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Compliance with national guidelines for stroke in radiology

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ABSTRACT

Stroke is a medical emergency, and if patient outcomes are to be optimised there should be no delays in accessing treatment. This project focuses on the application of Operational Research methodology to investigate how a hospital can comply with the revised computerised tomography (CT) scanning guidelines for stroke. Such guidelines, released by the Royal College of Physicians recommend a 50% reduction in time from hospital admission to report of a CT head scan to just 12 hours. The results of statistical analyses of historical data were used to populate a discrete event simulation model of patient flow through the CT scanning unit. The model was then used to explore a number of operational modifications to the CT scanning system through a series of scenario analyses. The results of this investigation presented evidence of a number of strategies to support operational improvements in relation to revised stroke guidelines.

1. Introduction

Stroke is a serious medical illness with a mortality rate higher than most forms of cancer (Davis et al. [1]). Each year, approximately 15 million people worldwide and 152,000 people in the United Kingdom suffer a stroke (Townsend et al. [2]). Recent publications from the British Heart Foundation report that during 2010, stroke was the fourth largest cause of mortality in the UK (Townsend et al. [2]). If outcomes for stroke patients are to be optimised, accessing treatment should not be delayed (Jauch et al. [3]).

Previously, guidelines provided by the Royal College of Physicians (RCP) have suggested that a computerised tomography (CT) brain-imaging scan has to be delivered within a maximum of 24 h of hospital admission for all patients with symptoms of stroke. However, the latest clinical guidelines released in December 2012 (RCP [4]) have recommended a 50% reduction in the aforementioned time window to just 12 h. The main aim of this paper is to investigate the effect on various aspects of the system and therefore evaluate the likely benefit, or otherwise, in relation to specific targets for stroke. This has been achieved by incorporating various modifications to a simulation model that models current CT scanning activity. The key outputs of interest were the overall time in the system for stroke patients and the percentage compliance under guideline time frames. The model predicted that by necessitating that all routine stroke patients are seen for a CT head scan on the day it is requested, an improvement in compliance with revised 12 h stroke guidelines could be achieved. Moreover, additional benefits were projected when routine stroke patients were re-prioritised further, ahead of patients with non-urgent, unscheduled CT scan requests.

This project was conducted within the Radiology Department of the Royal Gwent Hospital, Newport, Aneurin Bevan University Health Board (ABUHB). ABUHB is one of the seven local health boards in Wales which serves an estimated population of over 639,000, approximately 21% of the total Welsh population.

The existing Operational Research (OR) literature surrounding planning for CT scanning processes focuses mainly on scheduling (Boland [5]; Patrick and Puterman [6]; Vermeulen et al. [7]; Van Lent et al. [8]). Discrete event simulation is employed as the most appropriate modelling technique for the identified decision support problem. Several studies have been conducted where use of a simulation model facilitated improvement in the overall acute stroke pathway (Bayer et al. [9], Churilov and Donnan [10], Churilov et al. [11], Cordeaux et al. [12], Lahr et al. [13,14], Mar et al. [15], Monks et al. [16,17] and Pitt et al. [18]); however there is a distinct lack of research concerning the specific use of discrete event simulation in the CT scanning environment. The main contribution of this paper to the existing literature is a case-study applied to the CT unit. It is hoped that this area will greatly benefit from this application.

The paper is organised as follows. In Section 2 statistical analysis of CT request data is described. In Section 3 the model is introduced, which is then validated and verified in Section 4. In Section 5 results from 'what if...?' scenarios are discussed before summarising the findings in Section 6.

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Table 1
CT scan request categories.

Patient origin	Pathology	Urgency of scan	Description	Request category
RGH Ward	Thrombolysis	Immediate	Ward patients who qualify for an assessment of their suitability for thrombolysis treatment	Inpatient Thrombolysis
	Routine Stroke	By the end of the day following the request	Ward patients with suspected stroke for which thrombolysis treatment is known not to be appropriate	Inpatient Routine Stroke
	Not Stroke	Immediate	Ward patients who require a CT scan immediately	Inpatient Immediate
	Not Stroke	By the end of the day the request is made	Ward patients who require a CT scan on the day of request	Inpatient Today
	Not Stroke	By the end of the day following the request	Ward patients who require a CT scan by the end of the day following its request	Inpatient Tomorrow
A&E	Thrombolysis	Immediate	A&E patients who qualify for assessment of their suitability for thrombolysis treatment	A&E Thrombolysis
	Routine Stroke	By the end of the day the request is made	A&E patients with suspected stroke for which thrombolysis treatment is known not to be appropriate	A&E Routine Stroke
	Not Stroke	Immediate	A&E patients who require a CT scan immediately	A&E Immediate
	Not Stroke	By the end of the day the request is made	A&E patients who require a CT scan on the day of request	A&E Today
Outpatient	Not Stroke	Must be seen on day of appointment	GP referrals with pre-scheduled appointments	Outpatient

2. Statistical analysis of CT request data

The data set was extracted from the radiology information system, RadIS II, which contains a fairly complete record of CT activity at the RGH. An additional data set contains all A&E activity. Both data sets relate to the same two-year time frame, from the 1st June 2011 to 31st May 2013.

CT scans are requested at different levels of urgency for a number of different patient types. This information is summarised in Table 1. A total of 1,869 CT scan requests were stroke related and from these, 295 necessary to assess whether thrombolysis treatment was appropriate. Thrombolysis is a treatment to dissolve blood clots by pharmacological means. It works by injecting clot-busting drug into blood vessels. This mode of treatment is only suitable for victims of ischaemic stroke and must be delivered within four and a half hours of symptom onset (Emberson et al. [19]).

Monthly, weekly and hourly time-dependency analysis was completed in an attempt to establish patterns and trends in the frequency of unscheduled CT scans requested with respect to time. Kruskal Wallis analysis was applied to investigate whether the frequency of CT scan requests differed significantly across month of the year and day of the week. Pairwise Wilcoxon testing has been applied to group patient categories by weekday. Classification and Regression Tree (CART) analysis was applied to partition a full data set into smaller, homogeneous subsets for each weekday grouping and for each request category.

For each request according to month of the year, a p-value is reported: A&E Thrombolysis (p-value $=$ 0.7570), A&E Routine Stroke (p-value $=$ 0.5201), A&E Immediate (p-value $=$ 0.999), A&E Today (p-value $=$ 0.722), Inpatient Thrombolysis (p-value $=$ 0.366), Inpatient Routine Stroke (p-value $=$ 0.955), Inpatient Immediate (p-value $=$ 0.966), Inpatient Today (p-value $=$ 0.463) and Inpatient Tomorrow (p-value $=$ 0.853). P-value greater than 0.05 for each category suggests no seasonal trends.

The frequency of CT requests was not shown to differ significantly across day of the week for the Inpatient Thrombolysis (p-value $=$ 0.082), Inpatient Immediate (p-value $=$ 0.061), A&E Thrombolysis (p-value $=$ 0.074) and A&E Routine Stroke (p-value $=$ 0.077) groups. For each of the remaining categories, an observed p-value < 0.05 evidenced that frequency of CT scan requests placed did in fact differ significantly according to day of the week. The following weekday groupings were proposed:

- A&E Today, Inpatient Today and Inpatient Routine Stroke: Monday–Friday and Saturday–Sunday.
- A&E Immediate: Monday–Thursday and Friday–Sunday.
- Inpatient Tomorrow: Monday–Thursday, Friday, and Saturday–Sunday.

A summary of the results conducted for each request group and for each weekday partition is presented in Table 2. Note that for stroke patients from A&E time of request was considered as admission to A&E, not the actual request for a CT scan as the request time for this patient category was unavailable.

3. Development of a patient flow model

The CT scanning system can be conceptualised by a series of activities, queues and waiting lists. Patients arrive into the system at the request for a CT scan. Then patients either join a physical queue outside of the CT unit or are placed on a waiting list. Following the administration of a CT scan, medical images are uploaded electronically onto the database, to be reported by a team of radiologists. An DES model was produced in SIMUL8 and the CT flow diagram is presented in Fig. 1.

The first aspect of the system considered was the arrival of patients, initiated by either the request for a CT scan or admission into A&E. Recall that CT scan requests fall into 10 categories. Nine of these categories relate to unscheduled requests from inpatient wards and A&E and for all the 31 h groups described in Table 2 a negative exponential inter-arrival distribution was found as the best fit. The AIC (Akaike Information Criterion) goodness-of-fit test was used to select the most appropriate probability density functions and estimated parameters are presented in Table 2. Time check code was applied within the model to update inter-arrival distributional parameters according to hour of the day and day of the week. The arrivals of outpatients with pre-scheduled CT scans were modelled by incorporating a front end scheduling system directly within the model. The most appropriate service time distributions are presented in Table 3. A fundamental aspect of the system is the time stroke patients spend in A&E, prior to a CT scan request. In direct consideration of the CT scanning targets for stroke, this aspect of care was addressed separately for patients assessed for thrombolysis and those considered to be routine stroke.

A priority system based on existing protocols at the RGH was integrated into the model to characterise queueing conduct and the behaviour upon various waiting lists. Patients considered for thrombolysis treatment are given highest priority for CT scanning, closely followed by those with immediate requests. Patients with pre-scheduled appointments take the next priority level. Capacity constraints within the Radiology department necessitate that