A Web-based System to Monitor and Predict Healthcare Activity

Helen Brown

School of Informatics, University of Edinburgh, 1 Buccleuch Place, Edinburgh, EH8 9LW, UK Email: helen.brown@ed.ac.uk

Abstract. The UK National Health Service is subject to variation in demand for medical services, particularly during the winter. Such variations can cause major problems for the management of services to patients. This paper describes System Watch, a real-time system to assist with healthcare planning in NHS Scotland.

1. Introduction

'System Watch' monitors and predicts health service activity in real-time across Scotland via a web-based interface. Real-time information is available on: hospital emergency activity (subdivided into medical and surgical specialties), rates of infectious illness, and on ambulance emergency call-outs. Predictions are provided of numbers of emergency admissions and of bed occupancy. In addition to producing information on activity, System Watch also identifies vulnerable groups of patients admitted to hospital for whom intervention may be beneficial, for example repeated emergency admissions in elderly patients. Details of such patients are sent automatically to a hospital clinician who assesses whether the patient's care can be managed differently to help prevent future re-admissions. Information on the website is updated immediately in response to new data and data may be submitted as frequently as a user requires.

2. User Consultation

System Watch was designed following consultation with potential users and other groups with an interest in monitoring healthcare activity and identifying patients with particular health attributes. Groups consulted included: Ayrshire and Arran Health Board who expressed a particular interest in the project during its early stages and agreed to pilot its use, the Scottish Centre for Infection and Environmental Health (SCIEH), the Performance Management Division of the Scottish Executive Health Department (SEHD), NHS24 (Scottish out of hours telephone service) and the Met Office who had started a project with similar aims to System Watch in England [1].

Discussions with these groups established that there was a role for a system bringing together real time data from several areas of the health service. The groups agreed to collaborate on the development of System Watch and where appropriate to make data available.

3. Data

A wide range of potential data sources were considered relating to: the acute sector, primary care, social services, prescriptions, local monitoring systems, weather and air pollution. Ideal sources of data were those that were available both historically, to allow predictive modeling, and also in real-time. (The term 'real-time' is used here to mean up-to-date rather than 'as soon as recorded', i.e. there is not a continuous feed of data.) Obtaining real-time data was often a limitation and several data sources that may otherwise have been useful could not be included. Table 1 summarizes the data that were eventually made available to the project and each source of data considered is described below.

Table 1. Project Data

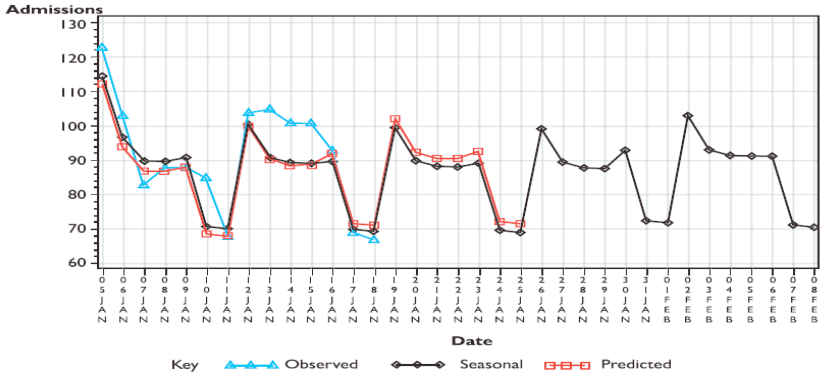
Data	**Extent of Historical Data**	**'Real-Time' Availability**	**Used by System Watch?**
Hospital admissions	1981-2002	Individual records sent weekly	Yes
'Flu rates	1992-date	Weekly by health board	Yes
NHS24	Dependent on area - earliest from 2003	Individual records sent weekly	Yes
999 call-outs	1999-date	Weekly call-out frequencies by health board	Yes
Local monitoring information		Weekly updates of local monitoring information for some health boards	Yes
Weather	1981- date by health board	Available but not set up	No
Air Pollution	Earliest 1993 Dependent on area	Available but not set up	No

4. Predicting Activity

Poisson regression models have been used to model daily frequencies of admission and bed numbers [6]. Two types of prediction are produced. Model 1 is constructed using historical data from 1981 but weighted more heavily towards recent years. It fits week of the year (calculated from 1st January), day of the week and public holidays. No account is taken of real-time information and the predictions can be calculated for any time into the future. Model 2 includes the same factors as Model 1 and additionally real-time information on hospital admissions and rates of flu. This model predicts daily activity for three weeks ahead and is updated each time new data are received. Separate models were fitted for each of the 12 mainland health boards because patterns varied between areas and no advantage was gained from modeling all health boards in a single model. Hospital predictions were based on scaled down health board models because local decisions (e.g. a ward closure) could not be reflected in the model. All models were refitted regularly to take into account the latest additions to the historical dataset of hospital admissions. Results obtained from the models were found to be sufficiently accurate to be used in the bed management process [7].

Figure 1 is an example graph showing daily numbers of admissions to Edinburgh Royal Infirmary along with predictions. The triangular line shows observed bed occupancy figures, the diamond line is fitted using Model 1 and is referred to as a 'Seasonal' prediction giving a prediction for an indefinite period ahead, and the square line is fitted using Model 2 and gives short term predictions for three weeks ahead taking into account real-time data. Past predictions are also included to give users an idea of their expected accuracy. Each graph is accompanied by a table showing the values plotted with 95% confidence intervals for predictions.

Graphs of weekly totals, routine admissions, by specialty type and for individual hospitals are also available. In a typical health board with four hospitals 360 graphs would be updated each time new data are received. Flu rates, ambulance emergency call-outs and NHS 24 symptom frequencies are also displayed via separate links, although predictions are not yet provided for these statistics.



[**Figure 1.** Example graph from website showing daily admissions in Edinburgh Royal Infirmary]

5. Implementation

The information generated is made available via a web-based interface to give easy and immediate access to all users. It has been designed so that updates can be carried out at any time in response to new data being received. This gives control to users over how frequently information is updated for their area, for example during a pressure period it is likely that a hospital will choose to send data more frequently.

Providing information in real-time is a major feature of System Watch and it is important that the update process functions reliably and that any problems can be quickly rectified. Problems so far have included: errors with transferring data, server downtime, computer hardware problems, downtime of web servers, FTP and email problems.

6. Generating Information on Individual Patients

So far the role of System Watch as a planning aid to monitor and predict activity has been described. However, the availability of real-time patient-level data also allows information to be generated on individual patients. Vulnerable groups of patients can be identified (e.g. those experiencing multiple admissions), up-to-date patient histories can be requested by drawing from historical patient record databases, and predictions of the risk of various patient 'events' can be formed (e.g. risk following a procedure, risk of becoming repeatedly admitted to hospital, probability of requiring a procedure in patients referred to a clinic, probably of not attending a clinic appointment). Such knowledge can aid clinicians and other healthcare professionals in making decisions about an individual patient's care. One example is the Evercare model of care for at-risk older people used in the US and currently piloted in the UK [8,9] to coordinate care in community-based settings and in nursing homes.

A scheme to identify elderly patients who are repeatedly admitted to hospital has been set up within System Watch. Details of any patient aged over 80 admitted to hospital more than three times in a year are automatically emailed to a hospital clinician. The patients are then reviewed and discussed with the patient's GP who, if necessary, makes changes to their care. Although this information could be obtained manually from hospital notes, it is not routine practice for clinicians to check patients' admission histories. Three health boards are participating in a pilot study using this approach [10]. There is also the potential to identify other groups of patients, for example identifying repeated admissions for self harm or in young children.

A feature has been built into System Watch to allow users to request details of a patient's history of admissions to Scottish hospitals. Patients are identified by either their hospital case reference number or their Scottish community health index (CHI) number, and their history can be made available immediately to hospital staff via a secure web file transfer system. However, this feature has yet to be implemented as patient confidentiality issues must be considered.

7. Discussion

System Watch has demonstrated the feasibility of monitoring and predicting activity in real-time, and to derive, process and feed back information on individual patients. There are however several ways in which its scope can be extended: making more real-time data available and with a greater frequency, improving the accuracy of predictions, and by generating more diverse information on individual patients.

During the next few years it is expected that real-time information from electronic GP systems, results of laboratory tests, details of prescriptions received, out-patient clinic and accident and emergency attendances will become available to System Watch. At present the project relies on the co-operation of data providers to carry out manual extracts of data and analysts to initiate updates upon its receipt. An automated process to both extract and send data on a daily basis and to update the website is planned. This would reduce errors in the data extraction and update process and would lead to a more up-to-date system.

Historical records are maintained at ISD covering many areas of healthcare (e.g. hospital out-patient clinic attendances, birth, maternity, cancer, mental health, genetic abnormalities, etc) and provide a rich source data on patients. Interfaces are planned to access this information automatically on request. The availability of historical information combined with real-time information could form a basis for an integrated care record.

Vulnerable groups of patients are at present identified to hospital clinicians by email. However, in some situations it may be more appropriate to use other means, such as a mobile device. Such devices could also be used to request and receive patient information during consultations where there is no computer access, for example during home visits or by ambulance staff. It is also possible to arrange for a chosen patient contact to be automatically informed by email or mobile phone when the patient is admitted to hospital.

Forming predictions for individual patients is an area ripe for further development in healthcare. One example is described by Oniscu et al. [12] where survival of patients listed for renal transplant is predicted based on their co-morbidity and whether or not they receive a transplant. Other potential applications are: risk following a procedure, risk of becoming repeatedly admitted to hospital, probability of requiring a procedure in patients referred to a clinic, probably of not attending for an appointment, risk of abuse in children. Predictions can be generated automatically and flags provided if risk for a patient exceeds a particular level. However, such predictive approaches need to be constructed in consultation with clinicians to ensure that they have a practical use.

When making patient-level information available, patient confidentiality is an important consideration and procedures for obtaining the required permissions need to be put in place. Correct linkage of records is also important. This can be achieved with a high level of accuracy when the CHI number (Community Health Index) is attached to a record. There is currently an initiative in Scotland to attach the CHI number to all electronic medical records and encourage its use.

Readers with access to NHSNet can access the website at http://www.show.scot.nhs.uk/systemwatch using login: system and password: watch.

References

1. Forecasting the Nation's Health: A summary by the Met Office. Met Office publication, (2002).
2. http://www.metoffice.com/health/nationhealth.html
3. TIS Available at www.informatics.nhs.uk/cgi-bin/item.cgi?category_cs=795, (2003).
4. Clarke K, Hartswood M, Procter R, Rouncefield M, Slack R "Minus nine beds": Some Practical Problems of Integrating and Interpreting Information Technology in a Hospital Trust. In Bryant J ed. Proceedings of the BCS Conference on Healthcare Computing, 18-20 March 2002, Harrogate 219-25.
5. Richardson K 'Bed Management in Glasgow' Internal document, Greater Glasgow Health Board, (2004).
6. McCullagh P and Nelder JA Generalized Linear Models, Chapman and Hall, 2nd edition, London (1989)
7. Brown, H. A web-based system to monitor and predict healthcare activity, Health Informatics Journal, Vol 11(1): 63-79, (2005).
8. Ever Ready. A model of care for older people. Health Services Journal, 26-27, 2004.
9. Smith R Improving the management of disease, BMJ, 327, (2003).
10. Myers E, Brown H, Conway M, Gordon C, Kendrick S, Plummer S, Rhind G 'Recurrent admissions collaborative group', presented at Centre for Change and Innovation Showcase Conference, (2004).
11. SCI. http://www.show.scot.nhs.uk/sci/, (2002).
12. Oniscu G, and Brown H 'A model to predict patient survival in the renal transplant assessment clinic', in preparation, (2005).