or physiotherapy in the preceding 12 months.

Interventions Six weeks of physiotherapist intervention with off the shelf foot orthoses, flat inserts, multimodal physiotherapy (patellofemoral joint mobilisation, patellar taping, quadriceps muscle retraining, and education), or foot orthoses plus physiotherapy.

Main outcome measures Global improvement, severity of usual and worst pain over the preceding week, anterior knee pain scale, and functional index questionnaire measured at 6, 12, and 52 weeks.

Results Foot orthoses produced improvement beyond that of flat inserts in the short term, notably at six weeks (relative risk reduction 0.66, 99% confidence interval 0.05 to 1.17; NNT 4, 99% confidence interval 2 to 51). No significant differences were found between foot orthoses and physiotherapy, or between physiotherapy and physiotherapy plus orthoses. All groups showed clinically meaningful improvements in primary outcomes over 52 weeks.

Conclusion While foot orthoses are superior to flat inserts according to participants' overall perception, they are similar to physiotherapy and do not improve outcomes when added to physiotherapy in the short term management of patellofemoral pain. Given the long term improvement observed in all treatment groups, general practitioners may seek to hasten recovery by prescribing prefabricated orthoses.

Trial registration Australian Clinical Trials Registry ACTRN012605000463673 and ClinicalTrials.gov NCT00118521.

INTRODUCTION

As an alternative or adjunct to physiotherapy, foot orthoses are commonly used to treat active people with patellofemoral pain syndrome. A systematic review of the clinical efficacy of foot orthoses [1] identified two small clinical trials in people with patellofemoral pain syndrome that suggested orthoses may be of benefit.[2 3] No high quality randomised controlled trials have evaluated the use of foot orthoses for treating patellofemoral pain syndrome in the short or long term. We evaluated the short and long term clinical efficacy of foot orthoses in the treatment of patellofemoral pain syndrome compared with flat inserts or physiotherapy alone, and whether orthoses improved the effects of physiotherapy.

METHODS

We carried out a single blind, randomised clinical trial in a community setting in Queensland, Australia, for 12 months. Eligibility criteria were age 18-40; insidious onset of anterior knee or retropatellar pain of greater than six weeks' duration and provoked by at least two of prolonged sitting or kneeling, squatting, running, hopping, or stair walking; tenderness on palpation of the patella, or pain with step down or double leg squat; and pain over the previous week of at least 30 mm on a 100 mm visual analogue scale.[4]

A blinded assessor not involved in the randomisation process determined eligibility. Participants were randomly assigned to foot orthoses, flat inserts, physiotherapy, or foot orthoses plus physiotherapy.

Interventions

Interventions were administered by one of 17 trained physiotherapists. Participants attended six appointments for 20-60 minutes over six weeks. Participants assigned to orthoses received prefabricated,

commercially available orthoses (Vasyli International), which were fitted to their shoes. We used flat inserts as controls, made from identical material to the orthoses. Physiotherapy consisted of a combined therapy approach of proved efficacy in patellofemoral pain syndrome.[4] Participants assigned to orthoses plus physiotherapy received both interventions as described and had an extra appointment with the physiotherapist as needed.

We permitted use of over the counter drugs. Cointerventions used for symptoms of patellofemoral pain syndrome, and any adverse effects arising from intervention, were recorded.

Outcomes

The blinded assessor carried out reliable and valid outcome measures[5 6] before randomisation (baseline) and at 6, 12, and 52 weeks after randomisation. The primary outcome measures were global improvement,[5] severity of usual and worst pain over the preceding week, the anterior knee pain scale,[7] and the functional index questionnaire.[8] We measured global improvement on a five point Likert scale ("marked improvement" to "marked worsening") and visual analogue scale. We reduced categorical data to success equating marked or moderate improvement.[4]

Statistical analysis

Statistical analysis was done on a blinded, intention to treat basis using SPSS software (version 15.0). The dichotomous measure of success was expressed as relative risk reduction and numbers needed to treat. We analysed continuous outcome measures using univariate analysis of covariance, with baseline as a covariate and group allocation as a fixed factor. We included the characteristics of the participants and other baseline outcome measures as covariates in models to determine their impact on outcome. Significance was set at 0.01.

RESULTS

Overall, 179 volunteers were enrolled (see bmj.com), with 164 (92%) followed up at six weeks, 161 (90%) at 12 weeks, and 171 (96%) at 52 weeks. With the exception of duration, all groups were well matched at baseline (see bmj.com).

Significant effects favoured foot orthoses over flat inserts at six weeks, with differences of 19.8 mm (99% confidence interval 4.0 to 35.6) on the continuous scale of global improvement, a number needed to treat of 4 (2 to 51) on the categorical scale (success equating marked and moderate improvement), and success rates of 85% (35/41) for foot orthoses and 58% (23/40) for flat inserts (see bmj.com). At six and 12 weeks no significant differences were found in global improvement between physiotherapy and foot orthoses, or between physiotherapy and combined physiotherapy and orthoses (see bmj.com). For each of the three a priori pairwise comparisons no significant differences were found between the groups on other outcome measures (see bmj.com).

Over 52 weeks all groups had clinically meaningful improvements in worst pain severity (>20 mm on pain visual analogue scale), anterior knee pain scale (>10 points), and functional index questionnaire (>2 points; see bmj.com).[6] Three of the four groups (foot orthoses, physiotherapy, foot orthoses plus physiotherapy) also had clinically meaningful improvements in usual pain severity, while the improvement in usual pain for the group receiving flat inserts was slightly less than 20 mm. No significant differences were found between groups on any primary measure at 52 weeks.

Cointerventions

No significant differences were found in reported rates of use of cointerventions (see bmj.com) between foot orthoses and flat inserts (14/40, 35% *v* 15/39, 38%; relative risk reduction 0.09, 99% confidence interval −0.6 to 0.76), physiotherapy and foot orthoses (16/43, 37% *v* 14/40, 35%; −0.06, −0.78 to 0.68), or foot orthoses plus physiotherapy and physiotherapy alone (9/40, 23% *v* 16/43, 37%; 0.4, −0.3 to 1.01). Two participants assigned to flat inserts crossed over to foot orthoses after 12 weeks.

Side effects

A greater proportion of participants reported mild side effects with the foot orthoses (foot orthoses 31/43, 72%; foot orthoses plus physiotherapy 20/41, 49%) than with the flat inserts (15/39, 38%; relative risk reduction −0.58, 99% confidence interval −1.01 to −0.09). Thirty four participants (physiotherapy 18/44, 41%; foot orthoses plus physiotherapy 16/41, 39%; relative risk reduction 0.05, −0.59 to 0.67) reported a reaction to daily patellar taping. Two participants (physiotherapy group, orthoses group) had low back pain that required additional physiotherapy.

DISCUSSION

Foot orthoses produced short term improvements beyond that of flat inserts, with the number needed to treat indicating that four patients would need to be treated with orthoses to have one additional patient experience improvement. Foot orthoses were similar in effect to physiotherapy, and combining them did not provide additional improvement. In the long term, clinically meaningful improvements occurred in pain and function for all interventions. The overall pattern of effect implies that foot orthoses and physiotherapy each hasten resolution of the condition.

The interventions produced only mild side effects in the early phase of treatment. Despite the orthoses having relatively more side effects than the flat inserts, they showed a greater improvement in the first six weeks, suggesting that side effects did not adversely influence outcomes.

Our study provided level II evidence for the use of orthoses in patellofemoral pain syndrome. Our data corroborate findings from a smaller study, which found

WHAT IS ALREADY KNOWN ON THIS TOPIC

Patellofemoral pain syndrome is highly prevalent in sports medicine and presents often to general practices

Foot orthoses are often prescribed despite a lack of evidence highlighted by systematic reviews

WHAT THIS STUDY ADDS

Foot orthoses produce earlier and larger improvements in patellofemoral pain syndrome than flat inserts

Adding foot orthoses to physiotherapy does not improve physiotherapy outcomes

statistically significant improvements in pain after eight weeks' treatment.[2]

In keeping with previous work (see bmj.com), we detected differences in point estimates of effect between foot orthoses and flat inserts on measures of global improvement but not on measures of pain or physical function.

Strengths and limitations

The prescription of foot orthoses for musculoskeletal pain is characterised by a lack of solid evidence from quality clinical trials.[1] We studid the long term efficacy of foot orthoses in the management of patellofemoral pain syndrome, a highly prevalent condition for which orthoses are prescribed worldwide. We incorporated the recommendations from the consolidated standards of reporting trials into the design, which further strengthens the validity of findings.[9] Importantly, the attrition rate was low, with 8% of primary outcome data missing at six weeks, 10% at 12 weeks, and 4% at 52 weeks.

Unlike other clinical trials, we did not select those treated with orthoses on the basis of foot posture,[3] largely because no valid method exists to identify those who may benefit from orthoses. It is possible that participants fitted with orthoses in our trial were (randomly) heterogeneous for foot posture, yet we still found small but beneficial effects of prescribing orthoses compared with flat inserts. If the classification of patients becomes possible,[10] the point estimates of effect we report are likely an underestimate.

The characteristics of our participants were similar to those reported by others,[4 11-13] feasibly strengthening the external validity of our findings. Also, we used physiotherapists from primary care practices in the community with only brief training in the protocol (1.5 days).

A limitation of this study is the number of comparisons between groups. Although we used 99% confidence limit to assist in control of type I errors, it is possible that the significant finding between orthoses and flat inserts was due to chance. Notwithstanding this, a number needed to treat of 4 could be regarded as clinically meaningful and in part countering possible type I error.

Although we cannot categorically state that orthoses or physiotherapy are better than no treatment, largely because we did not study a no treatment control group, the 80% improvement rate after 52 weeks in our study compares favourably with the 50% improvement rate of participants followed up at four years in a prospective long term study of the clinical course of patellofemoral pain syndrome.[14]

Conclusions

Prefabricated foot orthoses are superior to flat inserts in the short term management of patellofemoral pain syndrome, implying that their contoured shape is therapeutic. We found no differences between the effects of orthoses and physiotherapy, nor was there any benefit of adding orthoses to physiotherapy.

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Abdominal aortic aneurysm events in the women's health initiative: cohort study

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ABSTRACT

Objective To assess the association between potential risk factors and subsequent clinically important abdominal aortic aneurysm events (repairs and ruptures) in women.

Design Large prospective observational cohort study with mean follow-up of 7.8 years.

Setting 40 clinical centres across the United States.

Participants 161 808 postmenopausal women aged 50-79 enrolled in the women's health initiative.

Main outcome measures Association of self reported or measured baseline variables with confirmed abdominal aortic aneurysm events assessed with multiple logistic regression.

Results Events occurred in 184 women and were strongly associated with age and smoking. Ever smoking, current smoking, and amount smoked all contributed independent risk. Diabetes showed a negative association (odds ratio 0.29, 95% confidence interval 0.13, 0.68), as did postmenopausal hormone therapy. Positive associations were also seen for height, hypertension, cholesterol lowering treatment, and coronary and peripheral artery disease.

Conclusions Our findings confirm the strong positive associations of clinically important abdominal aortic aneurysm with age and smoking in women and the negative association with diabetes previously reported in men.

INTRODUCTION

Aortic aneurysms are several times more common in men[1-5] but are more deadly in women.[6 7] The aetiology of aortic aneurysm and the reasons for these sex differences remain unknown. Most studies of abdominal aortic aneurysm have focused primarily on men, and little reliable information is available for women.

The women's health initiative was a large complex clinical investigation of strategies for long term prevention of common diseases involving 161 808 women at 40 clinical centres and comprising a set of overlapping clinical trials and an observational study.[8 9] We assessed the associations between potential risk factors and subsequent clinically important abdominal aortic aneurysm events (rupture and repair) in postmenopausal women.

METHODS

This analysis included all 161 808 women enrolled in the women's health initiative clinical trial (68 132) or observational study (93 676). Eligible women were postmenopausal, aged 50-79 at entry, had an expected survival of at least three years, and could be expected to adhere to the protocol. Women were enrolled during 1993-8 and followed up until the end of the main study in 2004-5.[8 9]

At the time of enrolment, participants were asked if a doctor had ever told them that they had each condition considered, including a previous diagnosis of abdominal or thoracic aortic aneurysm. Height, weight, waist circumference, and blood pressure were measured directly.

An abdominal aortic aneurysm event was recorded when a participant was admitted to hospital during the study period with an aneurysm that was symptomatic or required intervention (such as vascular or surgical procedure), or both, and had a diagnostic or interventional procedure that demonstrated the aneurysm. These events were identified when participants or their proxies completed standardised questionnaires (every six months for participants in the clinical trial and every year for those in the observational study) that asked about all admissions since the last update. Because a symptomatic abdominal aortic aneurysm nearly always represents rupture, these events should essentially all be ruptures and repairs (either elective or emergent). (See bmj.com.)

We performed multiple logistic regression with SAS version 9.1. Missing responses were treated as "no" for specific diseases, including prevalent aortic aneurysm. The model was adjusted for participation in the clinical trial and assigned treatment. We used Pearson correlation coefficient to evaluate correlations between covariates and ran additional models to evaluate potential interactions between strong predictors.

RESULTS

At entry into the study, 301 women reported that they had been told by a doctor that they had aortic aneurysm. During follow-up (mean 7.8 years, median 7.9 years), 184 abdominal aortic aneurysm events were reported, 18 in the women who had reported a diagnosis of aortic aneurysm at entry, resulting in 467 women (0.3%) with aortic aneurysm before or during the study. Fourteen of the 184 women who had abdominal aortic aneurysm events died within five days of the event; all 14 deaths were attributed to "other cardiovascular cause," the category under which deaths related to aneurysm should be coded. Table 1 shows characteristics of the women with and without events.

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Table 2 shows multivariable odds ratios for the various factors for abdominal aortic aneurysm events. The ratio of events to covariates is higher than the 8:1 needed for robust logistic regression modelling.[10] After we eliminated waist circumference because of high correlation with weight, the highest remaining correlation (other than those between smoking variables) was 0.26 for height and weight.

Abdominal aortic aneurysm events were strongly associated with age and smoking and, as expected, with previous diagnosis of aortic aneurysm. There were negative associations with diabetes and with baseline use of postmenopausal hormone therapy. Positive associations with abdominal aortic aneurysm events were also seen for height, hypertension, use of cholesterol lowering drugs, and coronary and peripheral artery disease.

There was a significant interaction between smoking and diabetes ($P<0.005$), such that diabetes amplified the increased risk from smoking of having an event. When we compared current smoking with never smoking in a model that included pack years and all other variables, the odds ratio (95% confidence interval) for abdominal aortic aneurysm events was 8.73 (5.04 to 15.12). (For more results see bmj.com.)

Table 1 | Characteristics at time of enrolment of women with and without abdominal aortic aneurysm (AAA) events. Figures are percentages of women unless stated otherwise

Characteristic*	AAA event (n=184)	No event (n=161 624)
Mean (SD) age (years)	67.2 (6.2)	63.2 (7.2)
White	86.4	82.5
Black	8.2	9.0
Mean (SD) height (cm)	162.2 (6.2)	161.8 (6.7)
Mean (SD) weight (kg)	73.0 (17.2)	73.6 (16.9)
Mean (SD) waist circumference (cm)	88.8 (13.9)	86.5 (13.8)
Ever smoked (≥100 cigarettes)	82.6	48.4
Mean (SD) pack years of smokers	44.0 (28.6)	21.0 (22.2)
Current smoker	38.0	6.9
Hypertension	62.5	38.9
Medication for high cholesterol	27.7	13.3
Coronary artery disease	26.6	6.8
Cerebrovascular disease	9.2	3.2
Peripheral artery disease	12.0	2.0
Venous thromboembolism	3.3	3.9
Diabetes mellitus	4.3	5.9
Chronic obstructive pulmonary disease	12.0	3.5
Non-skin cancer	10.3	9.2
Previous diagnosis of aortic aneurysm	9.8	0.2
Postmenopausal hormone therapy:		
Current	19.6	40.1
Past	18.5	16.1
Alcohol use:		
Never	7.1	10.9
Past drinker	28.3	18.6
<1 drink/week	28.8	32.7
1–<7 drinks/week	20.1	25.5
≥7 drinks/week	15.2	11.6

DISCUSSION

In this large cohort of postmenopausal women we have confirmed the strong positive associations of abdominal aortic aneurysm events with age and smoking and the negative association with diabetes, previously reported in men.[1-5 11]

Previous screening studies that used ultrasonography have reported factors associated with abdominal aortic aneurysm in 3000-3500 women each,[1 2 5 12] but the numbers found to have abdominal aortic aneurysm (1-2%) were too small to generate robust models with more than a few independent variables.[10] Similarly, a recent report of the Life Line screening programme included 10 012 women but detected only 74 aneurysms.[13] Previous clinical diagnosis studies from Chicago and northern California identified 109 and 115 abdominal aortic aneurysm events in women, respectively,[11 14] though only the northern California study provided multivariable models by sex.[14] Strong associations with abdominal aortic aneurysm in women were found in all these studies for age and smoking and in some for coronary and cerebral vascular disease, and weaker associations were seen in most for height, hypertension, and high cholesterol concentration.

A negative association between abdominal aortic aneurysm and diabetes was described more than a decade ago,[3 15] and, though confirmed in various studies in men,[4 16] whether it occurs in women has been uncertain. Several studies found marked negative trends in women,[1-12 14] but these did not reach significance. The Life Line screening programme did not observe a negative trend,[13] and the Chicago clinical diagnosis study reported a significant univariable interaction between sex and diabetes, with a positive univariable association for women but a negative trend for men.[11] In our large study we examined factors associated with abdominal aortic aneurysm in women and found a significant negative association with diabetes. No adequate explanation of the mechanism of this negative association has yet emerged,[17] but the observation adds to the evidence for a common pathophysiology of abdominal aortic aneurysm in men and women and for a fundamental difference between aneurismal and occlusive vascular disease.[18]

We observed a negative association between postmenopausal hormone therapy and aortic aneurysm, which was significant for use at time of enrolment and for duration of use over five years. There is some precedent in the literature for this association: the northern California study reported a non-significant trend in the same direction,[14] and a recent review of animal data found evidence for "a possible role for estrogen in protection against abdominal aortic aneurysm."[7] On the other hand, 33 of the 184 aneurysm events described in our analysis have been included in previous publications from the women's health initiative, and these reported hormone therapy effects from the randomised trials that differ from the effects we observed from hormone therapy used before enrolment. Women randomised to hormone therapy

Table 2 | Multivariable model* of factors associated with abdominal aortic aneurysm event

Factor†	Odds ratio (95% CI)
No of women with/without an event‡	164/147 885
Age (per 10 years)	1.77 (1.37 to 2.29)
Black race (*v* white)	0.77 (0.43 to 1.38)
Other race (*v* white)	1.23 (0.63 to 2.39)
Height (per 10 cm)	1.50 (1.15 to 1.96)
Weight (per 10 kg)	0.96 (0.86 to 1.07)
Ever smoked (≥100 cigarettes)	1.94 (1.16 to 3.24)
Current smoker (*v* past smoker)	4.19 (2.93 to 6.01)
Pack years (per 5 pack years)	1.11 (1.08 to 1.14)
Hypertension (›140/90 or medication)	2.14 (1.51 to 3.03)
Medication for high cholesterol	1.66 (1.15 to 2.39)
Coronary artery disease	2.38 (1.61 to 3.51)
Cerebrovascular disease	1.15 (0.66 to 2.00)
Peripheral artery disease	1.81 (1.05 to 3.11)
Venous thromboembolism	0.58 (0.25 to 1.34)
Diabetes mellitus	0.29 (0.13 to 0.68)
Chronic obstructive pulmonary disease	1.44 (0.88 to 2.37)
Non-skin cancer	0.94 (0.57 to 1.56)
Previous diagnosis of aortic aneurysm	9.00 (4.71 to 17.20)
Current hormone therapy (*v* never)	0.48 (0.31 to 0.73)
Past hormone therapy (*v* never)	0.76 (0.50 to 1.14)
Current alcohol use (*v* never)	0.73 (0.39 to 1.36)
Past alcohol use (*v* never)	0.95 (0.49 to 1.83)

*Model also adjusted for participation in clinical trial and assigned treatment.
†Status at time of enrolment.
‡After exclusion of women with missing values.

had significantly more abdominal aortic aneurysm events than controls in the Estrogen Alone trial (14 *v* 6 cases, hazard ratio 2.4)[19] and a number similar to controls in the Estrogen plus Progesterone trial (7 *v* 6, hazard ratio 1.1).[20] Possible sources of discrepancies between baseline and randomised effects of hormone therapy in the women's health initiative have been reviewed and include both greater duration of treatment and possible confounding by differences in lifestyle in the baseline data.[21] Further studies will be needed to clarify the effect of hormone therapy on aortic aneurysm.

The small but significant association we found between height and aortic aneurysm has been seen in previous studies in both men and women,[3 4 11 12 14] even when abdominal aortic aneurysm was defined relative to the suprarenal aorta rather than by unadjusted diameter,[3] though to our knowledge no explanation for this association has been proposed. Neither our study nor the northern California study[14] provide support for a recent report of an association between alcohol consumption and abdominal aortic aneurysm.[22]

It remains unclear why prevalence of abdominal aortic aneurysm differs so much by sex, even after multivariable adjustment for known associations. These adjustments might have been incomplete or there might be an as yet undiscovered biological explanation, possibly related to sex steroid hormones. Regardless, the negative association of abdominal aortic aneurysm with diabetes seems to be common to both sexes.

WHAT IS ALREADY KNOWN ON THIS TOPIC

Abdominal aortic aneurysm is more common in men but more deadly in women

Most previous studies have included too few women with aortic aneurysm to generate robust multivariable models.

WHAT THIS STUDY ADDS

There are strong positive associations between age and smoking and clinically important abdominal aortic aneurysm in women

The negative association between abdominal aortic aneurysm and diabetes previously reported in men is also seen in women

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Contributors: See bmj.com.
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Introduction of shared electronic records: multi-site case study using diffusion of innovation theory

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ABSTRACT

Objective To explore the introduction of a centrally stored, shared electronic patient record (the summary care record (SCR)) in England and draw wider lessons about the implementation of large scale information technology projects in health care.

Design Multi-site, mixed method case study applying utilisation focused evaluation.

Setting Four early adopter sites for the SCR in England—three in urban areas of relative socioeconomic deprivation and the fourth in a relatively affluent rural area.

Data sources and analysis Data included 250 staff interviews, 1500 hours of ethnographic observation, interviews and focus groups with 170 patients and carers, 2500 pages of correspondence and documentary evidence, and incorporation of relevant surveys and statistics produced by others. These were analysed by using a thematic approach drawing on (and extending) a theoretical model of complex change developed in a previous systematic review.

Main findings The mixed fortunes of the SCR programme in its first year were largely explained by eight interacting influences. The first was the SCR's material properties (especially technical immaturity and lack of interoperability) and attributes (especially the extent to which potential adopters believed the benefits outweighed the risks). The second was adopters' concerns (especially about workload and the ethicality of sharing "confidential" information on an implied consent model). The third influence was interpersonal influence (for example, opinion leaders, champions, facilitators), and the fourth was organisational antecedents for innovation (for example, past experience with information technology projects, leadership and management capacity, effective data capture systems, slack resources). The fifth was organisational readiness for the SCR (for example, innovation-system fit, tension for change, power balances between supporters and opponents, baseline data quality). The sixth was the implementation process (including the nature of the change model and the extent to which new routines associated with the SCR aligned with existing organisational routines). The seventh influence was the nature and quality of links between different parts of the system, and the final one was the wider environment (especially the political context of the programme).

Conclusion Shared electronic records are not plug-in technologies. They are complex innovations that must be accepted by individual patients and staff and also embedded in organisational and inter-organisational routines. This process is heavily influenced at the micro-level by the material properties of the technology, individuals' attitudes and concerns, and interpersonal influence; at the meso-level by organisational antecedents, readiness, and operational aspects of implementation; and at the macro-level by institutional and socio-political forces. A case study approach and multi-level theoretical analysis can illuminate how contextual factors shape, enable, and constrain new, technology supported models of patient care.

INTRODUCTION

Healthcare information systems are complex; they raise unique technical, administrative, and security challenges. Introducing new technologies into a complex system requires extensive changes in individual roles, relationships, and business processes—the so-called "socio-technical" aspects of change.

The national programme for information technology is delivered centrally by Connecting for Health and locally by strategic health authorities and primary care trusts. One component of this programme is the summary care record (SCR) (box).

In 2007-8, the SCR was introduced into early adopter sites across the United Kingdom. This is an evaluation of four of them. We sought to build a rich picture of the introduction, implementation, and routinisation of the SCR at these sites at both individual and organisational levels, so as to draw insights about the process of socio-technical change.

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METHODS

We set up a research advisory group with a lay chair and representatives of patients, clinicians, professional bodies.

Design and setting—We used mixed method case study evaluation across the four SCR early adopter sites. Each site consisted of a primary care trust, participating general practices, and one or more linked unscheduled care settings (such as an emergency department, walk-in centre, out of hours service). The catchment populations of three sites were of lower than average socioeconomic status and higher than average levels of limiting long term illness; the fourth site was an affluent rural area with low levels of illness (see full report for demographic details[1]).

Theoretical framework—The data collection was driven by Patton's utilisation focused evaluation method.[2] Our goal (which contrasts with that of many programme evaluators) was interpretation rather than prediction. We used a multi-level theoretical framework of complex innovation in health service organisations (see bmj.com).[3]

Data sources and analysis—Data sources are summarised on bmj.com and set out in detail in our full report.[1] This study generated large amounts of qualitative data of different forms (such as field notes, documents, interviews, informal stories) as well as some quantitative data (such as closed item questionnaires, monitoring statistics). Analysis occurred in three overlapping stages: we analysed each data source separately by using an appropriate technique; we further integrated these first order analyses by using narrative synthesis, so as to produce a coherent, multi-level interpretation of the story at each early adopter site; and we further synthesised insights from individual case studies in a cross-project analysis.

Key characteristics of the summary care record

Technology—The summary care record (SCR) is a centrally stored summary of key medical details that is created from a person's existing NHS record (currently, the detailed record held by their general practitioner) and made available to NHS staff in emergency and unscheduled care situations (emergency departments, general practitioner out of hours clinics, and walk-in centres).

What information does the SCR contain?—Information held on the SCR is currently limited to current drugs, allergies, and adverse reactions (the "phase 1 upload"), but a minimum clinical dataset (for example, whether someone has diabetes) (the "phase 2 upload") is being developed and added at selected sites.

Security safeguards—Extensive technical safeguards have been built into the SCR to prevent unauthorised access. Role based access controls restrict access to NHS staff with a legitimate relationship to the patient. Access by staff without such relationships are logged and audited; penalties for unauthorised access are severe and may include dismissal.

Consent model—At the time of the study, the consent model for the SCR was one of implied consent or "opt-out" (that is, unless a person explicitly withdrew consent, an SCR would be created), although this model is now being revisited. At the time of writing, patients may choose one of three options: "don't store" (a blank SCR will be created; nothing will be uploaded beyond the demographic details that are already on the spine); "store and share" (a full SCR will be created); or "store but don't share" (a full SCR will be created, but explicit consent must be obtained from the patient every time a health professional wishes to access it). An option for a "virtual sealed envelope" will also exist—a "store but don't share" option applied to selective sensitive information.

MAIN FINDINGS

SCR early adopter programme: overview

Connecting for Health's approach to the SCR programme was one of active control, characterised by detailed planning, tight monitoring, extensive documentation, and frequent reporting. This was to some extent mirrored at primary care trust level, where implementation had several formal stages: set-up, preparation, "go live," and deployment.

The first early adopter site began preparation in spring 2007, and the first SCRs were created in June 2007; deployment began on a limited scale in October 2007. The second site followed soon after, but at the third and fourth sites (which used different general practice suppliers), go live was delayed by several months, mainly because of technology failures. As of the end of April 2008, the SCRs of 153 188 patients at the first two sites had been created. A total of 614 052 patients in four early adopter sites had been sent a letter informing them of the programme and their choices for opting out of having an SCR (or limiting access to it). Of these, fewer than 1% had opted out of having an SCR and 0.03% had asked for data on their SCR not to be shared.

Many technical glitches and operational problems occurred with the SCR and the technical infrastructure that supports it. Non-participation of general practices in the programme ranged from 7% to 42% across the early adopter sites. Key influences on how the programme unfolded are listed below.

Material properties and attributes of the SCR

At the time of the study (May 2007 to April 2008), users perceived the SCR to be an immature technology. Wide variability existed among NHS staff on whether they felt the SCR had significant benefits, although most were broadly enthusiastic. A widespread perception existed that the consent model, the opt-out model, and role based access controls were "too complicated to work in practice." We noted an inherent imbalance between people who must work to upload patients' SCRs (general practitioners and their staff) and those who will see its benefits most directly (staff working in emergency settings).

A small minority of general practitioners saw the SCR as fundamentally eroding the essence of their work and their professional identity. However, others argued that contemporary health care requires a radical change in how confidentiality and privacy are defined (from a property of the individual doctor-patient relationship, mediated by the human qualities of the doctor, to a property of the system as a whole, mediated by technical and operational security measures).

Concerns about the SCR and its use

The main concerns of general practices in early adopter sites were workload and the ethics of consent. Workload for phase 1 was lower than anticipated. General practitioners were concerned that an "opt-in" consent

model for the imminent phase 2 upload would generate a large workload for practices. Other concerns included whether the implied consent model was legal, whether patients understood the choices they were being asked to make, whether the record was technically and operationally secure, whether participation in the programme would erode patients' trust in the practice, and the risk of the system grinding to a halt during the upload. Concerns of staff in unscheduled care settings mainly related to the technical usability of the software.

Influencing people's decision to adopt the SCR

This study showed that mass media campaigns (mail shots, press coverage, road shows) were relatively ineffective in influencing people's attitudes to the SCR.[4] Connecting for Health recognised the need for interpersonal influence and appointed two "opinion leaders" (national clinical leads), who travelled the country to explain what the SCR was, hear concerns, and try to make audiences more receptive. All participating primary care trusts also had at least one local champion—an enthusiastic general practitioner or senior nurse.

In general, general practitioners who also worked in the out of hours service were keen to see the SCR implemented. These "boundary spanners" seemed to be powerful agents of change.

Organisational antecedents for innovation

Absorptive capacity for new knowledge—Absorptive capacity is defined as a combination of formal expertise, informal organisational know-how, technical infrastructure, and relevant interpersonal networks.[5] Practice 16, for example, was one of the first to successfully upload records. It had a top of the range information system, and the senior partner was technically keen and capable. In contrast, practice 37 experienced many delays and problems and was very dependent on external technical support. Despite the fact that the practice was large with an engaged management team, little in-house expertise in information technology existed.

Leadership and management capacity—The importance of strong leadership, good strategic vision, good managerial relations, and committed and competent staff in introducing complex innovation is well established.[6] In practice 1, some staff had initial reservations about the SCR project. One partner championed the project and persuaded others that it was well aligned with the overall goals of the practice and would benefit patients. In contrast, practice 6 signed up to the SCR project but was characterised from the outset by lack of leadership from the senior partner and to some extent also the practice manager.

Risk taking climate—A risk taking climate is one in which experimentation is encouraged; failed projects lead to reflection and efforts to improve features of the system.[6] For example, a general practitioner from practice 28 reflected, "We've gone through the years making mistakes, you see. And you learn from them."

Efficient data capture—Our findings confirmed that innovation is more readily introduced when systems are in place to capture data on performance and feed it into organisational learning.[6] Practice 31, which easily achieved the data quality standards, showed a systematic and reflexive approach to data collection and analysis. This approach contrasted markedly with that of practice 33, where the practice manager felt that "data quality is no better than it was before. . . [audit] has just created a lot of extra work."

Slack resources—"Organisational slack" is a term used to denote spare time, money, or expertise that can be channelled into new projects.[7] In this study, small practices in particular found that lack of any staff who could free up time to spend time on the project was an important barrier to successful implementation.

Organisational readiness for SCR

Innovation-system fit—Innovation-system fit refers to the degree of alignment between the organisation's wider development goals and the introduction of a specific innovation.[3] For example, the manager of out of hours clinic E linked the SCR to a wider strategy for an integrated service to replace the previous fragmented one, and described a vision of a "state-of the art" out of hours service with a new building, well trained professional staff, efficient infrastructure, and seamless communication between organisations.

Tension for change—Tension for change refers to the extent to which people are uncomfortable with the status quo and feel that something has to change.[8] In out of hours clinic E, for example, clinicians felt that assessing patients without access to records was "stabbing in the dark" and placed patient safety at risk. Considerable enthusiasm existed for the SCR as a potential solution to this unacceptable situation. In contrast, several practices that had initially signed up to the SCR project but had subsequently withdrawn from it reflected that little tension for change had existed within their organisation.

Balance of support—Where supporters of a complex innovation outnumber its opponents and are more strategically placed, innovation is generally more successful[8]; our data affirmed this. In practice 2, for example, one of the three partners and the practice manager strongly supported the SCR project and the senior partner was also broadly supportive. The third partner was somewhat opposed, but his position was not strong enough to stop the practice from participating.

Specific preparedness—Innovation in organisations is more successful when preliminary groundwork has been done to the necessary standard.[3] Many practices attributed the relatively smooth upload of records to the SCR to good overall quality of data, usually linked to the information management and technology directly enhanced service initiative (a financial incentive scheme to improve the quality of data). In contrast,

one practice that struggled with preparations for the upload phase subsequently reflected, "We were surprised we were chosen [as an early adopter of the SCR], because we have only computerised 60% of our records so far, and when we started we were on nothing" (manager, practice 6).

The implementation and routinisation process

Appropriateness of change model—All complex innovation requires a judicious balance between managerial ("make it happen") and developmental ("let it emerge") approaches.[3] Many interviewees complained that, in the circumstances, the unseemly haste was somewhat absurd and felt that depth of commitment had suffered.

Effective project management—In general, operational management was good in most early adopter organisations. When this was not the case (for example, when posts were unfilled, managers lacked key skills, or workload outstripped available funding for staff), organisations struggled and delays occurred.

Autonomy of front line teams—Complex innovation is generally more successful if responsibility for operational decision making is devolved to front line teams.[3] To some extent, our data affirmed this. Several practices, for example, described a process of adapting the instructions provided by Connecting for Health or the primary care trust so as to make them workable locally. However, we also found that many practices were happy for the primary care trust to take over the change process and seemed to welcome the lack of autonomy.

Human resource problems—One of the most successful practices (practice 2) had a longstanding and close knit team of staff—the two senior administrators had been there for more than 20 years—and a good balance of skills including information technology and project management. Staff attributed their success to the input, enthusiasm, and goodwill of all team members. At primary care trust level, limited success with implementation of the SCR was often attributed to failure to appoint staff with key experience and qualities. Another aspect of human resources is training—especially hands-on, on the job training for individual staff members; informal and "helpdesk" support for new users; and team training for tasks requiring teamwork.[3] The manager of practice 8 commented that "the PCT people arrived with their packs and slide shows, and it's just nothing like that" and that after this initial training session "we were dreading it [the SCR upload]."

Alignment of routines—A key determinant of successful innovation is whether the new routine associated with the innovation aligns rather than conflicts with existing organisational and inter-organisational routines.[9] In one emergency department (A), the SCR could not be accessed as part of the receptionist's role, because of the promise made in the Connecting for Health confidentiality leaflet that receptionists would not see patients' clinical details. The task was allocated to healthcare assistants, but it was poorly aligned with their existing role, so accessing patients' SCRs proved difficult operationally.

Links between different parts of the system

One system level aspect of innovation previously shown to have a significant impact on innovation success is "linkage"—that is, ongoing formal and informal exchange of knowledge between different parts of the system.[3] In this study, we identified two important problems with linkage.

Linkage between technical developers and SCR users—Links between the technical developers of the SCR and its end users (such as general practitioners) tended to be characterised by lack of shared vision or language and low levels of mutual understanding. Many end users attributed the SCR's persistent "clunkiness" to poor linkage with the product's designers.

Intra-organisational and inter-organisational knowledge sharing—The early adopter programme was characterised by relatively weak lateral links between participating organisations in relation to their work on the SCR. We found few examples of specific exchange of knowledge, however. This may partly explain why some participants felt a sense of "reinventing the wheel" rather than building on the experience of others.

Wider socio-political environment

Official policy from the Department of Health was supportive of the SCR, but other forces were operating in the opposite direction. In particular, many stories in the media in 2007-8 reported large scale losses of data by government and the NHS; a strong civil liberties movement was arguing for less state control of private data, including opt-out campaigns led or endorsed by doctors. All this contributed to a climate of uncertainty.

DISCUSSION

This case study, as well as our linked paper on the perspective of patients,[4] has illustrated that shared electronic patients' records are not plug-in technologies. They are complex innovations that must be accepted by individual patients and staff and embedded in organisational and system level routines.

Self selecting innovators

All early adopter primary care trusts studied in this evaluation, and many participating general practices, scored highly on organisational antecedents for introducing new technologies, organisational readiness for the SCR, and operational aspects of managing the SCR project. As the SCR programme expands, organisational weaknesses that were not seen in the early adopters are likely to become apparent. One way of tackling this is to try to build absorptive capacity through approaches such as the information technology training and facilitation for practices offered by the PRIMIS+ support team (see www.primis.nhs.uk/). Another is to continue to work proactively with opinion leaders.

WHAT IS ALREADY KNOWN ON THIS TOPIC

Many countries have recently introduced shared electronic patients' records to support care in emergency and unscheduled settings and improve coordination of care

Information technology projects in health care are known to require social as well as technical change

WHAT THIS STUDY ADDS

The fortunes of the summary care record (SCR) programme so far are explained by properties of the technology itself, attitudes and concerns of users, organisational antecedents and readiness, and the wider socio-political context

Shifting the change model from "technology push" to "socio-technical development" may improve the chances that the SCR will be used extensively to support patient care in emergency and unscheduled care settings

An evaluation approach that aims for interpretation and understanding rather than prediction and "effect sizes" can generate important insights about the mechanisms of success or failure in complex change programmes

Unpopular aspects

One of the least popular aspects of the SCR programme was the "hybrid" consent model, which some participants viewed as unethical and others as unworkable. These positions represent the poles of a trade-off between high coverage of the population and gaining explicit consent for every record uploaded. Shared electronic record programmes in Scotland, Wales, and France have combined "implied consent to upload" with "explicit consent to view" at the point of care, although this has not been without controversy.[10-13] Connecting for Health is reviewing the SCR consent model in the light of our findings.

Our suspicion that the SCR programme would be characterised by a high degree of uncertainty and unpredictability, and that the burden and impact of the programme would be impossible to quantify with any precision, was confirmed.

Technology push or socio-technical change?

The predominant change model adopted for the SCR programme was one of "technology push"—centrally driven, rationalistic, with a focus on documentation and reporting, and oriented to predefined, relatively inflexible goals. Connecting for Health has been criticised in the past for such an approach and is actively seeking to change it.[14] Our data, along with research on comparable initiatives within and outside the UK, suggest that as the SCR programme expands, further movement in this socio-technical direction is likely to improve its chances of success.

However, political expectations could stymie this radical shift in the change model. A widespread assumption is that the SCR programme should be evaluated primarily in terms of the extent to which it is on schedule, rather than by softer, more emergent metrics such as the extent of clinical and public engagement or innovation-system fit.

Any measures of the success of large scale information technology programmes in health care must be developed organically alongside the operational characteristics of the technology in use, through a process of technological (re)design, consultation, negotiation, and policy deliberation—and the fitness for purpose of such metrics must be continually questioned as the programme develops.[15] In our view, for the SCR to have any chance of bucking the current trend of failed large scale information technology projects in health care, politicians, press, and public must begin to conduct their deliberations within this wider socio-technical discourse.

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