Location of services and the impact on healthcare quality: insights from a simulation of a musculoskeletal physiotherapy service

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Abstract

Many healthcare systems are being redesigned to deliver local care with more services within the community. Relocation may enhance access but other aspects of healthcare quality should also be considered, notably waiting times and equity of care. This study examined a musculoskeletal physiotherapy service using a discrete event simulation with simple heuristics to model patient-behaviour. This combination provided an effective mechanism for incorporating the individuality of the patients in the flows along the patient-pathways, subject to the varying availabilities of key resources. In particular it captured the feedback that is critical in system performance, especially where waiting times are important. The model recognised the heterogeneity of patient attitudes and demonstrated how the behaviour of a relatively small proportion can affect the experience of all patients. The study suggested that, with careful operational management, more care could be delivered locally while exploiting many of the benefits of a centralised service.

Keywords: simulation; health service; behaviour; location; quality

1. Introduction

1.1 Balance of care and healthcare quality

There is a long history of the balance of healthcare delivery shifting between local, community based facilities and more specialised acute centres. The potential economies of scale, health governance and the exchange of knowledge have often acted as pressures encouraging the concentration of healthcare at acute hospitals (University of York, 1997; Ferguson et al, 1997; Sowden et al, 1997). However there are many benefits in local delivery of care; easier access can be particularly important for an ageing population and a growing prevalence of chronic conditions. A shift in this balance of care towards more delivery in the community may well be advantageous for many services but others can suffer a reduction in quality, and also efficiency (Sibbald et al, 2007). The balance of care has become the focus of the redesign of many services within the National Health Service (NHS) in the UK with proposals to transfer services from acute hospitals into local communities, and even patients' homes (Harvey and McMahon 2008; Shifting the Balance of Care Delivery Group 2009; NHS Quality Improvement Scotland 2010). While the balance of care can encompass many issues, this paper focuses on the location of services and the consequences for healthcare quality, using musculoskeletal physiotherapy as an example.

Although there is much debate about the definition of healthcare quality, a widely adopted classification defines six domains: safety; timeliness; effectiveness; efficiency; equity and patient-centeredness (Institute of Medicine, 2001). Interpreting and measuring these quality domains in the context for any specific service is critical in any redesign, not least when shifting the balance of care (Harvey and McMahon, 2008). In the case of shifting the balance of care for the physiotherapy service the six quality domains are illustrated by the criteria in Table 1; other studies might well select alternative criteria more relevant to the particular service.

Quality domain	Physiotherapy service
clinical safety	treatment is permitted only at a centre providing the essential requirements for facilities/ staff (most physiotherapy patients do not have such requirements) and no harm is done to patient; in many cases this requirement may be related to the need for an appointment with a consultant
timely	waiting time between referral and the first physiotherapy appointment is minimised
effectiveness	when possible, patients are treated at centres offering the best facilities given the individual requirements, e.g. gym, hydro-pool or exit routes
efficiency	assuming a fixed resource, annual treatment capacity reflects efficiency
equity	the variation in patients' waiting times should be minimised
patient centred	patient-travel should be avoided where possible patients should be directed to the correct pathway, minimising the number who are redirected in order to ensure safe treatment

Table 1 Interpreting the six quality domains

1.2 Musculoskeletal physiotherapy in NHS Fife

This study began with a specific analysis in support of the redesign of musculoskeletal physiotherapy services in NHS Fife, Scotland. Patients accessed the musculoskeletal physiotherapy service either by referral from their General Practitioner (GP) or a consultant, typically as a part of a programme of care following an attendance at an acute hospital. Physiotherapy was provided at a variety of sites: some patients received a local service at their GP clinic; some travelled to a small community hospital; others went to an acute hospital. There was no systematic referral system, and no routine allocation of resources to match demand, resulting in considerable variation in waiting times and access to specialised facilities. A key objective of the redesign of the service was to provide a more local service while reducing the inequalities.

1.3 Developing generic insights

The study was part of a larger programme of work developing a number of models in support of various balance of care initiatives. The main objective of the study described in this paper was to provide a timely input into a debate about the possible effects of adopting new principles in the organisation of musculoskeletal physiotherapy. A discrete event simulation

(DES) was constructed but its initial; use was in “soft” role, enhancing understanding and debating options (Robinson, 2001; Bowers et al, 2011). The simulation was an idealised version of the physiotherapy system and the management options: the simulation omitted some local, detailed complexities in an attempt to identify more generic insights. It is often claimed that simpler models can provide clearer insight and more effective generic guidance, especially in the NHS (Proudlove et al, 2007). The simulation was used to explore a wide range of distinct options, including some which were impractical due to local constraints, at least in the short term. The options were chosen to provide more general insights with potential relevance to the design of other healthcare services. The simulation was constructed such that local detail could be included later for use in the more traditional, “hard” DES roles such as assessing specific proposals for improving the organisation of musculoskeletal physiotherapy.

The simulation incorporated various measures of healthcare quality but it focuses on the trade-off between equity in waiting times and patient travel times. This trade-off is particularly important when considering the relocation of services from a centralised provision to more local healthcare delivery. But it cannot be assumed that patients have identical preferences: some may place a greater emphasis on waiting time, others may be more concerned about travelling. The healthcare system, and the simulation, need to accommodate these preferences wherever possible.

1.4 Modelling features

The simulation explored service configuration options and also the effects of policies involving different forms of resource or demand pooling. Particular features of the study include:

- rules to model patient behaviour and preferences;
- a degree of heterogeneity in patients’ preferences and the consequences for the system behaviour;
- the use of a range of sources, notably the results of discrete choice experiments, to populate the model of patient behaviour;
- a comprehensive set of performance measures reflecting the multiple domains of quality in healthcare.

2. Modelling and the design of a decentralised service

2.1 Simulation in healthcare system reconfiguration

Systems dynamics is particularly applicable to modelling the overall effects of the healthcare policy, identifying the patterns of behaviour and avoiding unnecessary detail (Milstein et al, 2010). Indeed system dynamics has been used to model the balance of care, exploring both the intended and unintended effects of moving care closer to the patient (Taylor et al, 2005). However DES offers more scope to model the detailed flow of individual patients through complex healthcare systems (Davies and Davies, 1994). Literature reviews of the academic literature suggest that most DES studies of healthcare facilities examine patient scheduling and capacity planning within a single healthcare unit (Jun et al, 1999; Brailsford et al, 2009; Fone et al, 2003; Katsaliaki and Mustafee, 2011), typically modelling patient flow on a disease specific pathway (Davies and Davies, 1987) or through a discrete facility (Harper and Gamlin, 2003). Relatively few studies consider the interrelationships between units and the larger healthcare system, as required when analysing options for reconfiguring services.

Simulation has been used to assess the effects on equity and access of options involving various levels of centralisation of services, typically assuming that patient flows are determined by the distances implied by the potential locations of different hospitals (Taket, 1989; Harper et al, 2005). These studies provided useful estimates of the relative merits of the configuration options, focussing on travel time as the measure of quality of service. However, they did not consider the possible effects of management or patients' behaviours in selecting hospitals, and in particular responses to variations in waiting times. Hospital management decision making has been modelled in some simulation studies of the capacities of networks of healthcare units, incorporating rules to reallocate patients if the first choice unit was not available (Dumas, 1984; Dumas, 1985). Simulations have also incorporated management actions such as pooling resources or demand, evaluating the benefits of such policies offering a compromise with a degree of decentralised care while retaining economies of scale (Vanberkel et al, 2010). Pooling demand can be especially important in the organisation of expensive, vital services such as emergency intensive care beds. The desired levels of care may be provided at a lower cost by a network of units: some transfers are inevitable but simulation can help explore trade-offs between transfers and utilisation of resources (Fournier and Zaric, 2013). The current study aimed to assess the joint service of a network of units offering physiotherapy, using a comprehensive set of performance measures to capture the various domains of healthcare quality and explicitly incorporating management and patient behaviour.

2.2 Incorporating patient behaviour in simulations

Many discrete event simulations consider the participants to be passive homogeneous entities making random decisions as they move through the modelled system. However, system behaviour can often be dependent on individuals' behaviours and their interactions. Agent-based simulations have been used to explore such systems in many application areas (Macal and North, 2010) but there are few examples in healthcare (Escudero-Marin and Pidd, 2011). The reported healthcare applications focus on social interactions (Anderson et al, 2007) and infection (Meng et al, 2010) rather than management systems. This is despite the recognition that the individuality of the patient is often critical and there is a need to incorporate human behaviour (Brailsford et al, 2006). Some studies have included simple models of human behaviour in simulations, incorporating some of the principles of agent-based modelling while retaining the power of DES to model the detail of patient flows (Brailsford et al, 2006; Brailsford et al, 2012). Such an approach was used in exploring the possible impact of expanding patient choice in the NHS (Knight et al, 2012). In that study of congestion-related choice, patients' selection of a preferred hospital for elective knee surgery was modelled using a cost function assimilating hospital reputation, travel distance and waiting time. Various scenarios were explored considering the effect of increasing choice on waiting times. The study presented in this paper used a similar approach with simple rules modelling patient behaviour but also including some critical aspects of dynamic management behaviour, such as redeploying staff to cope with disparities in waiting times. A further feature of the current study is that it captures some of the heterogeneity of patients, identifying groups with different priorities resulting in greater diversity of individual behaviour, with potentially significant consequences for the system behaviour.

The current model only considers patients referred to the NHS physiotherapy service. Some patients may choose to receive treatment from a private practice, possibly influenced by the waiting lists for treatment. Furthermore, NHS physiotherapy is usually only available as a result of a doctor's referral; the tendency to refer may be influenced by perceived waiting lists for the service. Both behaviours may produce feedback but extensive data are needed in order to detect this effect, distinguishing other factors such as seasonality in referrals. Classic queuing models have been adapted to incorporate this feedback suggesting that it could be most significant in managing system behaviour (Worthington, 1989). While this feedback may be important in some services (Smethurst and Williams, 2002), it is not always significant (Freckleton and Sutherland, 2002). If more referrals data were available this could provide a useful area for further study, examining such feedback in a congested service such as NHS physiotherapy.

2.3 Treatment decisions and patient choice

In this application, the key decision for each patient was the location of treatment. This decision is made considering:

- the patient's characteristics and clinical requirements;
- the services available at the various treatment centres;
- the times for the patient to travel to each centre;
- the current waiting times at each centre.

The study adopted a mixture of approaches to provide quantitative approximations of the relative importance of each of these criteria: interviews with staff, local patient surveys and also data from the literature. Discrete choice experiments provide one approach to understanding patient preferences, asking patients to express their preferences when presented with a number of standardised scenarios; this approach can provide very useful insights but great care is required in the experimental design (Ryan et al, 2001). In healthcare applications, a metric such as travel time or waiting time (Knight et al, 2012) is often used to compare the values of different attributes, capturing the possible trade-offs that might be considered when deciding on the treatment centre. Studies of NHS outpatients' preferences suggested that patients were willing to travel further in order to reduce their wait for treatment: typically patients were willing to accept an additional 40-140 minutes travel time in order to be treated a month sooner (Dixon et al, 2010; Burge et al, 2004). While the values associated with the trade-offs may vary, a similar pattern of preferences has been also been observed in the USA (Tai et al, 2004) and Netherlands (Varkevisser and van der Geest, 2007): substantial proportions of patients are willing to travel further in order to obtain better quality or access to healthcare but this propensity is dependent on age, education and wealth. The results from these studies provided a useful basis for quantifying patient preferences but this generic understanding was combined with interviews with staff and patients, considering physiotherapy specifically and capturing the local context.

3. Developing the simulation

3.1 Modelling demand and patient flows

Musculoskeletal physiotherapy in NHS Fife was subject to considerable pressures. Constrained resources combined with increasing demand and expectations had led to long waiting lists and dissatisfaction, in some areas. However, the service appeared to work well in for many patients in other areas. Numerous internal reviews of the service had been undertaken but it was decided that a more systemic analysis of the options was needed, considering the various centres providing physiotherapy as an interconnected system. In particular the analysis had to consider proposals arising from the national policy to shift the balance of care (NHS Quality Improvement Scotland, 2010): it was suggested that while this policy might improve access, other aspects of healthcare quality might suffer. The study was undertaken as an input to a debate about the options, aiming to develop an understanding of the general benefits, and problems, of the alternative approaches to organising the musculoskeletal physiotherapy service.

The simulation was developed, using Simul8, to understand the impact of the different management options on the flows of patients through the physiotherapy system. An overview of the model is provided in Figure 1. It provides a mechanism for modelling the stochastic nature of the demand and the consequent problems in matching patient requirements with the available resources at the different sites. The simulation reflects a typical arrangement of the physiotherapy service, as in the Kirkaldy and Levenmouth Community Health Partnership which constituted part of the whole region covered by NHS Fife. This service spanned eight treatment centres offering physiotherapy within the community, in addition to the care provided at the acute hospital (centre 1). A programme of physiotherapy typically involved a number of repeat visits to the allotted centre before being discharged.

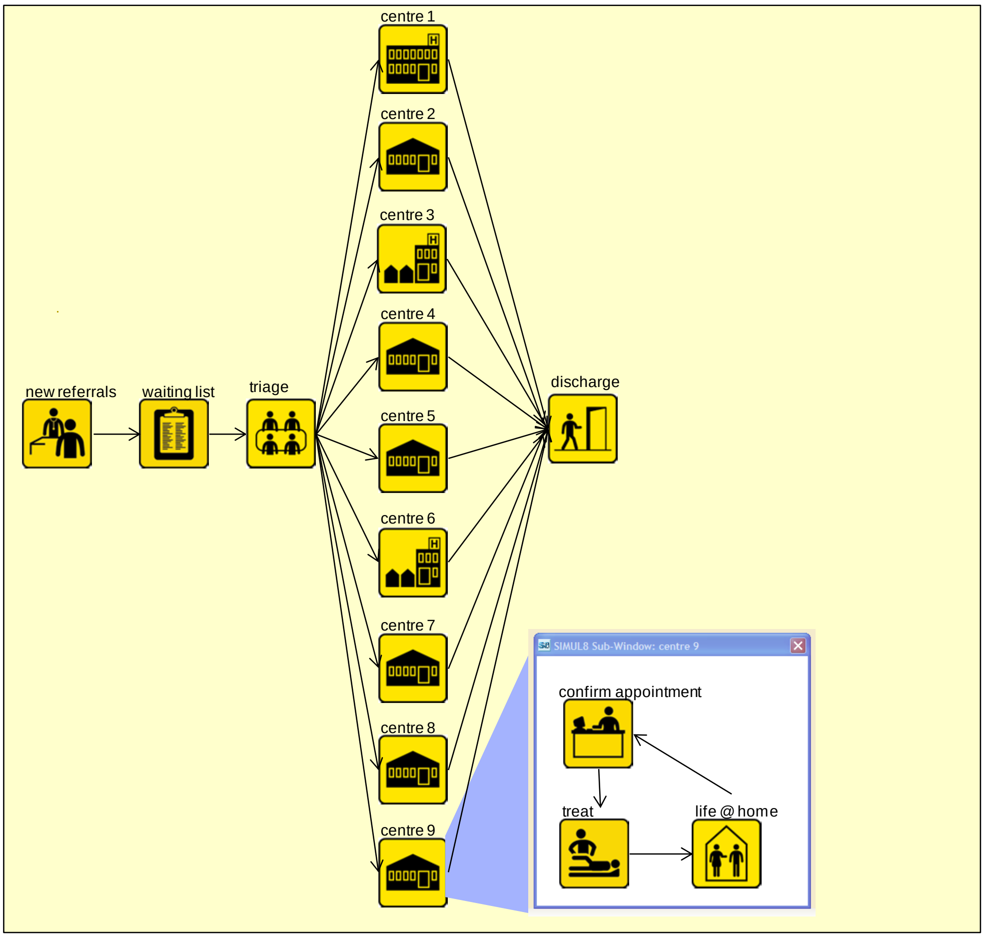

Figure 1 The physiotherapy simulation

The patient referrals were modelled using a non-homogeneous Poisson model (Alexopoulos et al, 2008) reflecting the historic seasonality, daily and hourly variations in activity. The short term variations have little impact on the longer term waits associated with gaining access to the physiotherapy service. However, the seasonal variations in referrals and the capacity of the service, typically reflecting holiday patterns, can be important in a system with little spare capacity. These variations in activity can generate seasonal cycles in waiting times, contributing to a greater range of patient experience over the year (Bowers, 2011).

3.2 Patient characteristics

Patients' preferences were modelled considering three key characteristics:

- home location *i*, using a distribution reflecting the historic patterns of demand;
- clinical requirement *m*; patients were allocated to one of ten categories reflecting different sets of needs including access to a consultant, specialist facilities (e.g. gym or hydro-pool) or exit routes;
- willingness to travel *k*; patients were allocated to one of three categories reflecting different attitudes towards travelling: k=1 implying a patient who is indifferent to travelling; k=2 for a typical patient; k=3 if the patient has restricted mobility and cannot, or is unwilling, to travel any distance unless clinically critical.

3.3 The treatment decision

Each centre *j* was considered as a possible location for a patient's treatment. The centres have varying levels of services that are considered in relation to the patient's clinical requirements, as well as the travelling time and waiting list, when deciding where a patient should be treated. The patient preferences were summarised in terms of the additional weeks wait that would be accepted as a trade-off for choosing one centre rather than an alternative. An illustrative example is included in Table 2 which quantifies the willingness of an individual patient to travel as $L(i,j,k)$: patients are distinguished by one of nine home locations, each with a possible local treatment centre; a patient living at location 5 would only accept treatment at centre 6 rather than the local centre if this reduced the wait by more than 6 weeks, assuming otherwise identical care is available at both centres. Three categories of patients were modelled with different propensities to travel, reflecting the noted diversity of patient preferences: the "typical", those with restricted mobility and patients who are largely indifferent to travelling. Similarly the gap between a patient's clinical requirement *m* and a centre's provision p_j services was summarised using the measure of additional weeks wait $C(m,p_j)$: where the gap could imply an unacceptable risk to a patient's safety, a high value was specified (C=100) to preclude the patient being allocated to a clinically inappropriate treatment centre.

		location of treatment centre								
		1	2	3	4	5	6	7	8	9
home location	1	0	2	2	2	2	4	4	4	4
	2	2	0	2	4	6	2	4	6	6
	3	2	2	0	2	4	4	2	4	6
	4	2	4	2	0	2	6	4	2	4
	5	2	6	4	2	0	6	6	4	2
	6	4	2	4	6	6	0	2	4	6
	7	4	4	2	4	6	2	0	2	4
	8	4	6	4	2	4	4	2	0	2
	9	4	6	6	4	2	6	4	2	0

Table 2 A typical (k=2) individual patient's willingness to travel, expressed in weeks-wait

The critical mechanism in the simulation is a utility function that aggregates the characteristics of each possible centre, measured from the perspective of each patient. As in other studies, a linear additive utility function was adopted with utility being expressed in terms of waiting time (Knight et al, 2012). The utility $X(i,m,j)$ was estimated for each patient with a home location i and requirement m being considered for treatment at site j where the current estimated waiting time for new additions to the list is $T(j)$:

$$X(i,m,j) = L(i,j,k) + C(m,p_j) + T(j)$$

The site j_0 offering this patient the smallest value of $X(i,m,j)$ was identified and the patient added to the waiting list for that site. Such an approach can help ensure that the patient receives the most effective physiotherapy care and reduces variability in waiting times. However, this is achieved at the expense of additional travelling and the organisation of a triage system. The decision mechanism was incorporated in an algorithm, illustrated in Figure 2, encoded in the Simul8 work centre logic describing the triage activity.

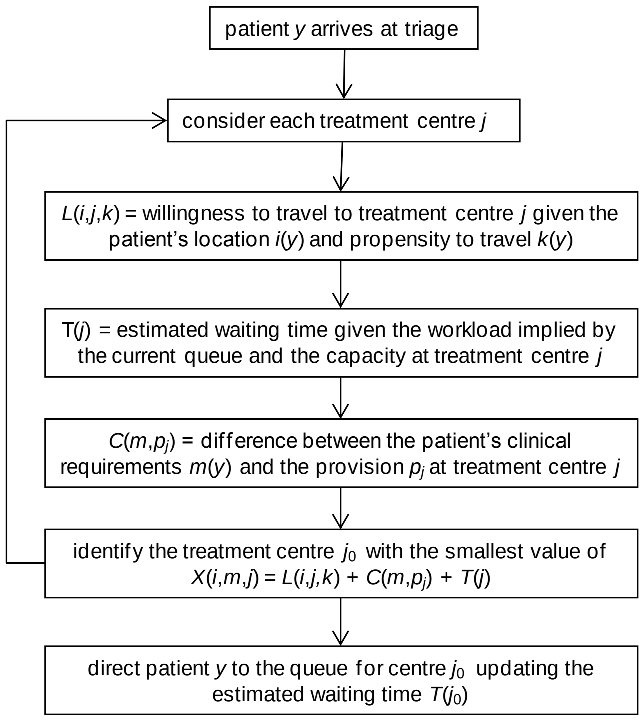

Figure 2 The algorithm modelling the choice of treatment centre

The waiting times at each site are monitored and the peripatetic staff are allocated to the sites with the greatest need. This approach reduces variability in waiting time without asking patients to travel. However, some patients may not receive the most effective care if their local site has a restricted range of services. The additional costs of implementing a system to monitor waiting lists and redeploying staff, and the extra staff travelling times, may be significant. Even if the financial costs are not large, flexible deployment may involve changes in working practice for some staff.

4. Assessing options

4.1 Management options

A number of possible approaches to organising musculoskeletal physiotherapy were examined; these arose from observing physiotherapy practice throughout NHS Fife, a neighbouring Health Board, NHS Lothian, and also a literature review of physiotherapy practice. The options reflected both pragmatic attitudes, driven by a concern about the resource constraints, and the concepts of shifting balance of care with the emphasis on more local delivery. Since the study was intended to develop a better understanding of the relative benefits of alternative approaches to organising the musculoskeletal physiotherapy service, a wide range options was considered, see Table 3. Specific local constraints precluded some options for NHS Fife, at least in the immediate future, but their inclusion was intended to provoke debate and develop more general insights into service reconfiguration and the balance of care. The options range from a completely centralised physiotherapy service to an organisation involving triage and flexible staff deployment across nine possible treatment centres. In practice many Health Boards offer a mixture of these different approaches. Indeed, the original arrangement of musculoskeletal physiotherapy in NHS Fife could be described as a combination of options 1 and 3, with just a degree of informal triage: GP's access to local physiotherapy facilities and their referral practices varied significantly across the region. The costs of each option are not considered in any detail in this paper: the scope of this analysis is to determine the benefits of each option in relation to the various quality domains and the balance of care objectives in particular.

Options 1, centralised care at a single site, and 4, directing patients to treatment centres potentially far from home, may offer benefits in terms of shorter waits and more appropriate care. While these options provide a useful standard for timeliness, effectiveness and equity they are contrary to the principles of achieving a better balance of care and its emphasis on more local delivery. An alternative approach is to move the resources to meet the demand, organising the staff around the patient needs (option 5), and in particular to use a more flexible staff deployment responding to the changes in waiting lists at the various sites.

option	key features
1. single site	this may appear to offer the most effective, efficient and equitable organisation of care but fails to deliver any of the Balance of care objectives
2. local sites with all facilities	this idealised scenario offers the full range of staff and facilities at every site; the total capacity is not enhanced but all patients can receive the best possible care at their local site
3. local sites with restricted facilities	a typical current provision implying good local care for some patients but lower levels of effectiveness and/or travel for others
4. triage	a systematic approach to directing referrals to the most appropriate site considering patients' requirements and waiting lists; this could take a number of forms but in this study it is envisaged to be "virtual"
5. flexible staff deployment	a proportion of the staff are peripatetic, allocated to different sites in response to variations in demand
6. triage & flexible deployment	a combined approach moving both patients and staff to help ensure an effective and equitable service

Table 3 Management options

4.2 Equity and waiting times

The simulation was used to model each option, replicating one year of activity. Figure 3 illustrates the changing queue length for treatment at two of the nine sites, with and without triage. In order to aid comparison it is assumed that each site starts with a waiting list corresponding to eight weeks of activity. There is much variability, due to both the seasonality of activity and the stochastic nature of the referrals, but distinct patterns of behaviour emerge. Without any triage, the waiting times across the nine sites can diverge substantially over the period of the simulation: large queues develop at sites such as 7 while other sites, such as centre 4, have negligible queues at the end of the year. Implementing triage (option 4) eliminates the systematic development of unequal queues: all nine sites have approximately the same waiting times at the end of the simulation.

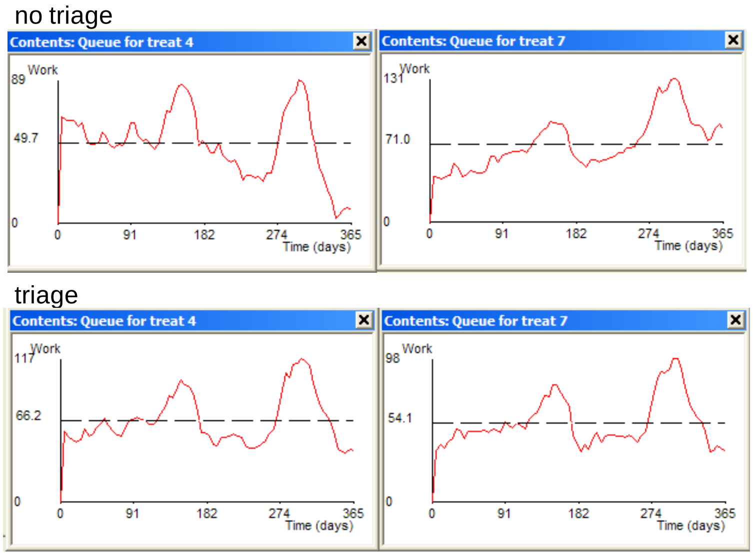

Figure 3 Reducing variability in queuing with triage

4.3 Measuring quality of care

Waiting time is just one aspect of quality of care. Other metrics were identified to capture the effects on the other quality domains, see Table 4. The term "effectiveness" is used as a measure of the available physiotherapy services relative to the perfect provision: in the large majority of cases the clinical outcomes are not affected even if the facilities are not a perfect match to the patient's clinical requirements. These desirable but non-essential requirements were distinguished from those that affect clinical safety. Adopting these metrics, a variety of management options were assessed using multiple (50) trials of the simulation to obtain statistically robust estimates of the impact on quality of care; the estimated means of each metric are recorded in Table 5, together with the 95% confidence limits where they are non-trivial.

Quality criterion	Simulation output
clinical safety	% of patients with a critical requirement $C(m,p_j) = 100$ for some j treated at a site with appropriate facilities to ensure safety
timely	mean waiting time and % waiting > 12 weeks
effectiveness	% of patients treated at sites s.t. $C(m,p_j) = 0$, i.e. receiving care at sites with the best possible facilities/patients' requirements
efficiency	complete programmes of patient physiotherapy care p.a.
equity	standard deviation in waiting time
patient centred	% receiving local care, provided at the nearest site
	% attending at just one site rather than being redirected to a second site

Table 4 Quality of care metrics

4.4 Analysing the options

The simulation was used to analyse the management options of Table 3; the results of Table 5 suggest that no one option is the best: the ranking varies with each criterion. Concentrating all physiotherapy care on a single site (option 1) offers an effective service with great equity, as reflected by the low standard deviation in waiting times. But this is achieved at the expense of many patients having to travel a significant distance: only 20% receive local care. If there were the resources available to provide a full range of facilities at all of the treatment centres (option 2), local and highly effective care could be provided for every patient. However, there would be localised difficulties with waiting times resulting in inequalities, as reflected in the standard deviation of 3.3 weeks and the 7% of patients waiting for more than 12 weeks. Adopting a triage system to allocate patients to the most appropriate centre (option 4) results in a service that ranks reasonably highly for every criterion; a substantial proportion of patients travel to receive care, in order to reduce their waiting times or receive more effective care, but most (70%) are treated locally. In a truly "patient-centred" system it might be expected that rather than the patients travelling to the sites with shorter waiting times, staff should be redeployed to meet the patients' needs (option 5). Such flexible staff deployment reduces inequities in waiting times and also delivers local care. However, there may be significant management costs in implementing flexible staff deployment and it is not as effective (65%) as some other options since the locally treated patients do not have access to a full range of facilities. Furthermore the extra staff travelling-time will reduce efficiency and the capacity of the system.

	option	safe	effective	mean wait (weeks)	s.d.	<12 weeks	local care	not redirected	patients p.a.
1	single site	100%	100%	7.09±0.13	1.94±0.02	97.4±0.5%	20%	100%	4118± 8
2	local sites with all facilities	100%	100%	6.84±0.32	3.34±0.08	92.9±0.6%	100%	100%	4110±11
3	local sites with restricted facilities	100%	65%	6.96±0.20	4.11±0.09	86.7±0.9%	100%	98%	3805±11
4	triage	100%	77%	6.86±0.14	2.66±0.04	96.7±0.5%	70%	100%	4129±11
5	flexible staff deployment	100%	65%	7.03±0.15	2.66±0.06	94.9±0.6%	100%	98%	3816± 9
6	triage & flexible deployment	100%	82%	6.96±0.14	2.35±0.03	96.6±0.5%	69%	100%	4122± 9
	best scenario	1-6	1,2		1	1	2	1,2,4,6	1,2,4,6
	worst scenario		3,5		3	3	1	3,5	3,5

Table 5 Comparing the physiotherapy management options

5. Willingness to travel and its effect on care

Previous studies (Dixon et al, 2010) using patient surveys and discrete choice experiments indicate that patients' willingness to travel can vary substantially. The staff and patient interviews undertaken in this study confirmed this, and the model adopted three categories of behaviour quantifying an individual patient's willingness to travel L, measured in a trade-off with weeks-waiting:

$k = 1$: those who were indifferent to travel $\quad L(i,j,1) = 0 \quad i = j$
$\quad L(i,j,1) = 2 \quad i \neq j$

$k = 2$: typical patients with a willingness to travel as described in Table 3

$k = 3$: patients with restricted mobility $\quad L(i,j,1) = 0 \quad i = j$
$\quad L(i,j,1) = 18 \quad i \neq j$

with the proportions of patients in each category being described by w representing the population's willingness to travel.

In the current study the proportions of patients in each category were estimated as $w = (20,60,20)$ for the categories $k = 1,2,3$. However, these estimates included a substantial degree of subjectivity and sensitivity analyses were undertaken to consider the effects of varying these proportions. A series of simulation experiments considered various degrees of the population's willingness to travel ranging from $w = (0,0,100)$, corresponding to a population of patients who refuse to travel unless clinically essential, to $w = (60,40,0)$ representing a high proportion of mobile patients willing to travel to obtain better care. Figure 4 summarises the consequences in terms of two key variables: the proportions (with 95% confidence limits) of patients treated within 12 weeks and those receiving effective care, as defined in Table 4. Inevitably, as more patients are willing to travel, it is easier to achieve a better match of their healthcare needs and the facilities available at the various locations, increasing the proportion who receives more "effective" care. Of course it is only those patients who are willing to travel who can benefit directly; those with restricted mobility may continue to have less effective care, potentially increasing inequities in the healthcare system.

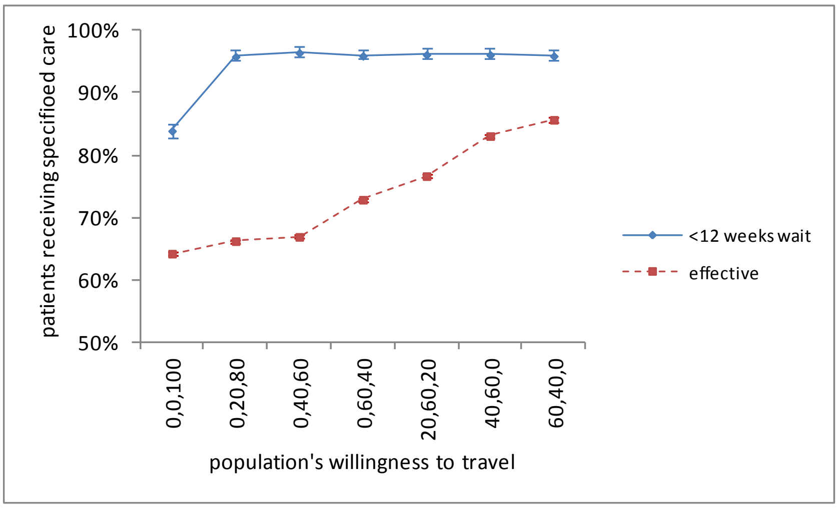

Figure 4 Willingness to travel and the effect on healthcare

The impact on excessive waiting times is more dramatic. When there are no patients willing to travel for any reason other than clinical necessity, $w = (0,0,100)$, 84% of patients wait less than 12 weeks: although the overall mean wait is not affected, considerable inequalities in waiting time become established with large variations between the different treatment centres. However, it only requires a small proportion (20%) of patients to be willing to travel to affect the system behaviour ensuring that 96 % wait less than 12 weeks.

6. Discussion

The simulation experiments illustrate how the behaviour of a few can affect the whole system behaviour. The experience of one patient depends on the actions of others: a patient who is unwilling to travel may have a shorter wait if those ahead in the queue elect to go elsewhere to receive their care. In this example the proportion waiting for excessive periods is substantially reduced from 16% to 4% if just 20% of patients are willing to travel. The results illustrated in Figure 4 suggest that encouraging even greater mobility of patients offers little advantage. However, other aspects of system performance patients exhibit different responses: the proportion receiving effective care increases approximately linearly with the willingness to travel. The dominant relationship in determining the effectiveness of care is the individual patient's ability to travel to a more appropriate treatment centre; the feedback reducing excessive waiting lists can enable a few more patients to gain access to the most effective care but this is a relatively minor effect in this case. Studies assuming homogeneity in decision-making amongst the participants, have suggested that their behaviour can cause feedback with a substantial impact on system performance (Worthington, 1989; Knight et al, 2012). This study, incorporating a degree of heterogeneity in attitudes to travel, illustrates how such system feedback can be generated by the behaviour of a relatively small proportion of the population.

Alternative approaches, such as agent-based modelling, may provide more sophisticated insights into the effects of patient and staff behaviour in healthcare systems (Escudero-Marin and Pidd, 2011). However, this study illustrates how a combination of discrete event simulation, to model queues and the flows along the patient pathways, with simple rules to capture basic behaviour provides a useful basis for developing a better understanding of the system performance and the response to individuals' decisions. Indeed such a combination has been advocated more generally when using simulation to investigate service industries (Siebers et al, 2010).

Populating models of behaviour will always be challenging, contributing to the recognised problems of validation of simulations incorporating such features (Knight et al, 2012; Siebers et al, 2010). A variety of sources, such as surveys and more specific discrete choice experiments, can provide useful input but the particular context has to be considered. Patients' trade-offs when contemplating serious surgery will be very different than those expressed when choosing a treatment centre for physiotherapy. Simply accepting the data from previous studies may produce inappropriate models of behaviour: a degree of expert, subjective judgement is inevitable and consequently sensitivity analysis will always be a crucial element of any assessment using these models.

7. Conclusions

Shifting the balance of care with an emphasis on local delivery may offer many benefits with a more patient-centred service. However, it is important to consider the full range of healthcare quality domains, not just patient-travelling time. Other aspects of quality may suffer, notably equity in waiting times. Simulation experiments examining options for the organisation of musculoskeletal physiotherapy suggest that it is possible to provide more local care and also exploit some of the potential benefits of a centralised service if careful operational management is implemented with:

- triage to ensure equity and efficiency, though this implies that many patients have to travel to receive care, contravening the ideal of balance of care;
- flexible staff deployment to ensure equity of waiting with minimal patient travel, but with some reduction in efficiency and the system capacity.

The study used a simple model of patient-behaviour incorporated in a discrete event simulation. This captured some of the feedback that can be critical in system performance, especially where waiting times are important. A simple model of the heterogeneity of patient attitudes illustrated how the behaviour of a relatively small proportion can affect the experience of all patients. The combination of discrete event simulation and simple rules to model behaviour offers an effective mechanism for incorporating the individuality of the patient in the flows along the patient-pathway, subject to the varying availabilities of key resources.

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