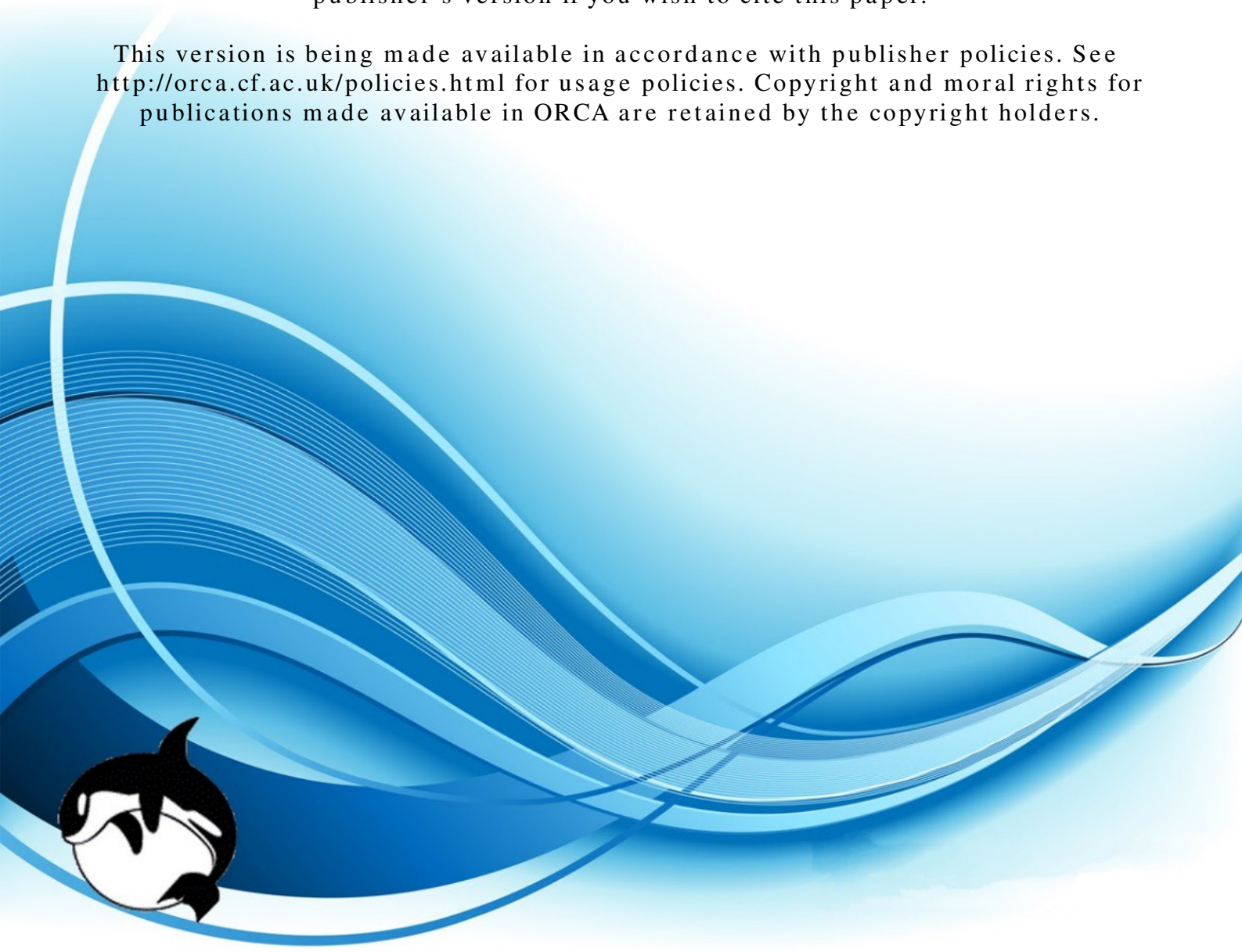

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CASE STUDY

Modelling of psoriasis patient flows for the reconfiguration of secondary care services and treatments

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Abstract

This paper describes work in collaboration with a large dermatology directorate in South Wales to map out current patient flow and activity levels for psoriasis management. Psoriasis is a chronic skin disease that often has a high impact on patient quality of life. Clinical services for patients with moderate to severe psoriasis tend to be located in secondary care hospitals. The range of services that were studied, their geographical location in relation to the distribution of population, and the population demographics in this health board were not unique; similar profiles for these factors can be found throughout the NHS in England and Wales. The model was created to analyse patient flow through different therapies, with the aim of maximising throughput of patients, eliminating bottlenecks, improving patient access to services and improving patient safety. It was shown that reducing waiting times and improving access to phototherapy would lower overall service costs, as fewer patients would subsequently require systemic and biologic therapies. The model has been used to quantify how recent year-on-year increases in overall spend on psoriasis treatments might be slowed and eventually halted. This would require reallocation of notional cost-savings generated by reducing the rate of increase in the drug spend to fund the development of a more balanced and accessible network of more basic psoriasis services.

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Introduction

The demand for healthcare services in the U.K. continues to increase while economic pressures mean that the National Health Service (NHS) will likely face an effective budget reduction of £36 billion by 2018 (HM Treasury, 2013). The deficit between supply and demand proves to be economically costly and typically has a detrimental impact on factors such as waiting times. Operationally, healthcare systems are a complex combination of resources (staff, equipment, operating rooms, hospital beds, etc.) and patient demand (which can possess significant levels of variability). Extensive research has demonstrated that use of discrete-event simulation (DES) is an appropriate and effective tool for modelling complex healthcare systems and assisting with operational decisions (Jun *et al*, 1999, Harper, 2002; Fone *et al*, 2003; Brailsford *et al*, 2009; Katsaliaki & Mustafee, 2011).

In this paper, we consider the provision of secondary care services for treatment of psoriasis, a common chronic skin disease, in a large health

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board in South Wales. Psoriasis has a population prevalence of 1.3–2.2% (Parisi *et al,* 2011) and sometimes affects the joints. It is not yet possible to predict which treatment will be safe, effective and convenient for individual patients with psoriasis. Treatment tends to be hierarchical, commencing with topical therapies prescribed by general practitioners (GPs) in primary care (creams and ointments), before referral to secondary care for more potent options prescribed by teams led by consultant dermatologists (NICE Clinical Guideline 153, 2012). Secondary care treatment of psoriasis usually commences with ultraviolet therapy (NICE Clinical Guideline 153, 2012) which is given two to three times per week for up to 10 weeks. Patient access to phototherapy depends on geographical location of the phototherapy unit relative to the patient's home or workplace, and the capacity of the phototherapy service (Anstey, 2013). In patients who fail with phototherapy or who are unable to access the service, systemic drugs (tablets and occasionally injections) are the next option. Most of these drugs work by suppressing adaptive immunity, requiring regular blood tests to monitor for drug-induced toxicity and dosage optimisation. In patients with psoriasis who fail to respond to standard systemic therapies, biologics may be indicated (NICE Clinical Guideline 153, 2012). The first biologics for psoriasis were approved by NICE in 2006 for moderate to severe psoriasis in patients who had failed to respond, were intolerant of, or had contraindications to standard systemic therapies and PUVA (a form of phototherapy). In a subsequent NICE Clinical Guidance (NICE Clinical Guideline 153, 2012), omitting phototherapy was recommended for patients who responded poorly or where phototherapy was poorly tolerated; furthermore, it was advised that patients should not have phototherapy if accessing treatment was difficult for logistical reasons such as travel, distance, time off work or immobility (NICE Clinical Guideline 153, 2012). Biologic therapies cost close to £10,000 per patient per annum (Eedy, 2008) and are typically prescribed for long-term use in an open-ended fashion.

In summary, the model of psoriasis care described above consists of multiple *therapy lines*, which may be thought of as a set of possible care pathways depending on patient need. Each therapy line has a number of potential treatments. Furthermore, each treatment in each therapy line is administered and monitored in different ways with varied levels of required resources. Thus overall management of psoriasis care for large hospital dermatology departments, providing care for large volumes of patients across multiple therapy lines within resource constraints, is a complex process. An overview of psoriasis treatments is provided in a NICE pathway (NICE Clinical Guideline 153, 2012).

Working with the Dermatology Directorate within the Aneurin Bevan University Health Board (ABUHB), South Wales, the project explored the potential use of DES to provide a model for the allocation of treatment therapies that capture sufficiently the complexities of the patient flows in the current system. The motivation was to use this model to provide recommendations on alternative service configurations to help improve efficiency, improve access to high-volume low-cost therapies, reduce waiting times and lower overall service costs. In particular, the focus was to assess the impact of increased capacity and improved geographical access to phototherapy on other more costly and potentially toxic psoriasis treatment options. The authors are not aware of any other literature on operational research and simulation modelling applied to the delivery of healthcare services for psoriasis patients, thus this is seemingly a novel application.

Background

ABUHB serves a large geographical area of South Wales, providing services to a population of approximately 600,000. Parts of the region are among the most deprived areas of the U.K., and include patients from areas of inner-city deprivation, post-industrial urban decline as well as deeply rural, relatively isolated communities. Such diversity adds to the complexity of planning and organisation of services across ABUHB.

The target relating to referral to treatment time in Wales is a maximum of 36 weeks (Welsh Government Report, 2011). Furthermore, the aim is to ensure that a minimum of 95% of patients access planned services within 26 weeks. In July 2012, it was reported this target was being met in ABUHB with 92.7% of all patients seen within 26 weeks and 100% compliance within 36 weeks (National Assembly for Wales Research Note, 2012). However, the Dermatology Directorate in ABUHB was not performing as successfully as the overall health board. Psoriasis care in secondary care is costly as psoriasis is common and patient care is labour-intensive (systemic therapy monitoring; dermatology day case treatments; phototherapy staff; inpatient care) and includes the prescription of very expensive drugs (ciclosporin, Fumaderm, biologics). Therefore, this project was initiated to evaluate ways in which access to psoriasis treatments could be improved.

Psoriasis is a chronic relapsing dermatological disease that causes flaky, crusty and red patches of skin, often identified by silvery scales. Severity of psoriasis varies greatly (Krutman *et al*, 2008). For some it is merely an irritation, while for others it can have a major impact on their health-related quality of life (Krueger *et al*, 2000). Although there is currently no cure for psoriasis, there are a variety of specialist therapies that are effective in controlling psoriasis. In NHS Wales, these therapies are obtained through GP referral to a local health board, usually dedicated to dermatology and rheumatology services.

Treatments for psoriasis fall into four main categories that respectively define the varied lines on therapy available: topical therapy, phototherapy, systemic oral therapy and biologic therapy (NICE Clinical Guideline 153, 2012). These four categories differ in their route of administration, necessary reviews, monitoring and, consequently, resources required. Furthermore, the order described above is usually the natural course a patient is expected to follow, whereby a patient will only progress to the next therapy line upon

failure, toxicity or intolerance of the current treatment. Importantly, costs involved tend to increase as patients progress through the therapy lines. Therefore, it is important to ensure patients are allocated their optimum, and most cost-effective treatment. NICE guidance for psoriasis is underpinned by comprehensive health economic analysis (NICE Clinical Guideline 153, 2012); if clinicians adhere to the guidance, biologics will usually be resourced by the NHS. This is important as it prevents the withholding of effective high-cost treatments from patients who qualify according to NICE criteria.

There are a number of dermatology clinics within ABUHB, each of which is run by a variety of medical personnel including: consultant dermatologists, GP clinical assistants, clinical nurse specialists, dermatology specialist registrars (a training grade for prospective consultant dermatologists) and general nurses. At these clinics, patients with psoriasis are appropriately managed and given access to the available therapies listed above according to expert advice.

Development of a patient flow simulation model

The provision of available therapies for psoriasis in ABUHB may be considered as a complex network of queues and activities, thus lending itself to being modelled by DES. For the purposes of handover and reusability, a Simul8 model coupled with a bespoke user-friendly Excel interface was developed. A brief overview of the data and model structure is now described.

Mapping patient pathways

An integral part of the process of generating a fully validated patient flow simulation model is through careful design and construction. This ensures that the flows accurately represent real-life patient pathways. All available psoriasis therapies were included along with all the necessary medical review processes. A conceptual model describing patient pathways was constructed with the assistance of a number of key medical professionals in the dermatology directorate.

The sole patient entry point to the system is through GP referrals to the dermatology directorate. New patients are initially seen by one of the six consultant ABUHB dermatologists, for whom there is currently a waiting list of approximately 28 weeks. Following a diagnosis of psoriasis, each consultant assigns a patient to one of the various lines of therapy. These are: topical treatments (first line), phototherapy (second line), systemic therapy (third line), biologic therapy (fourth line), or in rare cases admitting a patient immediately to the ward for inpatient care. Furthermore, if a clinician performing a review believes there is sufficient improvement in a patient's condition, it is possible to assign them a period of no treatment. Patients can move around the therapy lines in the system according to success or failure of treatment.

A screenshot of the developed Simul8 model, showing the complexities of pathways, is shown in Figure 1. Given the variety of pathways and processes, Figure 1 is shown to provide the reader an appreciation of the system rather than all the specific details. Each therapy line however has been mapped onto Figure 1 to show the major stages of patient care, and each line is briefly introduced below.

- *Topical therapy:* Some patients are deemed not to have severe enough psoriasis to receive second line or higher therapies (NICE Clinical Guideline 153, 2012). Therefore, consultants occasionally ask the patient to use topical therapies to treat psoriasis. Often, complex combinations of these topical treatments are given to the patient. However, as all these treatments can be prescribed by GPs, it is often assumed that the patient has tried some topical therapy before being referred to the dermatology clinic. Therefore, few patients are asked to use topical treatment alone.
- *Phototherapy:* Phototherapy is one of the more popular options prescribed by consultant dermatologists for new psoriasis patients (NICE Clinical Guideline 153, 2012). There are two phototherapy clinics within ABUHB: one at St. Woolos Hospital (SWH) in Newport and one at the newly built Ysbyty Ystrad Fawr (YYF) in Ystrad Mynach. There is currently a waiting list of approximately 16 weeks for SWH and 4 weeks for YYF. Phototherapy usually involves patients attending for a few minutes three times per week for up to 10 weeks. Following a course of phototherapy, a patient will either leave the system if they have responded well, or will request a review with a clinician. At this review, other options considered included further phototherapy or other treatment therapies.
- *Systemic therapy:* Modelling systemic therapy was a very complex process that required good understanding of the system and reliable estimates from the medical staff. The modelling utilised the protocol for reviews for patients with psoriasis, where the inter-review times are differently defined for each of the four compounds (treatments) available: methotrexate, acitretin, Fumaderm and ciclosporin. NICE clinical guidance for systemic therapies excludes Fumaderm as this novel drug is not yet licensed for use in the U.K. However, Fumaderm was included in the current study as it is extensively used by the consultant dermatologists at ABUHB. These systemic drugs can be stopped at any stage during the course of treatment, either at the discretion of the clinician, or at the patient's request. Reasons for stopping include a lack of observed clinical effect, unacceptable side effects or drug-induced organ toxicity. In this situation, patients are prescribed a different systemic compound, or may be referred for an alternative therapy line.
- *Biologic therapy:* The sub-system of biologic therapy is similar to that of the continual review system of systemic therapy. However, it was more straightforward to model as the reviews are performed at regular intervals of 3 months for all compounds (treatments). Each of the four compounds used (etanercept, adalimumab, infliximab and ustekinumab) have different efficacy rates. Additionally, variation in dosage, frequency of administration and

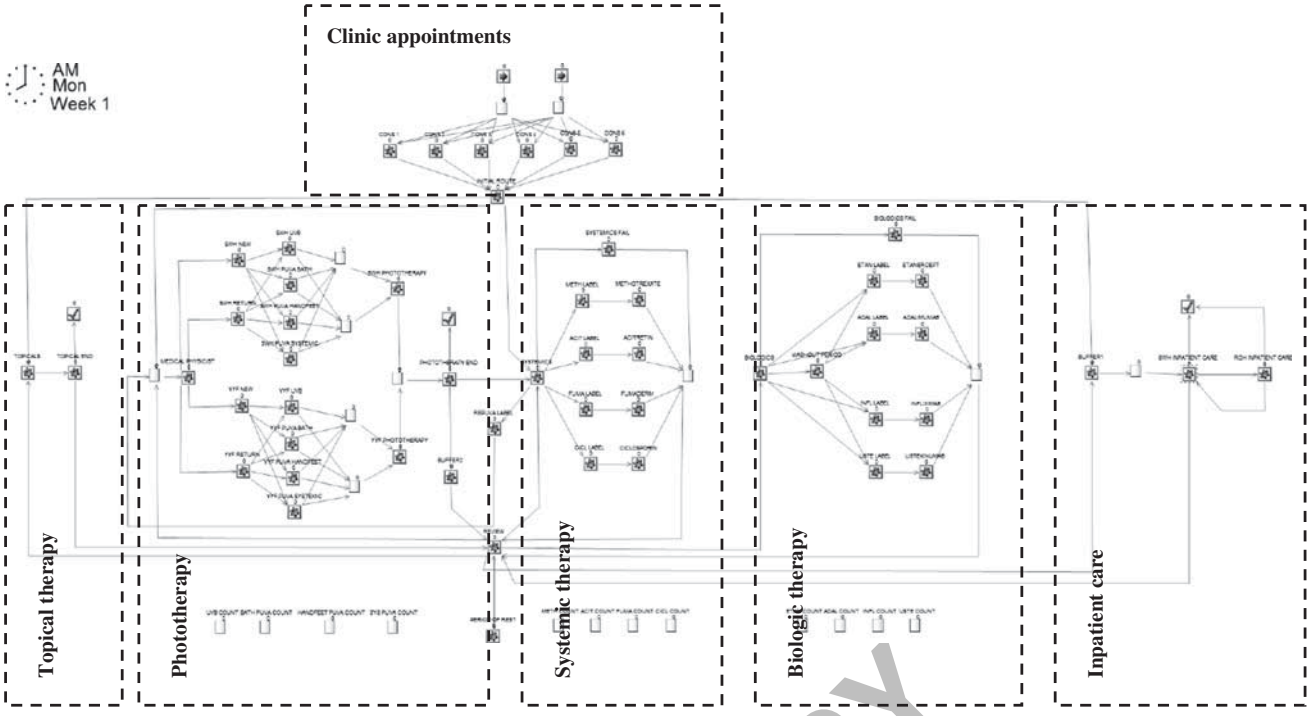

Figure 1 Psoriasis therapy lines captured in the simulation model.

route of administration provides options for shared decision making between the prescribing dermatologist and their patient.

- *Inpatient care:* Patients with severe, poorly controlled psoriasis may occasionally require inpatient care at SWH. Occasionally, such patients may become generally unwell, requiring more intensive nursing care on a high dependency care unit.

Data sources

Due to the complex structure of the therapy lines, there were a large number of data considerations. The data used in this project had to be extracted and manipulated from a number of sources. In ABUHB, an online tool is utilised to store patient information and hospital appointments. A time-dependent cluster sample was extracted using this tool, which encompassed all patients who had a psoriasis-related appointment scheduled in January 2012. Any patients in this cohort then had their entire treatment history recorded. In total, 521 appointments were recorded for 224 patients.

Phototherapy data had to be manually sourced from the filing cabinets in the phototherapy unit. In total, 215 courses of treatment were recorded for 130 patients. Data for biologic therapy was provided by ABUHB and included the sequence that the therapies were given to each patient. Data for of 69 admissions to the dermatology inpatient unit (covering the period August 2010 – July 2012) was also obtained.

It was evident through initial consultations with various members of the clinic staff that a number of data requirements would not be readily available. Therefore, seven semi-structured interviews were conducted with medical personnel. This allowed the staff to impart their knowledge and expert opinion, by providing some numerical estimates for various parts of the model. Furthermore, by performing these interviews independently, the model was enabled to capture the variability (relating to behavioural aspects) between the decisions that the consultants take in clinic.

The necessary parameters for the model were appropriately derived, using various data manipulation packages including SAS, Excel and @Risk. Parameters that were derived included those for

- inter-arrival times;
- service rates and distributions for appointments, length of treatment(s), wash-out periods and inter-review times;
- probabilities representing various decisions in the system;
- success rates for all treatments;
- estimated capacities for the two phototherapy clinics and the availability of beds for inpatient care; and
- varying costs associated with the model, including treatment costs, resourcing costs and phototherapy equipment costs.

Runtime parameters

The simulation clock ran daily from 08:00 to 18:00 (duration of 10 h). A warm-up period of 1 year was selected in

order to stabilise the other parts of the system. This time frame was chosen as upon investigation, it appeared that the system was running at a stable point by this time, where the numbers and waiting lists reflected real practice. The length of time for which actual results were collected and analysed was chosen to be 3 years past this initial warm-up period. One hundred iterations were run in the trials, unless otherwise stated.

Verification and validation

For model verification, any parts of the system that called parameters from the Excel interface had to be appropriately checked. All parameters were carefully inspected and subject to via extreme values testing; by setting the parameters to extremely large and extremely small values. The system was then run for each parameter to observe whether the changes made were reflected in the behaviours of that particular model entity. All components were fully verified through this method. For model validation we adopted both *white box* and *black box* methods (Kleijnen, 1995). Frequent visits were made to the Academic Dermatology Unit at SWH. A number of preliminary discussions with medical personnel allowed for development of the model. Pathways and entities were altered accordingly, if required. Furthermore, observation of patients attending a number of clinics enabled a more thorough consideration of timings through the system.

Operational validation compares the results from the simulation model with a suitable reference to show that the model can support its intention. For this project, this was performed by comparing the waiting lists and number of patients on each treatment therapy with the responses from the interviews or the data collected. For example, an important waiting list is for phototherapy treatment. It was imperative to model this well, as the focus of the later part of the project was observing the effect of a number of operational changes to the system on waiting lists for phototherapy. The medical physicist suggested that the typical length of time of the waiting list for SWH was 16 weeks, while it was 4–5 weeks for YYF. The simulation model generates an average queueing time of 113.67 days for SWH (95% confidence interval is (105.54, 121.8)) and 30.93 days for YYF (95% confidence interval is (25.24, 36.62)). Therefore, the lengths of time on the waiting lists generated by the simulation model are of a similar order and in fact are not statistically significantly different at the 5% level. Similar statistical analyses were conducted for other key parameters and overall it was concluded that the simulation model was successfully tested to be working as intended, and furthermore replicates clinical practice well. A full account of all data parameters and model functionality may be seen in Putman (2012). For the purposes of this paper and conciseness, we have presented only the most important elements.

Investigation of changes to clinical practice

Through discussion with the ABUHB staff, it was evident that many patients were excluded from phototherapy due to the length of the waiting lists and geographic dispersion. This meant that many patients were missing out on phototherapy by being routed to systemic therapies. By allowing a larger proportion of patients to reach third-line therapies, the system was inundated with patients requiring frequent reviews. Furthermore, arrival within third-line therapies also opened up the subsequent possibility of biologic therapies. The simulation model also demonstrated phototherapy (second-line therapy) as a major bottleneck in the system. Therefore, the scenarios below were identified with the intention of reducing the length of time that patients spend on phototherapy waiting lists. Improving access to phototherapy was another issue that was explored.

Study 1: Sensitivity analysis of current capacity

Observation of the phototherapy unit at SWH showed that it was operating below capacity. It is hypothesised that this was due to the flexible nature of patient scheduling for subsequent treatments. Patients were not allocated a specific appointment time but instead a time that is suitable for both parties was negotiated (e.g. 'around midday' was often heard). Another feasible way to increase current capacity is through empowering the patients to undergo their phototherapy at the two existing units outside of opening hours. This involves teaching the patient how to use the phototherapy equipment and how to control their doses. This may be advantageous for some patients as having the option to attend the phototherapy unit between, say, 05:00 and 08:00 would allow them to undergo their treatment before work. However, this approach is novel, with a single preliminary study published (Yule, 2013) and no definitive clinical governance framework for safe and effective provision of this model of care. Therefore, it was considered interesting to investigate the effect on waiting lists if the capacities of phototherapy units were increased accordingly, with consideration of the same demand.

For each phototherapy unit, capacity estimates were incrementally altered from the current capacity. The simulation model was used to evaluate the impact of the waiting time at each capacity change. Figure 2 summarises the average time patients spend on the waiting list. The 95% confidence intervals are also presented.

For each discrete increment change in capacity (i.e. the unit can handle an additional patient), a 2.9% change from baseline in SWH capacity, and a 4% change from baseline in YYF capacity, is reflected. It is evident that waiting lists are reduced significantly, even in the case that both units' capacities were only increased by 10%. Further reduction is seen by a 20% increase, although not as significant. Additionally, it is apparent that the effect of increasing the capacity plateaus for SWH after an increase by four to six patients, and for YYF, after an increase by two to four patients.

Study 2: Equal allocation to SWH and YYF

As previously noted, currently more patients are routed towards the phototherapy unit at SWH than YYF. A particular

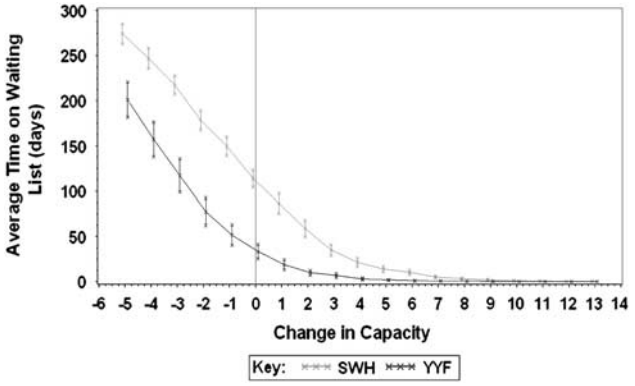

Figure 2 Plot of changes in average length of waiting lists resulting from capacity changes at SWH and YYF phototherapy units.

Table 1 Summary of results for matching capacities at SWH and YYF phototherapy units

	Mean	*95% CI*
SWH waiting time	–107.2 days (–93.2%)	(–107.7, –106.8)
YYF waiting time	–20.1 days (–67.2%)	(–20.3, –19.8)
Cost	–£118,350 (–4.0%)	(–130,819, –105,881)

scenario posed by the staff concerned the effect of attributing equal quantities of patients to each unit in an attempt to reduce the waiting list for SWH. This was modelled by matching available resources (human resources, equipment and opening hours) at both units. The probability of a patient choosing YYF and SWH was also equal. As waiting lists were expected to diminish, it was postulated that more patients would be open to the choice of phototherapy. Therefore, the decision for all consultants to choose phototherapy was accordingly increased to reflect the higher likelihood of patients choosing phototherapy.

Table 1 shows the mean difference from baseline with the corresponding confidence interval. The percentage difference ratio from baseline is also shown in brackets. Paired *t*-tests were performed to show that all indicators were statistically significantly different from the baseline model at the 5% level.

Study 3: Additional phototherapy units

A further method to reduce phototherapy waiting lists in ABUHB was to create additional phototherapy units at new geographical locations. In this scenario, the treatment would occur in some other chosen hospitals within the ABUHB catchment area. The suggested three additional units were located at Abergavenney, Monmouth and Chepstow. Therefore, patients would be strategically targeted from more remote areas in ABUHB to undergo their phototherapy at these units, thus improving access to phototherapy services.

It was necessary to deduce what proportion of patients would be attributed to each phototherapy unit. Using geomapping analysis, each postcode polygon and its population were assigned to a hospital. Figure 3 shows how the postcode districts were assigned to each phototherapy location. It is evident that the chosen destinations geographically cover the ABUHB area well. The populations of each hospital unit were calculated and proportions were derived. Due to increased provision of services, it was logical to assume that waiting lists would reduce under this scenario, and hence that more patients would be open to the option of phototherapy. Therefore, the proportion of routing into the different lines of therapy was changed for each consultant.

Table 2 shows the mean difference from baseline with the corresponding confidence interval. The percentage difference ratio from baseline is also shown in brackets. Paired *t*-tests were performed to show that all indicators were statistically significantly different from the baseline model at the 5% level, thus localised provision of phototherapy would be highly beneficial.

Discussion and recommendations

The focus of the project was on mapping the flow of psoriasis patients through available therapies in ABUHB using DES. Following development and validation of a simulation model, a number of alternative scenarios were investigated. The results of this analysis confirmed that the existing provision of services for psoriasis management was not performing as efficiently or as cost-effectively as possible.

By performing a sensitivity analysis on the current capacities of SWH and YYF, possible reduction in length of time on waiting lists was seen. It was observed that by increasing capacities (number of available slots for patients) by just 10%, the length of time on waiting lists could decrease by 79.5 and 79.8%, for SWH and YYF, respectively. This is a feasible operational change as the phototherapy units could potentially be opened out of hours, enabling the patient to undergo their phototherapy course without the medical staff. This resonates with the recent advice by the British Association of Dermatologists, www.bad.org.uk. Alternatively, there appears to be scope for improved patient scheduling to increase the number of patients who can be seen in the clinics, thus ABUHB are recommended to examine this further.

Another feasibility scenario was matching the capacities of SWH and YYF phototherapy units. Currently, the same equipment exists at YYF as SWH. However, due to shorter opening hours and less staff, fewer patients are managed at YYF. By opening to the same hours as SWH and providing matched staffing levels, it was expected that YYF could absorb a great deal of demand from the phototherapy

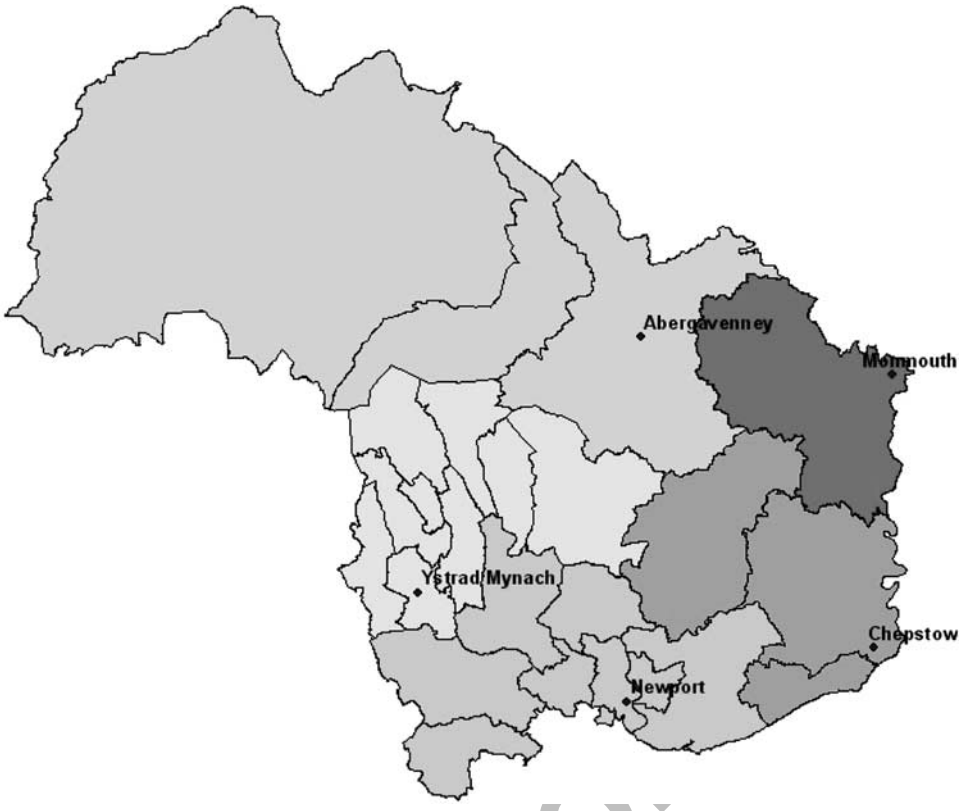

Figure 3 Map of postcode districts assigned to each phototherapy unit.

Table 2 Summary of results of localised phototherapy

	Mean	*95% CI*
SWH waiting time	–83.6 days (–72.7%)	(–83.9, –83.3)
YYF waiting time	–10.8 days (–36.1%)	(–11.1, –10.5)
Cost	–£237,765 (–8.1%)	(–253,419, –222,111)

waiting lists. When the model was altered to reflect this change, waiting lists at SWH were reduced by 93.2% and waiting lists at YYF were reduced by 67.2%. Additionally, the simulation model suggests that costs throughout the system would be reduced by 4%, a difference of £118,350 over 3 years. These cost savings are attributed to a 7% reduction in the number of patients who engage in systemic therapy and a 5% reduction in the number of patients on biologic therapy. Although the model does not account for staff costs in phototherapy, ABUHB have indicated that these would be significantly lower than the potential cost savings.

Finally, the scenario of opening additional phototherapy treatment units was considered. Results from the model showed that wider geographical coverage by opening new phototherapy units would improve access and reduce overall costs within the system. Length of time on waiting lists was reduced by 72.7% at SWH and 36.1% at YYF. Furthermore, there were significant costs savings of 8.1%. In real terms, this is the equivalent to £237,765 over 3 years. Such cost savings are a result of a predicted 4% reduction in the number of patients who engage in systemic therapy and a 15% reduction in the number of patients on biologic therapy. However, it is recognised that such cost savings would be notional rather than real. The modelling project was based on the assumption that by studying the whole system, resources released from one area could be reallocated to another area. The model suggests that such targeted reinvestment within the system would alter the dynamics of the whole system away from the currently unsustainable year-on-year increases in biologic prescribing.

The dermatology directorate of ABUHB were advised to give serious consideration to the potential benefits of any of the identified strategies, as the model predicts that they would prove to be beneficial not just by significantly reducing waiting times but providing large cost savings to make the service more sustainable in the future.

DES is a data-intensive process, therefore there were a large number of data requirements. Data were manually extracted from various sources. In the absence of complete data, other methods were employed in an attempt to gain some insight into how the system of psoriasis patient flow

performs. For example, semi-structured interviews with the staff were conducted and sampling from hand-written patient notes was necessary. Naturally, more complete quantitative data would have been advantageous and thus naturally we acknowledge such limitations, but have used verification and validation methods to be satisfied that the model is adequately reflecting real-life processes. ABUHB have been advised to implement a database system throughout dermatology services.

Conclusions

Through careful and collaborative design, a DES model was developed and successfully validated to show that it replicates current patient flows of psoriasis patients in the Aneurin Bevan University Health Board (ABUHB) in South Wales. The model successfully represents the stochastic nature of various patient or clinical choices.

A number of alternative service configurations were explored by appropriately altering the simulation model or by manipulating the decision variables to evaluate the effect on several key performance indicators, including length of time on waiting lists, and costs. These alternative designs were selected through discussion with the staff in the dermatology directorate and were all aimed at improving waiting lists and access to phototherapy. By achieving this, it is hoped that fewer patients would require referral to third- or fourth-line therapy; hence significant opportunities for cost reallocation within the system. The identified scenarios demonstrated significantly reduced waiting lists and revealed potential cost reallocation opportunities. This is particularly important for the health board at a time with rising demand and financial pressures. Reconfiguring the services as suggested would help to provide a sustainable service while improving patient safety by reducing the rate of referral to more complex and risky treatments. This project has gone a long way to try and understand the complex behaviours and interactions between patients and staff in the system of psoriasis management in ABUHB. It is hoped that the verifiable results shown in this project will lead to implementation of a suggested strategy in ABUHB, or at least provide a framework for development of this work in the future. In order to achieve this aspiration, a significant expansion of phototherapy services is needed, which this model predicts will lead to long-term savings through reduced spending on high-cost and higher-risk treatments.

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