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The cost implications of informed decision-making: a mathematical simulation model of the potential financial effects of a web-based prostate specific antigen decision aid

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Abstract

Aim and Objectives: Web-based Prostate Specific Antigen (PSA) decision aids are known to promote informed decision-making. There is also some evidence that informed decision-making can result in reduced uptake of PSA testing, thus reducing subsequent costs related to urological intervention, specifically prostate biopsies. The aim of this study was to assess these potential financial benefits. The objectives were: first, to develop a mathematical simulation model based on data from a randomised controlled trial of a web-based PSA decision aid, Prosdex; second, to examine the effect of changes in PSA testing on prostate biopsy numbers and costs.

Methods: The simulation model was built using an animated simulation package, Simul8, which allowed for the input of parameter data: 1) Setting; 2) Intention to undertake a PSA test, derived from a RCT of a web-based PSA decision aid; 3) Costs related to PSA tests and prostate biopsies.

Results: Total costs varied with changes in the number of PSA tests at a single GP practice, all-Wales and UK level. At the single GP practice level, the effect on costs of changes in PSA testing was minimal. For example, a reduction in PSA testing from 4.6% to 3.6% reduced total costs for the practice by only £1,800. At the UK level, the same reduction in PSA testing lowered costs by approximately £10 million; a relatively small amount of financial resource in the context of a national health budget such as that of the UK National Health Service.

Conclusions: The financial impact of web-based PSA decision aids is minimal. The benefit of using PSA decision aids should be viewed in ethical terms and not in financial terms.

Keywords

Informed decision-making, mathematical simulation model, patient decision aid, person-centered medicine, prostate cancer, Prostate Specific Antigen (PSA), uro-oncology

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Introduction

Trials have shown that men's uptake of Prostate Specific Antigen (PSA) testing reduces after the use of patient decision aids (PDAs) [1], but there is no estimation available of the impact such informed decision-making might have on the use of healthcare resources. Web-based PSA decision aids promote informed decision-making in men considering the PSA test for prostate cancer [2]. This paper aims to investigate whether widespread use of these decision aids would generate financial benefits for health services.

The prevalence of prostate cancer is increasing in the developed world, partly due to an increase in the population of older men. The PSA test remains the only widely available screening test for prostate cancer in primary care and, as a blood test, it is both simple and inexpensive to use. However, it is not considered a diagnostic test and the value of the PSA test is limited by its relatively poor specificity and sensitivity [3,4]. Nonetheless, demand for the PSA test has gradually increased over the last decade. In 2004, the annual rate of testing in men with no previous diagnosis of prostate cancer was estimated at 6%, with a significant increase in testing between 1999 and 2002 [5]. In 2011, PSA testing rates were estimated at 6.2% [6]. While overall testing rates in the UK remain relatively low compared to the USA, where over half of men $\geq$ 50 years had a PSA test in a 12-month period [7], there is disproportionate uptake of the test in the 75-79 age group (11.3%) [6]. This, combined with an increasing population of older men, raises concerns over the potential increase in PSA test uptake.

Increased PSA testing for prostate cancer will have a significant impact on urological services worldwide. Men with a high PSA test result are commonly referred to urologists for an ultrasound-guided prostatic biopsy and the costs incurred therefore rise correspondingly. Additionally, if prostate cancer is diagnosed, additional costs related to further investigations and treatment are incurred. Balanced against these costs, of course, is the potential benefit of a reduction in palliative care treatment, including radiotherapy and chemotherapy and a reduction in mortality from prostate cancer. However, the evidence base for such a reduction in mortality following large-scale PSA testing is at best unclear, as demonstrated in 2 large population studies from Europe and the USA [8,9]. A more recent systematic review of the evidence concluded that PSA screening results in small or no reduction in prostate cancer-specific mortality and is associated with harms related to subsequent, potentially unnecessary, evaluation and treatments [10].

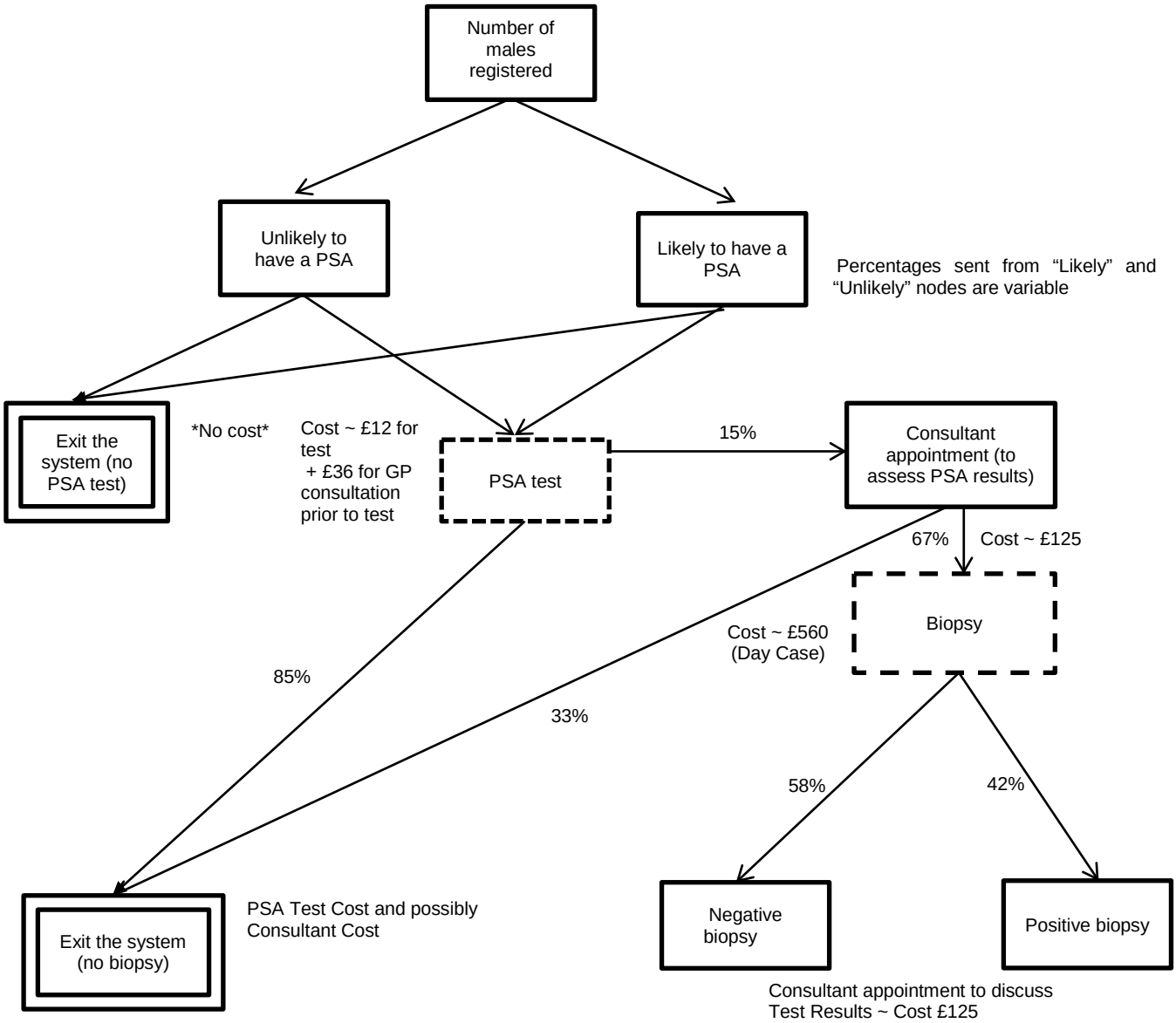
For this reason and due to the limitations of the PSA test, the US Preventive Services Task Force now recommends against PSA based screening [11] and there is no routine PSA screening for prostate cancer in the UK. Instead, the UK government established the Prostate Cancer Risk Management Programme (PCRMP), a strategy which promotes informed decision-making about PSA testing [12]. According to this strategy, informed decision-making is to be achieved in part by access to PDAs, one of which is the web-based PSA decision aid, Prosdex [13]. Informed decision-making is defined, with reference to Marteau and colleagues' original work on Down's syndrome, as high knowledge in the context of congruent attitudes and behaviours relating to the PSA test [14].

PDAs are interventions designed to help individuals make difficult choices. They have been developed for a range of health conditions to facilitate informed decision-making and have been shown to have an effect on patients' decisions both in terms of investigations and treatments [15]. In our previously published systematic review of the effects of PSA decision aids, we found they resulted in a 3.5% reduction in uptake of PSA testing [1]. More recently, we developed a web-based PSA decision aid, Prosdex [13] and conducted a randomised controlled trial (RCT) of its effect on informed decision-making. For the intervention group, we found an increase in knowledge ($p<0.001$) and also less favourable attitudes to testing ($p<0.001$) combined with lower intention to undergo testing ($p=0.02$). In other words, Prosdex was found to promote informed decision-making regarding the PSA test [2].

What is not known, however, is the potential financial impact of a PDA such as Prosdex on urological services. Simulation modelling offers the possibility of exploring the effect on costs up to, and including, prostate biopsies, as the epidemiological and cost data are fairly well established. In contrast, data for costs beyond the prostate biopsy result are much weaker. This is due in part to our limited epidemiological knowledge about the natural history of prostate cancer and also to the wide variation in treatment strategies employed for the condition. Simulation modelling is a commonly used methodology that allows us to examine the effects of variability in results from trials. For example, the RCT of Prosdex suggests that 4% of those in the intervention group who used Prosdex might opt for a PSA test, but this 4% is just a single point value. If the exercise were to be repeated, then a different percentage might result. The simulation program imposes a probability distribution around the RCT result and provides estimates, with expected limits of variation, on the likely consequences at a GP practice level or at a national level. These consequences are important not only in predicting the anticipated workload on clinicians, specifically with regards to prostate biopsies, but also in providing useful cost estimates. One of the most important features of this type of modelling is the ability to investigate a number of 'what-if' scenarios; for instance, the impact of widespread implementation of informed decision-making on PSA test uptake.

This study aimed to use simulation modelling to assess the potential financial implications for urological services of informed decision-making, as promoted by a web-based PSA decision aid, Prosdex. The objectives were: first to create a simulation model using data from the RCT of Prosdex in order to examine the effect of

Figure 1 Screenshot of mathematical simulation model



changes in numbers of PSA tests undertaken on prostate biopsy numbers and costs and second, to apply the model to changes in numbers of PSA tests undertaken, including that expected as a result of a PSA decision aid.

Methods

The simulation model

To determine the effect of Prosdex on uptake of PSA testing and also the impact on wider urological services, a simulation model was built using the simulation package SIMUL8 (www.simul8.com/healthcare). Simulation packages seek to imitate reality through a series of different events. The events can be arrivals, services, exits and also decisional nodes. An integral part of this software is its ability to incorporate random variations in the processes into its activities. Also, SIMUL8 provides the user with an opportunity to test many different scenarios and to establish their effect on the overall running of the system. SIMUL8 has an animated graphical interface whereby the user can visualise what is going on in the system without the need to understand complex mathematics. These factors imply that a simulation model and the use of the SIMUL8 package is suitable for this study. SIMUL8 also has the capability of linking to an Excel spreadsheet, which aids with the input of parameters and the analysis of results.

Figure 1 contains a flow chart of the simulation model. Unlike many uses of discrete event simulation models, we were not interested in the time taken for a person to pass through the model or in any queues formed. We were solely concerned with the numbers of patients who reached specific nodes, namely the "PSA test" node, the first "Consultant appointment" node and the "Biopsy" node. At each of these nodes an activity is

performed and thus a cost is incurred for the National Health Service (NHS). Figure 1 demonstrates each of the pathways that a respondent in the RCT can follow. The model is exhaustive and therefore all possible pathways through the system are considered. Also, the probabilities at each node are mutually exclusive and independent of one another.

Parameter data for the simulation model

In order to run the simulation model, parameter data was entered *via* an Excel spreadsheet. Parameter data included: a) Setting and population; b) Intention to undertake a PSA test, derived from a RCT of a web-based PSA PDA, Prosdex(2); c) Costs related to PSA tests and prostate biopsies.

a. Setting and population

Three settings were considered in the simulation model: a GP surgery from the associated RCT(2); Wales and the UK. For each setting, we considered men aged 50-75 years, as this was the age-range in our trial and also the group in which the greatest amount of PSA testing occurs. For the 3 settings, the number of men aged 50-75 were: GP surgery, 1,205; Wales, 443,261; UK, 7,773,913 [16].

b. Intention to undertake a PSA test

The likelihood of men undertaking PSA testing was derived from the intention outcome of our RCT [2], as shown in Table 1.

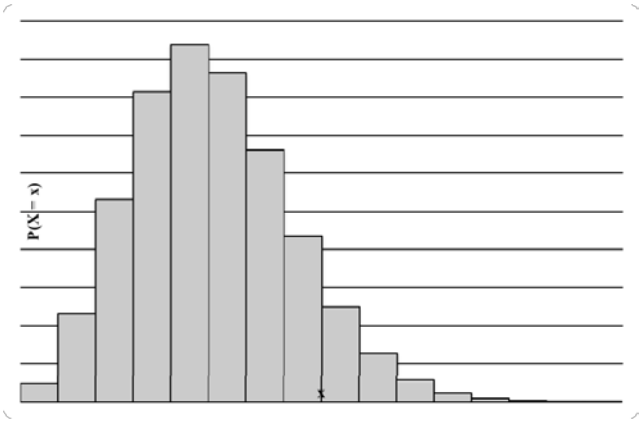
Table 1 Likelihood of taking the PSA test by RCT group

Group	How likely are you to have a PSA test?	
	Unlikely	***Likely***
Prosdex	63%	37%
Control Group	40%	60%
Paper version of Prosdex	47%	53%

It was assumed that the likelihood to opt for the PSA test was not dependent on the setting being modelled. Also, the variables "Group" and "Likelihood of having the test" are dependent upon each other (according to the chi-square test, p = 0.01): only 37% of respondents in the Prosdex intervention group are likely to have the PSA test, whereas almost 60% of the respondents in the control group are likely to have the PSA test.

In the simulation model, the percentage utilised for routing patients from the "PSA test" node to the "Consultant appointment" node is 15%, on average, but the simulation model imposes the Poisson distribution about this mean, thus the output changes depending upon the variability generated. The Poisson distribution is used frequently in simulation modelling to imitate the variability inherent in real life events [17]. Figure 2 displays a graph of the probability mass function (PMF) of the Poisson distribution, with a mean value of 4.6. It is clear from the graph that the most probable outcome is 4. The simulation model was also run with several other statistical distributions, including geometric and binomial, imposed upon the routing percentages; however, the results were relatively similar (within approximately 8%).

Figure 2 Probability mass function of the Poisson distribution



When running the simulation model, the likelihood of undertaking PSA testing was converted to actual PSA testing, as shown in Figure 1. If a man was sent to the "Likely to have a PSA" node, then he was routed either towards the "PSA test" node (percentage following a Poisson distribution, mean = 10%) or to the "No PSA test" node (percentage following a Poisson distribution, mean = 90%). In contrast, the respective mean percentages for a man sent to the "Unlikely to have a PSA" node were 1% for the "PSA test" node and 99% for the "No PSA test" node.

Consequently, according to the model, the annual PSA test rate was 4.6%. This figure compares favourably with the previously noted epidemiological data, which found the annual rate of testing in men with no previous diagnosis of prostate cancer to be 6% [5]. This baseline figure of 4.6% uptake was then varied (from 2.0 to 7.6) to investigate what effect the uptake of PSA tests would have on testing costs and biopsy costs. Downstream costs, such as treatment following a positive biopsy result, were not considered in this model due to lack of data.

c. Costs

i. PSA costs

Costing the actual PSA test is a difficult process as figures quoted in the literature vary significantly (from US$ 10 [18] to US$ 40.61 [19]). Privately, the cost for a PSA test is quoted as £12 [20], but a GP consultation is also required prior to the test at a cost of £36 on average [21]. This gives a total cost for the PSA test of £48. These PSA test costs, even at the highest level, are small and will not contribute a great amount to the downstream

Table 2 "What–if" type scenarios tested (Baseline in bold)

PSA test uptake from 'likely' node (%)	PSA test uptake from 'unlikely' node (%)	Prosdex group – total PSA test uptake (%)	Control group – total PSA test uptake (%)
5%	0%	2.0%	2.9%
7%	0%	2.8%	4.0%
9%	0%	3.6%	5.2%
10%	1%	4.6%	6.2%
11%	2%	5.6%	7.2%
12%	3%	6.6%	8.2%
13%	4%	7.6%	9.2%

costs. A value of £48 was used for the model, since this is the only UK cost found and private healthcare costs should account for all overheads present in the system.

ii. Prostate biopsy costs

According to our simulation model (Figure 1), once a man has had the PSA test, he is either sent out of the system or referred to see a consultant. Calculating the proportion of UK men who, after a PSA test, are referred for a biopsy is challenging due to a lack of epidemiological data. Melia *et al*. reported the rate of referral from 48 GP practices in England, for asymptomatic men, to be 5.5% in 2001-02 [22]. By 2003-4, this figure had risen to 8.5%, possibly due to the advent of the Prostate Cancer Risk Management Programme (PCRMP) [12]. Fifty-six percent of the participating GPs were aware of receiving a PCRMP pack. Assuming that UK-wide awareness of the PCRMP would be lower, but also taking into account the fact that both asymptomatic and symptomatic men were included in our model, we estimated the referral percentage to be 15%. From UK data, the initial consultant appointment was costed at £125 [23].

Following the consultant appointment, the men in our model are either sent out of the system or for a prostate biopsy. We received data from a study that was being conducted at the time the simulation model was developed, ProtecT, that 83% of the participating men eligible for a biopsy undertook the procedure (ProtecT Study Team, Personal Communication). To reflect non-experimental settings, we used a slightly more conservative average for the simulation model of 67% of men with a raised PSA undertaking a prostate biopsy. Combining these figures in the model resulted in an average of 10% of the men who have a PSA test receiving a prostate biopsy; a figure which is similar to the 9.4% identified by Melia *et al*. in a study of PSA testing and subsequent investigations in men whose first degree relatives had prostate cancer [24].

The cost of a prostate biopsy was obtained locally from the Cardiff and Vale University Health Board, UK (2008, formerly NHS Trust), as £559 for a day-case patient. An additional consultant appointment is then required to view the results of the biopsy and to discuss further treatment plans with the patient, at a further cost of £125 [23]. According to data obtained from the Cardiff and Vale University Health Board, the percentage of prostate biopsies diagnosed as prostate cancer (positivity) was 42% between 1996 and 2007 and this figure was therefore used in the model. The figure is similar to that from the aforementioned ProtecT study which, up to 2008, reported a positivity of 39%.

Results

The simulation model was run using the percentages outlined above as a baseline. The PSA testing likelihood data from the Prosdex intervention group in our trial was utilized and data on PSA test uptake, prostate biopsies and related costs were generated. We also considered a number of 'what-if' scenarios based on incremental changes to the baseline likelihood of PSA testing and associated PSA test uptake (Table 2). Note that the baseline figures of 10% and 1% correspond very closely to the results found from the uptake data.

The model was run 50 times to account for variability and the results obtained for each setting are shown in Table 3. A direct relationship is demonstrated between PSA test uptake and cost. For example, when the PSA uptake is increased by 1% from the baseline 4.6% to 5.6%, the costs at a UK level rise by approximately £10 million. Conversely, if the uptake of PSA is reduced by 1% to 3.6%, the costs decrease by approximately £10 million. The costs change in a linear manner and are approximately proportional to the percentage uptake (the slight deviations are accounted for by sample variation). In contrast, at a GP practice level, it is clear that the corresponding differences in cost are less substantial.

The above analysis is based on the likelihood to undertake PSA testing for participants in the Prosdex intervention group of the trial. The simulation model was also run for the control group (Table 3). It is clear from Table 3 that the Prosdex PDA has an impact upon cost when compared with the control group (at 7.6% uptake, the difference in cost is approximately £17 million, whereas at 2.0% uptake, the difference in cost is approximately £9 million).

Table 3 PSA tests, prostate biopsies and corresponding costs for the 3 settings (using likelihood of undertaking PSA testing from the Prosdex group)

	PROSDEX GROUP				CONTROL GROUP			
SETTING (MEN 50-75)	**PSA UPTAKE**	**MEAN NUMBER OF PSA TESTS (95% ELV)**	**MEAN NUMBER OF BIOPSIES (95% ELV)**	**COST (BASED ON MEAN NUMBER)**	**PSA UPTAKE**	**MEAN NUMBER OF PSA TESTS (95% ELV)**	**MEAN NUMBER OF BIOPSIES (95% ELV)**	**COST (BASED ON MEAN NUMBER)**
GP Surgery from the RCT (n=1,205)	2.0%	23.3 (21.9, 24.6)	2.3 (1.83, 2.77)	£3,100	2.9%	35.6 (33.0, 38.1)	3.3 (2.31, 4.29)	£4,600
	2.8%	32.3 (30.6, 34.1)	3.38 (2.87, 3.89)	£4,500	4.0%	48.4 (45.3, 51.4)	4.365 (3.37, 5.93)	£6,700
	3.6%	41.9 (40.2, 43.7)	4.36 (3.68, 5.04)	£5,800	5.2%	61.8 (58.0, 65.5)	6.10 (4.61, 7.59)	£8,300
	4.6%	**53.2 (51.1, 55.4)**	**5.76 (5.04, 6.48)**	**£7,600**	**6.2%**	**72.7 (69.4, 76.1)**	**7.45 (5.69, 9.21)**	**£10,100**
	5.6%	65.7 (63.3, 68.1)	6.82 (5.93, 7.71)	£9,100	7.2%	84.0 (80.8, 88.2)	7.90 (5.91, 9.89)	£11,300
	6.6%	78.2 (75.7, 80.8)	8.12 (7.15, 9.09)	£10,900	8.2%	98.4 (94.6, 102.1)	9.15 (7.04, 11.26)	£12,900
	7.6%	89.8 (87.1, 92.6)	8.82 (7.86, 9.78)	£12,000	9.2%	109.8 (105.2, 114.3)	10.20 (8.04, 12.36)	£14,300
Wales (n=443,261)	2.0%	8,885 (8,846, 8,923)	893 (875,911)	£1,204,000	2.9%	12,825 (12,764, 12,885)	1,288 (1,271, 1,305)	£1,737,000
	2.8%	12,410 (12,350, 12,470)	1,240 (1,220, 1,260)	£1,676,000	4.0%	17,951 (17,888, 18,013)	1,803 (1,779, 1,826)	£2,432,000
	3.6%	15,990 (15,940, 16,040)	1,600 (1,580, 1,630)	£2,163,000	5.2%	23,082 (23,011, 23,153)	2,322 (2,301, 2,344)	£3,132,000
	4.6%	**20,390 (20,310, 20,470)**	**2,060 (2,040, 2,080)**	**£2,773,000**	**6.2%**	**27,478 (27,399, 27,558)**	**2,767 (2,744, 2790)**	**£3,730,000**
	5.6%	24,810 (24,740, 24,880)	2,490 (2,460, 2,510)	£3,358,000	7.2%	31,908 (31,817, 31,998)	3,213 (3,191, 3,235)	£4,331,000
	6.6%	29,240 (29,170, 29,300)	2,940 (2,920, 2,960)	£3,966,000	8.2%	36,378 (36,288, 36,468)	3,670 (3,640, 3,699)	£4,944,000
	7.6%	33,670 (33,610, 33,730)	3,400 (3,370, 3,420)	£4,577,000	9.2%	40,775 (40,689, 40,861)	4,116 (4,084, 4,147)	£5,544,000
UK (n=7,773,913)	2.0%	155,400 (155,200, 155,600)	15,630 (15,560, 15,700)	£21,082,000	2.9%	225,200 (225,100, 225,400)	22,650 (22,580,22,720)	£30,554,000
	2.8%	217,500 (217,300, 217,800)	21,880 (21,780,21,980)	£29,515,000	4.0%	315,300 (315,000, 315,600)	31,670 (31,590, 31,760)	£42,746,000
	3.6%	279,700 (279,400, 280,000)	28,070 (27,970, 28,170)	£37,896,000	5.2%	405,400 (405,100, 405,700)	40,740 (40,650, 40,840)	£54,975,000
	4.6%	**357,600 (357,300, 357,800)**	**35,890 (35,800, 35,990)**	**£48,453,000**	**6.2%**	**483,300 (483,000, 483,600)**	**48,550 (48,430, 48,670)**	**£65,516,000**
	5.6%	435,100 (435,100, 435,700)	43,740 (43,660, 43,820)	£59,026,000	7.2%	561,300 (560,900, 561,600)	56,390 (56,250, 56,540)	£76,091,000
	6.6%	513,200 (512,800, 513,600)	51,550 (51,430,51,670)	£69,565,000	8.2%	639,000 (638,700, 639,300)	64,180 (64,070, 64,300)	£86,622,000
	7.6%	591,200 (590,900, 591, 600)	59,370 (59,270, 59,470)	£80,129,000	9.2%	716,900 (716,500, 717,200)	72,020 (71,870, 72,170)	£97,182,000

Discussion

Cost savings generated by web-based PSA decision aids are minimal. Using a simulation model, we found that small changes in PSA test uptake resulted in negligible cost differences at GP practice level. Specifically, if PSA test uptake in men aged 50-75 was reduced from 4.6% to 3.6%, as might result from the use of a web-based PSA decision aid, total costs for the practice would only be reduced by £1800. At the UK level, the same reduction in test uptake would result in cost savings of £10 million. This represents less than 0.1% of the £105.9 billion NHS budget for England in 2011-12 [25]. Therefore, the benefits of a web-based PSA decision aid should be considered in ethical terms, specifically the promotion of informed decision-making and not in financial terms.

We were able to develop a simulation model using best available national data pertaining to costs, complemented with data from a RCT of a web-based PSA decision aid, Prosdex. The PSA testing data was derived from the 'intention to undertake PSA testing' outcome of the RCT. This clearly does not equate with actual population PSA testing figures, although the figure we used for annual PSA tests, 4.6%, is in accordance with other epidemiological studies [5]. Moreover, the principal object of this simulation model was not to define absolute values but, instead, to describe the impact, specifically in terms of costs, of changes in PSA testing levels.

The costs quantified in this model were those of PSA tests, prostate biopsies and consultant appointments. Costs incurred after the prostatic biopsy result, in particular those relating to prostate cancer treatment, were not considered as the data used would be fairly speculative. This is a consequence of 3 main reasons. First, not all prostate cancers are alike and some are far more aggressive than others, potentially requiring more intensive treatment. Second, men with prostate cancer are of different ages and levels of health and differ in their suitability for certain treatments, particularly radical surgery. Third, there is no clear consensus on the most appropriate treatment for these different prostate cancers and there is a diverging pathway of options including conservative treatment, radical surgery and brachytherapy. All of these distal events in the prostate cancer treatment decision-tree carry costs of an order of magnitude larger than the costs calculated in our model. Therefore, the financial effect of changes in PSA testing levels, particularly on a UK basis, is likely to be greater than that reported here. On the other hand, of course, there are differential costs after the treatment stage. For example, the cost of a radical prostatectomy resulting in a cure would be expected to be much less than that of a more conservative approach which results in advanced prostate cancer and palliative care.

PSA testing and prostate cancer screening has been the subject of a number of modelling studies. In the USA, Feuer *et al*. (2004) presented a range of models, epidemiological and biological, to examine the effect of PSA screening on prostate cancer mortality. They found that they were dependent on key assumptions or parameter data, in particular the uptake of PSA 'screening' [26]. Similarly, Etzioni *et al*. (2008) outlined a simulation model, described as a 'surveillance modelling approach,' to examine the impact of PSA screening on the incidence of advanced stage prostate cancer in the USA. They found that PSA screening contributed to declines in distal-stage incidence and mortality [27]. In a subsequent study they used a 'calibrated model' that linked PSA changes with disease progression to explore the effect of a lower PSA value (2.5ng/ml), as opposed to the standard value (4.0ng/ml), as the cut-off for referrals. Lowering the cut-off was found to have a negligible benefit in the detection of curable disease [28]. In contrast to our study, however, none of these modelling studies directly quantified costs and the effect of changes in PSA test uptake.

One of the most comprehensive economic evaluations of prostate cancer testing/screening was undertaken in a systematic review by Ekwueme *et al*. in 2007 [19]. From the 28 studies included in the review they found that the 'pooled baseline resource cost' in the USA was $37.23 for screening with the PSA test, as opposed to $30.92 in 'other industrialised countries'. Whilst this gave a helpful indication of costs - £1.86 billion per year for the USA - it did not model the impact on costs of changes in population PSA testing levels [19]. The limitations of the evidence base and indeed the difficulty in researching this area, was highlighted in a recent systematic economic review of PSA screening [18]. Here, Imamura and Yasunaga found that most economic analyses, particularly cost-effectiveness and cost-utility analyses, were based on mathematical models and the authors were highly critical of their reliance on 'fragmented cost data and unconvincing outcome data'. However, the cost-utility ratio for PSA screening was found to range between $63.67 and $68.32 per quality-adjusted life years (QALY) gained and the authors concluded that there was a need for further economic evaluations on the basis of RCTs, especially large-scale population trials [18].

PSA testing simulation modelling is clearly difficult to undertake, in large part due to our limited understanding of both the epidemiology of prostate cancer and the optimal treatment strategies for the condition. Simulation modelling may well, however, have an increasing role in the future, not least due to its utilization in other complex areas of healthcare. In 2002, a mathematical modelling study of 3 treatment strategies for the primary prevention of cardiovascular disease demonstrated varying costs and clinical outcomes for the 3 interventions [29]. The effect of different treatment strategies for HIV/AIDS was also the subject of a simulation modelling study which described different scenarios with varying levels of incidence and prevalence [30].

The promotion of informed decision-making is arguably in itself a sufficient benefit of using web-based PSA decision aids. In other words, the ethical benefit of reinforcing patients' autonomy overrides all other concerns. However, the economic implications of these interventions cannot be ignored. What, therefore, is the impact of a web-based PSA decision aid such as Prosdex

on a large population outside an experimental/trial setting? This question currently remains unanswered, as the dissemination and large-scale uptake of PDAs in a number of clinical settings has been disappointing. Moreover, it should not be assumed that large-scale uptake of PSA PDAs would reduce levels of PSA testing. The incidence of prostate cancer is increasing sharply, as is the public interest in the condition and specifically testing/screening. There is a strong argument that PSA testing levels will rise, with or without the implementation of decision aids.

It is important that the cost implications suggested by our simulation model are put in context. As noted earlier, the full potential financial implications of web-based PDAs, such as Prosdex, remain unclear due to our understanding of the epidemiology and optimal treatment strategies for prostate cancer being limited. It is hoped that large-scale trials will allow greater understanding on this issue and enable simulation modelling to proceed further than the prostate biopsy level reached in this study.

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