

Discussion & Opinion

▶ Roles of pathway-based models and their contribution to the re-design of health-care systems

Gillian Mould and John Bowers

School of Management, University of Stirling, Stirling, UK

Summary

Care pathways provide a practical analytical tool that encompasses both organizational efficiency and individual patients' care. In the UK, constructing the care pathway has been a recommended starting point for the re-design of health-care systems. This paper examines the re-design cycle for health-care systems and looks at the role of pathway-based models in the design and operation phases of the cycle. In addition, the models provide further benefits for communicating recommended practice and audit of care and outcomes. The models span the classic care pathway with extensions to simulation modelling. An example of the use of care pathways in the re-design of an emergency department is used for illustration. This study shows the role of pathway models as: a tool for re-design, a catalyst for enhancing communication and as a repository for audit information. The final role of a tool for modelling contingencies was not implemented. From the example it can be concluded that sophisticated models can be useful, in some applications; however, the simpler approaches may often be the best, offering rapid, transparent recommendations based on a multidisciplinary approach.

Introduction

Care pathways can be used in many roles, contributing to design of health-care systems, communication between involved parties, audit and simulation of alternative configurations. The process of development of a care pathway can stimulate constructive reviews of existing practice and innovation in the health-care system resulting in improvements in both quality of care and the more effective use of resources. The finished pathway offers many other potential benefits ranging from national models of good practice to a record of the experience of individual patients.¹ This paper focuses on the roles of the pathway in contributing to the re-design of services. The process of re-design is essentially a cycle of continuous improvement based around the pathway. The use of pathway models can facilitate communication, and the resultant pathway can be used for audit and for experimentation. The European Pathways Association has defined the patient pathway as a complex Q1 intervention, focused on the needs of the patient,¹ which follows the patients journey through the health-care system. The tools of mapping and simulation which are used in many other sectors are highly appropriate to the task of re-design of care pathways as they place individual

processes in the context of the whole system and facilitate the focus of the re-design on the needs of the patient.

An extensive programme of re-design of both acute and primary-care health services has been undertaken in NHS Fife, covering services as diverse as elective orthopaedics and psychiatry. The programme of re-design made extensive use of pathway models and an example of the roles of care pathway models in the re-design of an emergency department is used for illustration.

Modelling is fundamental to management, enhancing the understanding of the current system and encouraging an evidence-based approach to assessing future options. The care pathway is one simple but powerful model and it is recognized as encouraging a systemic approach to improvement.² Mapping the current pathway provides a disciplined approach to assimilating knowledge from all those involved in the patient's care; this is usually the initial step in the re-design process for any service. Pathway mapping exists in many formats in the UK's National Health Service (NHS), fulfilling a variety of roles.³ It can be a traditional flow chart, a collection of post-it notes arranged on a large sheet of paper with interconnecting lines or an interactive computer-based pathway model with capabilities such as hierarchical maps and electronic dissemination. The key challenge of mapping is to provide both a high level view, such that staff can retain a vision of the whole care system, while retaining the vital detail. Given the relevant assembly of data presented in an accessible but rigorous format, various analyses are possible.

Accepted XX XXXX

Correspondence: Gillian Mould, School of Management, University of Stirling, Stirling FK9 4LA, UK (Email: gim1@stir.ac.uk)

G Mould and J Bowers Roles of pathway-based models

Pathways can fulfil a variety of roles exploiting new technologies both in their development³ and as a final product.⁴ Different members of the 'pathway community' see different benefits in pathways^{5,6} but one notable role of the pathway is in improving communication between clinical and management staff. However, this emphasis on communication can be at variance with more sophisticated modelling, which may require considerable detail of all stages in the pathway to accurately capture treatment processes, this may reduce accessibility by confuse users with too much information and detract from the understanding of the whole system. A case study of a re-design of an emergency department is used to illustrate the roles of the care pathway; it was found that a simple model of the care pathway produced many unexpected benefits; however, more sophisticated modelling techniques added little extra value to the original model.

Roles of the care pathway

.....

Many studies have focused on the potential clinical role of care pathways considering the barriers to their implementation⁷ and the direct impact on clinical outcomes and patient stay.⁸ However, if a wider definition of a care pathway is accepted which sees care pathways as a systemic methodology which can be used for individual patient management or as a tool for clinical governance,⁹ the scope for care pathways expands dramatically. The roles may be categorized by the phases of design, communication and audit which are comparable to the Deming cycle of plan-do-study-act.¹⁰ Classic quality management teaching views these phases as a cycle contributing to a process of continuous improvement.

The major contribution the care pathway to design of health-care systems is made during the development of the pathway, when existing practice is compared with alternatives and a revised pathway is agreed. However, the pathway product⁹ also contributes to the continual process of re-design: there is no final definitive pathway product just the latest representation of recommended practice that is reviewed as the environment changes or the opportunities arise to enhance patient care.¹¹ As a design tool, the classic care pathway can be seen as the basis for other complementary models such as simulation. The first pathway model is a simple pictorial representation of the patients journey through an episode of care, this model can be viewed as 'soft',¹² the model captures the sequence of events and can be used to aid understanding of the system. Simulation is a natural extension to this which provides a dynamic model of the pathway incorporating quantitative data describing the demand and capacities of the key components of the pathway to model the flows of patients through the system. The simulation provides an example of a 'hard' rigorous scientific approach to analysing the organization of care. Both modelling approaches can be valuable: some aspects of the organization of care can be

quantified but others are less easily measured but still important; care pathways are central to hard and soft approaches to analysing the design of care systems.

The pathway can be seen as a means of enhancing the communication of the staff involved in its processes, it provides a road map that describes in full detail the delivery of care over time and the contribution to it by each member of the caring team.¹³ Pathways have been shown to improve the effectiveness of the team delivering care and have a positive effect on the patient experience has been reported.¹⁴ Patients' pathways can be complex involving many different staff, each of whom may be expert in their own area but have an imperfect appreciation of the whole pathway. Hence a modelling technique which encourages everyone to share their knowledge can make a great contribution to health-care re-design.

Much of the debate about care pathways focuses on the audit role. The pathways are often portrayed as a means of defining practice with the delivered care then being compared with the standardized pathway through variance analysis.^{15,16} Many studies have claimed that greater standardization can provide both more efficient and effective health care.¹⁷ Though it has also been suggested that very high rates of adherence to the standard pathway could be seen as an indicator of poor clinical practice and contrary to a patient-centred view of health care.¹⁸

While there are many claims for the potential benefits of pathways in enhancing both the routine organization and the process of continuous improvement, it has proven difficult to measure the effect.¹⁹ The key challenge of mapping is to provide both a high-level view, such that staff can retain a vision of the whole care system, while retaining the vital detail. Equally, any tool has to be accessible such that all staff can contribute to the mapping exercise: wherever possible, the simplest approach is likely to be favoured.

Discrete event simulation can be seen as a natural extension to the mapping exercise, in fact the pathway map is the conceptual model upon which the simulation is based. Simulation produces a dynamic representation of the pathway which has been extensively employed in analysing and designing health-care systems.²⁰⁻²² In particular, it has been used in various studies of emergency departments.²³⁻²⁶ Some of these studies exploit the quantitative capabilities of simulation in modelling flows of patients, often within a stochastic environment. Other applications emphasize the softer contribution of simulation in helping develop a systemic view of the current system and re-design options. Studies have shown that simulation can be most relevant to re-design in the NHS, where understanding the whole system is of great importance and clinical involvement is essential.²⁷

The re-design cycle

.....

In some industries there is a clear distinction between the stages of re-design: data collection, analysis, identifying

options, assessment, selection and implementation. In health care, there is much less distinction with many staff and interest groups contributing at different stages. This collaborative approach is often deemed essential in ensuring patient-centred care, avoiding the mistake of designing a health-care system focused around the care providers. This approach implies more iterations with the new design emerging from a cycle of analysis and communication, see Figure 1. The various contributors provide data inputs such as their understanding of the current sub-systems or suggestions for improvement, and also provide an element of the analysis of the present systems and assessment of any proposed re-design, commenting on the clinical and logistical implications. In this environment clarity and accessibility are often more important than sophisticated analytical capability; hence, for example, pathway models may be more appropriate than simulation in many re-design exercises.

The new design then proceeds to the operational phase, where its implementation is again very dependent on the ability to communicate the detail of the pathway. In this phase there are continual audits of the care of individual patients, comparisons of performance with similar facilities and reviews of the care system refining the implementation. However, ultimately the design will have to be reconsidered: external pressures such as more stringent targets or clinical advances may imply that the system should return to the re-design phase. This cycle between operation and design reflects the process of continual improvement. In both the design and operation phases the pathway model is central to the re-design.

This cycle of re-design has been employed in the UK where the NHS has initiated a significant programme of

re-design to improve its service delivery.²⁸ The re-design methodology has been developed from techniques that have been found to be effective in industry²⁹ and a culture of continuous improvement has been recommended. The focus of the re-design programme has been on the needs of the patient and an important tool in understanding these needs is the patient pathway.²

Example: pathway mapping in an Emergency Department in Scotland

After considerable bad publicity between 2000 and 2003 on the length of time patients spent waiting in emergency departments in the UK, the Department of Health in England introduced a target that 98% of patients attending emergency departments should be treated within four hours. The NHS in Scotland followed this example and formed the Unscheduled Care Collaborative Programme³⁰ to improve services; and to deliver the four-hour treatment time target. In response to this initiative, NHS Fife (one of the 14 health boards that make up the NHS in Scotland), formed a multidisciplinary team to investigate and re-design patient pathways in the emergency departments at their two acute hospitals. The team was led by a senior clinician and a range of frontline staff including clinicians, managers, representatives from associated services and an analyst. The analyst had considerable experience of pathway mapping, but was new to simulation, and so was closely supervised by the authors who are experienced in this technique. The multidisciplinary nature of the team had been found to be an important element in

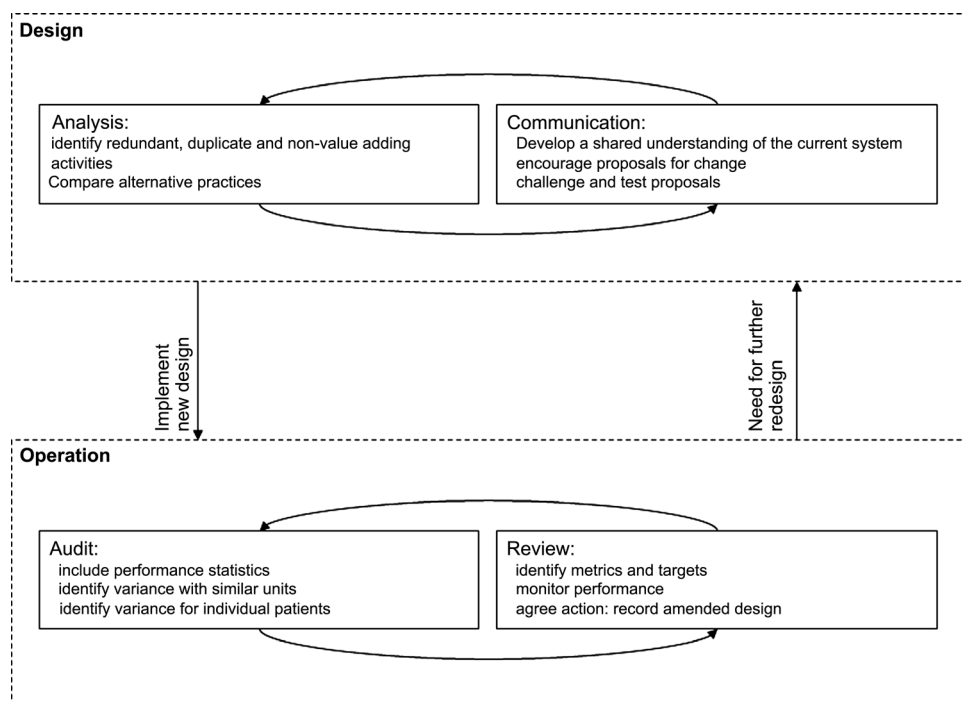


Figure 1 The re-design cycle

G Mould and J Bowers Roles of pathway-based models

transforming patient processes^{31,32} and the importance of a clinical lead was recognized.² The first stage in the re-design process was to understand the patient journey through the department by mapping the care pathway. This was the starting point of the re-design as it potentially offered a means of reconciling clinical and management interests.⁵

The care pathway in an emergency department is a good example of a complex intervention providing predictable care for a well defined group of patients.² It is a particularly good example of a web pathway as the department deals with a large variety of conditions, hence disease-specific pathways are not appropriate. The variety of conditions treated in emergency departments leads to a very complex care pathway with patients able to take many routes through the department. However, the high-level care pathway (Figure 2) is very simple and can be applied to the vast majority of patients. The pathway consists of five stages: assess; investigate; diagnose; treat and admit or discharge. The enormous variety of the work in the department is due to the great range of patient conditions presented and the variety of diagnostic investigations and treatments used.

Development of mapping medium

Initially, the maps used the traditional text-box representation (Figure 3) but these were not readily absorbed by the re-design team. A method of mapping was required that produced maps that were easily understood, could highlight redundancies and be used to compare services. Over time a pictorial icon base mapping medium was developed in Microsoft Visio and the pathways were made available in electronic format. This medium allowed a hierarchy of maps: a simplified high level pathway with the ability to drill down using HTML facilities to a detailed view of specific sub-processes. A further innovation was to distinguish the patient pathway, indicated by unbroken lines and yellow icons, from the information pathway, depicted by dashed lines and grey icons. This distinction helped the re-design team assess which activities were a genuine contribution to patient care, and which were unnecessary bureaucracy (Figure 4).³

The pathway review process

Once the patient pathway had been established and accepted, the work of the re-design team concentrated on

identifying improvement opportunities in three main areas: understanding and improving the patient flow through the department; matching capacity and demand and identifying and rectifying the major causes of breeches (patients who were not treated within the 4-hour limit). The patient pathway formed the basis of the analysis in each of these areas.

The maps were used to examine the sequence of processes to see if there was scope for a more effective organization, in particular all handovers were questioned. This exercise revealed a number of repeated or redundant activities. At this time Lean thinking³³ was being investigated as a potential improvement methodology hence an analysis of value added and non-value-added activities was undertaken and attention was paid to removing or reducing the non-value-added activities. The improvements were introduced as a series of small changes with the plan-do-study-act methodology being widely adopted. The pathway maps were updated and circulated to communicate the changes to members of the re-design team.

As the target deadline neared the team focused their activities on those patients who had breached the four-hour target. In an attempt to understand the causes of breaches performance data were added to the pathways (typically a user right clicked on an icon and the latest available data were displayed), enabling the pathway to become a repository for audit data such as resource requirements, performance and timing data. The performance statistics also facilitated the comparison of performance at the two acute hospitals. For example, the distribution of lengths of stay could be compared for patients admitted following attendance at the emergency department. It was highlighted that one hospital had a much greater proportion of patients with lengths of stay of less than 24 hours, this hospital had an acute receiving unit: a number of beds adjacent to the emergency department where admitted patients could be observed before discharged or transferred to a specialist ward. It was thought that this facility contributed to more efficient management of patients and it was subsequently replicated at the other hospital. A comparison of the daily distribution of discharge times showed that one hospital was able to discharge patients earlier in the day than the other. This hospital had a discharge lounge: where patients could wait while discharges prescriptions were made up and transport arranged; this allowed beds to be vacated earlier in the day and consequently reduced the build up of patients requiring admission in the emergency department. The acute receiving unit and the discharge lounge were located at the same hospital, the

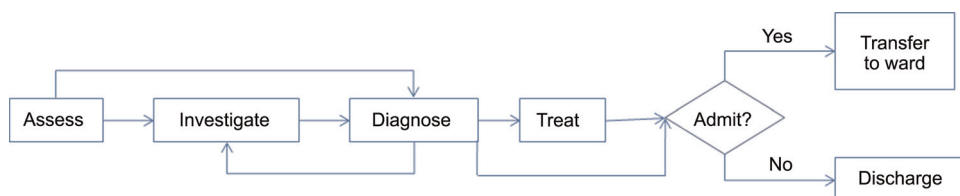


Figure 2 A traditional flow chart representation of the emergency department care pathway

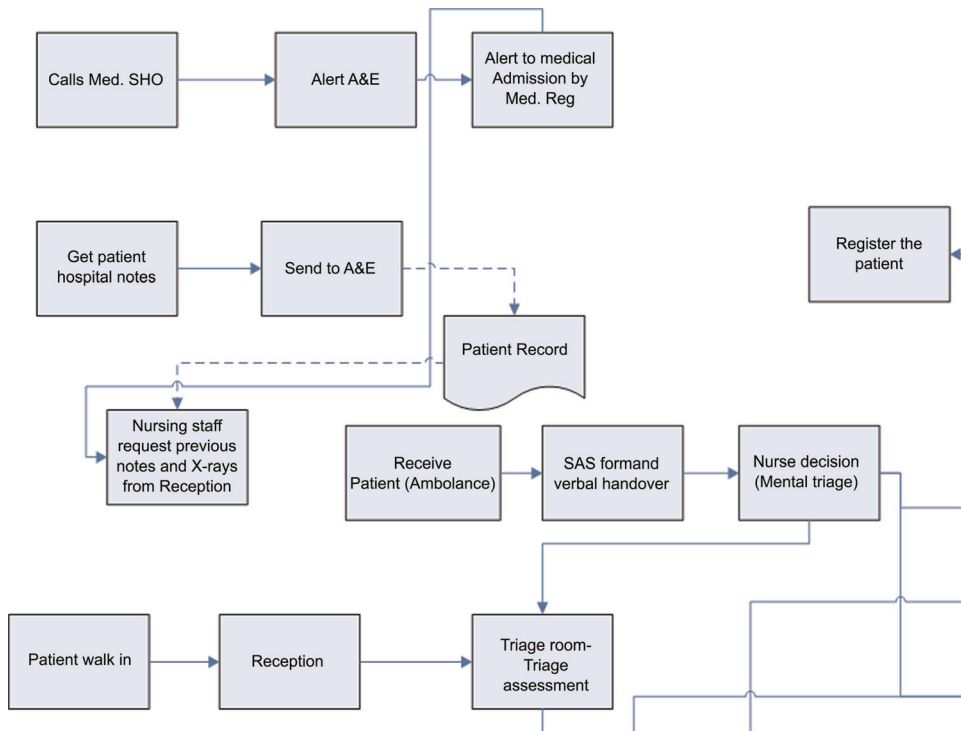


Figure 3 A high-level view of the emergency department care pathway

Q4

precise effect of these features on performance was difficult to determine but the hospital consistently returned fewer breaches.

Simulation model of the patient pathway

In an attempt to understand the impact of these features a simulation model of the emergency department was

constructed, as shown in Figure 5. The model was essentially a dynamic version of the pathway which could be used to investigate the effects of including more resources at critical points. The re-design team were enthusiastic about the potential for simulation as a tool to help them explore options for improvement and input screens were devised to enable the model to be used by members of the re-design team. However, the development of such a sophisticated model took time: it was important to collect accurate data on process timings and this required a patient

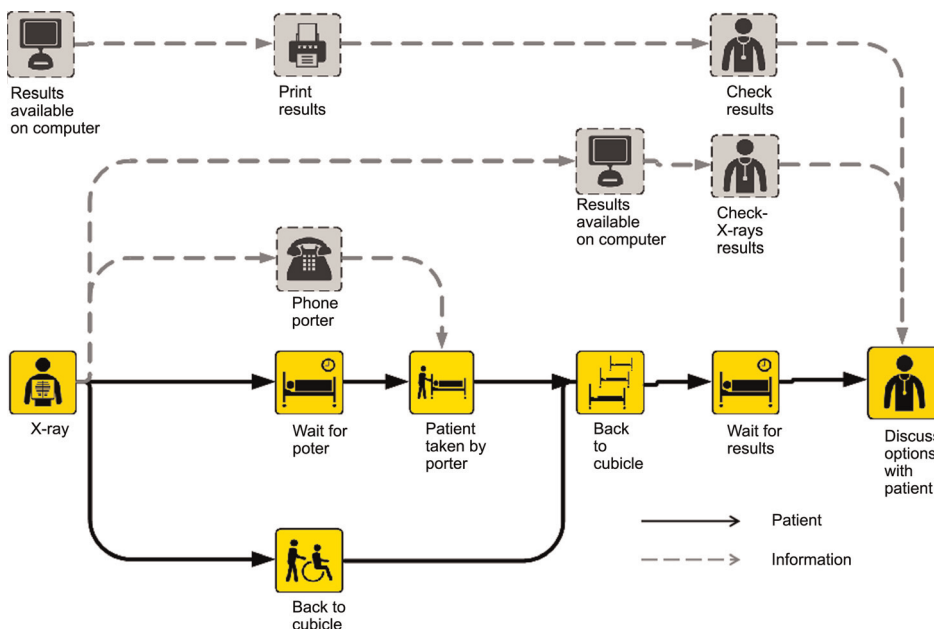


Figure 4 An investigation pathway for X-ray, using stylized icons distinguishing patient and information flows

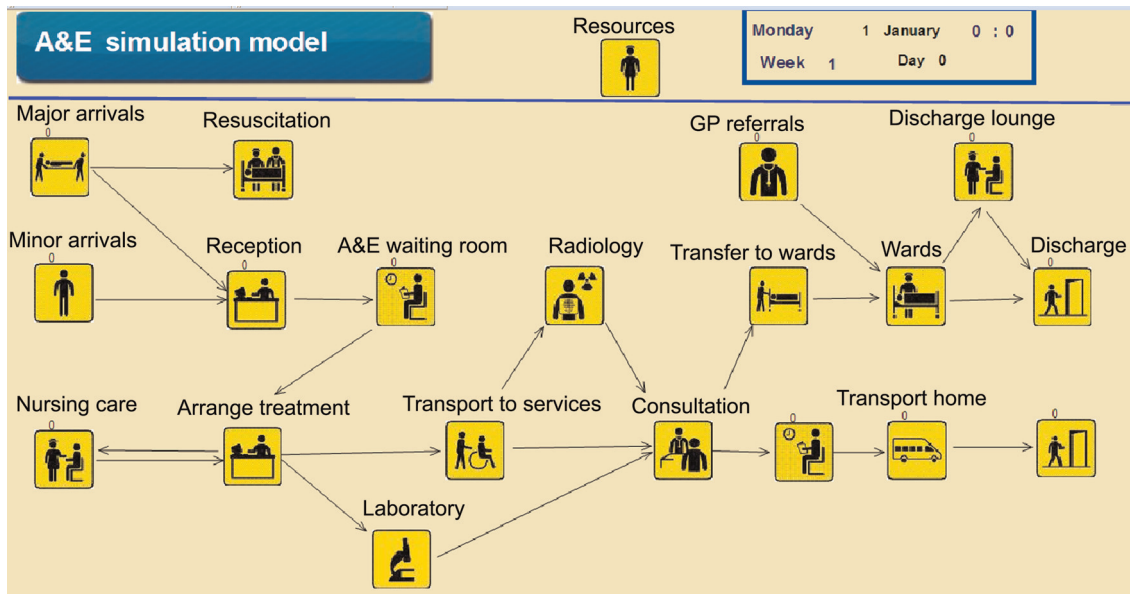


Figure 5 Accident and emergency simulation model

tracking exercise to be undertaken; subsequently staff had to agree that the timings were accurate, if there were any disagreements these were further investigated. Staff members were also consulted on the design of the user interface: the information they wished to vary; the level of details of the results required; this enabled them to undertake experiments independently. This process took some time but the modellers believed it to be essential if the model was to be trusted and used by staff. The development introduced a number of unplanned delays and the model was not ready for use until after the four-hour target had been met. Although the model was never used for the purpose for which it had been designed, the interest it generated during the construction process forced staff to further question their routines and its development added to their understanding of the processes and the impact of changing resources.²⁶

Discussion

Pathways as an aid to re-design

A key objective of the unscheduled care re-design programme was to focus on the needs of the patient, the use of care pathways ensured that the patients perspective was central to any proposed changes. The visual nature of the pathway maps facilitated the recognition of repeated or redundant activities, it also drew attention to the occurrence of similar activities, for example, times when the patient was made to wait between activities. The re-design team found it easier to compare pictorial maps than text based flow charts hence the pathways could be used to compare practice before and after the re-design and between hospitals. The number of handovers between staff, could be identified and questioned, the method of

information flow along the pathway could be highlighted and challenged if necessary. In addition, the electronic format of the pathways enabled certain activities to be highlighted, for example, the non-value-added activities could be emphasized and attention focused of reducing these. The user could also select a particular category of patient, e.g. major/minor, surgical/medical and view only the activities relevant for that patient. This encouraged discussion about specific patient categories and their needs. Once the pathway for minor patients was identified it was recognized that they could be treated by nurses, allowing doctors to concentrate on more seriously ill patients. Examination of the pathways led to question the value of triage and a proposal for a multidisciplinary team of clinicians that could be assembled for the rapid assessment of major trauma patients, ensuring good care for such patients while minimizing the disruption of the treatment for other patients. The role in re-design was much wider than anticipated with the pathways providing much more than a detailed documentation of processes. The completed pathways could be compared with those from other hospitals and variances explored this coupled with performance statistics helped to stimulate ideas for change.

Pathways as an aid to communication

The ability to have high-level and detailed views of the pathway enabled staff to appreciate the whole system as well as the details of their particular role, the combination of these views allowed staff to value the work done by others and see clearly how their contribution fitted in to the whole sequence of care. The HTML format also allowed them to be displayed on a large projection screen in team meetings and high level or detailed views presented as required with the analyst undertaking dynamic modifications as suggested by the team. The multidisciplinary

approach enabled staff to appreciate their interdependency and strengthened team working, which has been shown in a number of studies to have a positive impact on patient outcomes.¹ The maps were mounted on the intranet so staff could scrutinize them in the comfort of their own offices and send comments to the re-design coordinator by email. This encouraged junior staff to contribute to the review process, whereas in group discussions they might feel intimidated by more senior colleagues. This improvement in the group dynamics was an unexpected benefit of the new pathway format and a further example of how pathways can help a team work together.¹⁹ The maps had a further role of documenting the treatment process and were found to be a valuable training aid for clinical staff, in particular for Junior Doctors who routinely spend a few months of their training in emergency departments.

Pathways as a tool for audit

The audit and data features of the pathways allowed staff to question the use of resources. The provision of data on staffing levels and patient arrivals at the department caused staff to question why these were not more closely related, as a result a major review of shift patterns was undertaken. Staff requested that the pathways be used as repository for evidence and links to academic papers were included to provide an evidence base for the processes in the pathway.

Pathways as a basis for enhanced modelling capabilities

The use of the pathways for dynamic modelling or simulation of the patient flows was an unplanned extension of modelling process. The need for this was stimulated by the provision of audit information. The pathways could identify bottle necks, for example a bottleneck of waiting for assessment by a doctor was highlighted and the re-design team were keen to explore options for resolving this problem and simulation seemed a natural choice of modelling methodology. There were delays in the construction of a simulation model as detailed information on activity timings was required and a patient tracking exercise was undertaken, the results of this were then discussed and agreed with staff to ensure the processes were modelled accurately, any disagreements were further investigated until a consensus was reached. In addition, there were difficulties of deciding the boundaries of the system. The emergency department interacted with numerous other departments and services in the hospital, only details critical to the operation of the emergency department were included, less critical activities and timings were modelled by using aggregate statistical data. For example, it was thought important to model the use of porters within the department and detailed timings of their activities were collected, but diagnostic service timings were modelled by using the average daily distribution rather than distributions reflecting the time of day and day of the week. In addition, the development of a robust user interface

which would be suitable for use by clinical or management staff resulted in a two-month development time for the model. The staff were very keen to cooperate and were optimistic about how the model could help them in the re-design process. However, the delays proved critical and by the time the model was ready for use the four-hour target had been met and debate within the re-design team was concerned with how to maintain the performance. Despite the efforts to involve staff, the development of the simulation was seen as more of a black box since the intricacies of the modelling medium meant that the methodology was not readily understood by the whole team. This can be contrasted with the development of the pathway model which was very fast: often a model could be constructed in realtime during a meeting, enabling the team to see directly how their experiences translated into a pathway. This rapid construction within team meetings also contributed to the ownership of the pathways models by the group.

Conclusion

.....

From the experience of re-designing an emergency department it can be seen that pathway models had three successful roles: a tool for re-design, a catalyst for enhancing communication and as a repository for audit information. The final role of a tool for modelling contingencies was not implemented in this instance. These roles were not entirely independent for example using the pathway as a repository for audit information also enhanced communication, as these facts and figures were more accessible to staff. Similarly the audit information also provided some evidence of candidate processes for re-design. Finally, the pathway models provided a medium for enhanced communication which greatly facilitated the re-design process.

The response to the pathway construction from both management and clinicians was very positive. Staff felt that the mapping tool could provide the detail required for documenting processes and also communicate the relationship between individual processes and the whole system of care. As a result of the programme of change throughout Unscheduled Care, NHS Fife comfortably met the four-hour waiting time target. Many staff and actions contributed to this success, with the pathway maps contributing to the analysis of current practice and the identification of re-design options and enhancing the communication of the re-design team. The extension of the pathway model to simulation modelling has now been refined so that models can be constructed more quickly. There have been successful applications in re-design particularly where the system of care is less complex and critical timings and resource requirements are well understood. Mr Ken Laurie, Director of Strategic Change in NHS Fife said, 'The tools greatly assisted our understanding of clinical service delivery from the patient's perspective.

G Mould and J Bowers Roles of pathway-based models

Consequently, we were able identify pragmatic changes to our processes and procedures that enhanced patient experience and in many instances, directly improved the working lives of our staff'.³⁴

The case study presented here illustrates just one application of pathway models to aid re-design. The views expressed are those of the analysts involved in the re-design. A formal evaluation of the techniques used was not undertaken but the success of the re-design techniques have been publicized in health service news letters and case studies.^{35,36} Pathway based models were first used for the re-design of the emergency department in NHS Fife. The re-design was successful and the models were later used in a number of other services. In a further application, the mapping technique was used and a simulation model constructed and used to re-design outpatient clinic pathways. Subsequently the mapping technique and simulation modelling have been used on a variety of re-design projects such as re-designing a number of planned care treatment processes for the 18-week referral to treatment target; re-designing cancer treatment services; re-designing mental health services and community physiotherapy services. The pathway mapping technique has been widely disseminated to staff involved in re-design throughout NHS Fife, it is the accepted method of recording the patient pathway and the first stage in any re-design of care.

References

- 1 Vanhaecht K, Panella M, van Zelm R, Sermeus W. An overview on the history and concept of care pathways as complex interventions. *Int J Care Pathways* 2010;14:117–23
- 2 Bragato L, Jacobs K. Care pathways: the road to better health services? *J Health Organ Manag* 2003;17:164–80
- 3 Mould G, Bowers J, Ghattas M. The evolution of the pathway and its role in improving patient care. *Qual Saf Health Care* 2010;19:1–6
- 4 Rosique R. Do we need electronic support for pathways: the Spanish experience. *J Integr Care Pathways* 2009;13:67–74
- 5 Allen D. Care pathways: an ethnographic description of the field. *Int J Care Pathways* 2010;14:4–9
- 6 Allen D. Care pathways: some social scientific observations on the field. *Int J Care Pathways* 2010;14:47–51
- 7 Evans-Lacko S, Jarrett M, McCrone P, Thornicroft G. Facilitators and barriers to implementing clinical care pathways. *Bmc Health Serv Res* 2010;10:Q2
- 8 Rotter T, Kinsman L, James E, Machotta A, Gothe H, Kugler J. The experience of conducting a Cochrane systematic review of the impact of clinical pathways on professional practice, patient outcomes, length of stay and hospital costs. *J Integr Care Pathways* 2009;13:62–6
- 9 Panella M, Vanhaecht K. Care pathways and organizational systems: the basis for a successful connection. *Int J Care Pathways* 2010;14:45–6
- 10 Deming WE. *Out of the Crisis*. MIT Press, 1986
- 11 Savitz LA, Kaluzny AD, Kelly DL. A life cycle model of continuous clinical process innovation. *J Healthc Manag* 2000;45:307–15
- 12 Robinson S. Soft with a hard centre: discrete-event simulation in facilitation. *J Opl Res Soc* 2001;52:905–15
- 13 Vleugels A. Why pathways cannot be taken from the shelf. *Int J Care Pathways* 2010;14:150–4
- 14 Van Herck P, Vanhaecht K, Sermeus W. Effects of clinical pathways: do they work? *J Integr Care Pathways* 2004;8:95–105
- 15 Widjaja LS, Chan BP, Chen H, Ong BK, Pang YT. Variance analysis applied to a stroke pathway: how this can improve efficiency of healthcare delivery. *Ann Acad Med Singapore* 2002;312:425–30
- 16 Healy WL, Ayers ME, Iorio R, Patch DA, Appleby D, Pfeifer BA. Impact of a clinical pathway and implant standardization on total hip arthroplasty: a clinical and economic study of short-term patient outcome. *J Arthroplasty* 1998;13:266–76
- 17 Nolan T, Resar R, Haraden C, Griffin FA. *Improving the Reliability of Health Care*. 2004. Boston, Institute for Healthcare Improvement. IHI Innovation Series white paper. Cambridge, MA: Institute for Healthcare Improvement, 2004. See <http://www.ihl.org/IHI/Results/WhitePapers/ImprovingtheReliabilityofHealthCare.htm> (last checked 8 March 2011)
- 18 Goldmann D. Five puzzle pieces, ten cautionary notes. *Int J Care Pathways* 2010;14:33–5
- 19 Vanhaecht K, Panella M, van Zelm R, Sermeus W. Is there a future for pathways? Five pieces of the puzzle. *J Integr Care Pathways* 2009;13:82–6
- 20 Fone D, Hollinghurst S, Temple M, et al. Systematic review of the use and value of computer simulation modelling in population health and health care delivery. *J Public Health Med* 2003;25:325–35
- 21 Jun JL, Jacobson SH, Swisher JR. Application of discrete-event simulation in health care clinics. *J Opl Res Soc* 1999;50:109–23
- 22 Davies R, Davies HTO. Modelling patient flows and resource provision in health systems. *Omega* 1994;22:123–31
- 23 Fletcher A, Halsall D, Huxham S, Worthington D. The DH Accident and Emergency Department model: a national generic model used locally. *J Opl Res Soc* 2007;58:1554–62
- 24 Gunal MM, Pidd M. Understanding accident and emergency department performance using simulation. In: Perrone LF, Wieland FP, Liu J, Lawson BG, Nicol DM, Fujimoto RM, eds. Proceedings of the 2006 Winter Simulation Conference. Monterey, CA. IEEE; Piscataway, NY, 2006;vol. 1–5:446–52
- 25 Gunal MM, Pidd M. Understanding target-driven action in emergency department performance using simulation. *Emerg Med J* 2009;26:724–7
- 26 Bowers J, Ghattas M, Mould G. Success and failure in the simulation of an accident and emergency department. *J Simulat* 2009;3:171–8
- 27 van der Meer RB, Rymaszewski LA, Findlay H, Curran J. Using OR to support the development of an integrated musculo-skeletal service. *J Opl Res Soc* 2005;56:162–72
- 28 Department of Health. The NHS Plan: a plan for investment, a plan for reform, 2000. See http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_4002960 (last checked 8 March 2011)
- 29 Bell D, McNaney N, Jones M. Improving health care through redesign. *Br Med J* 2006;332:1286–7
- 30 Scottish Executive. An introduction to the unscheduled care collaborative programme. NHS Scotland, 2005. See <http://www.scotland.gov.uk/Resource/Doc/141079/0034895.pdf> (last checked 8 March 2011)
- 31 Locock L. Healthcare redesign: meaning, origins and application. *Qual Saf Health Care* 2003;12:53–7
- 32 Newell S, Edelman L, Scarbrough H. Best practice development and transfer in the NHS: the importance of process as well as product knowledge. *Healthcare Serv Manag Rev* 2003;16:1–12
- 33 Womack JP, Jones DT. *Lean Solutions*. New York: Simon and Schuster, 2005
- 34 KTP Centre. NHS fife applying process mapping and modelling tools to benefit healthcare services, 2009. See http://www.ktpcentre.com/linkedDocs/caseStudyDocs/KTP_NHS_Fife_0573.pdf (last checked 11 May 2011)
- 35 E Health Insider. Uni-NHS link up creates mapping tools, 2008. See <http://www.ehi.co.uk/news/ehi/4314> (last checked 11 May 2011)
- 36 The Chartered institute for IT. Collaboration helps enhance unscheduled care services. *Health Informatics Now* 2008;3:8–9. See <http://www.bcs.org/content/conWebDoc/23346> (last checked 11 May 2011)

QUERY FORM

Royal Society of Medicine

Journal Title: **IJCP**

Article No: **11-003**

AUTHOR: The following queries have arisen during the editing of your manuscript. Please answer the queries by making the requisite corrections at the appropriate positions in the text.

Query No.	Nature of Query	Author's Response
Q1	Ref [1] and [2] seem to be same, hence we have changed Ref [2] as [1] and renumbered the subsequent references. Please check.	
Q2	Please provide the page range for reference 7.	
Q3	Please provide the place of publication for reference 10.	
Q4	Please provide the expansion for SAS and SHO in Figure 3.	