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Monday 31st July

MO2.1-01 Parallel session: Simulation studies in health and care - 14:00-15:30

An agent based simulation of Hepatitis C transmission and treatment

Rudabeh Meskarian[1], Thomas Monks[1], Salim Khakoo[2], Leonie Grellier[3], Julie Parkes[2], Ryan Buchanan[2]
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Presented by Rudabeh Meskarian

Abstract

Hepatitis C virus (HCV) is a blood-borne virus that disproportionately affects people who inject drugs (PWIDs). The sharing of needles, syringes and ancillary equipment is believed to be the primary means of transmission.

Previous models of HCV transmission have typically made some assumption around individual contacts rather than consider the contact network of PWID or have lacked an empirically grounded contact network.

Here we explore HCV transmission and possible treatment strategies on empirically grounded simulated PWID contact networks based on data gathered in Isle of Wight UK. An agent based simulation model is developed in Anylogic for this purpose. The model includes information on 179 individuals and their attributes such age, gender, injecting/non-injecting social network, HCV status as well as information on behaviour such as sharing and injecting history.

The model can be used to investigate the effect of the individual social network, injecting frequency and infection rates on transmission of the infection. Four different treatment scenarios are presented including a) no treatment, b) randomly selected individual with chronic HCV, c) targeted treatment at those with largest injecting network, d) targeted treatment at those with largest social network. The scenarios are compared in terms of the chronic prevalence of HCV and incident rate of primary infection and re-infection.

MO2.1-02 Parallel session: Simulation studies in health and care - 14:00-15:30

Using bootstrapping to reflect variance in resource demand in simulation modeling of patient flow; the case of stroke treatment in Norway

Kim Rand-Hendriksen, Joe Viana, Mathias Barra, Fredrik Dahl
Akershus University Hospital

Presented by Kim Rand-Hendriksen

Abstract

An important characteristic of resource limitations and queueing is that waiting time tends to respond in a highly non-linear fashion to linear increases in demand. The ability to reflect such non-linear responses is one of the main strengths of simulation modeling over many classical statistical estimation methods. Since queuing will depend on the magnitude and duration of peaks, adequate reflection of variation in demand is crucial. In an ongoing project analyzing pathways for stroke patients in Norway, stroke incidence is modeled on historical records of from the national patient registry, using Poisson regression. The fitted regression model allows stochastic generation of patient agents with age, sex, and a geographic location in a simulation model tailored to record travel time and time to treatment in regional stroke units. The simulation is repeated a large number of times (10 000), in order to reflect variation in response to random sampling. However, we are concerned that this standard approach may underestimate actual variation in stroke incidence, as the fitted coefficients are determined by a fixed sample of patient records for which the underlying stochastic mechanisms are unknown. As an alternative, we propose to handle variation in incidence through the use of bootstrapping from the historical stroke records. 1000 random subsamples of size equivalent to the full set of records are drawn with replacement. For each subsample, a Poisson regression model is fitted, based on which the simulation model is set to run 1000 times. Thus, stochasticity is introduced both at the level of the regression model, and in the sampling from the resulting Poisson-models. Variance in travel time and time to treatment is collated overall, and compared to the standard approach. We invite a discussion of how the relative merits of these (and other) approaches to handling variance can be assessed.

MO2.1-03 Parallel session: Simulation studies in health and care - 14:00-15:30

Simulation of multi-appointment scheduling problems in hospitals

Joren Marynissen, Erik Demeulemeester
KU Leuven

Presented by Joren Marynissen

Abstract

The multi-appointment scheduling problem in hospitals focuses on patients who need multiple appointments. The goal of these problems is to create a schedule in which the patient receives the full treatment as soon as possible while keeping the hospital resources occupied. For this type of problem, we developed a new simulation package (SimInt) that is capable of testing multiple scheduling strategies and measuring the impact of these strategies on the operational processes. The package was tested using data from a cardiology department in a large university hospital. The first results of this analysis are presented and discussed during this presentation.

MO2.1-04 Parallel session: Simulation studies in health and care - 14:00-15:30

Using a combined discrete event simulation agent based model to improve drug production at the Radium Hospital, Norway

Joe Viana[1], Lise Raanes Rødøy[2], Tone Rojahn[2], Tone Breines Simonsen[1], Fredrik Dahl[1]
[1]Health Services Research Centre, [2]Sykehusapotekene

Presented by Joe Viana

Abstract

The preparation of drugs is a crucial logistical challenge for health services. Each drug has its own recipe, requiring different raw ingredients, each with potentially different shelf lives. Patients require different drug courses which follow specific protocols in terms of when the drugs are required, how much is required and how frequently.

The drug preparation facility at the Radium Hospital produces primarily chemotherapy drugs for the Radium hospital and other public and private hospitals in Oslo. The facility has invested in a robot to prepare drugs alongside pharmacists.

The pharmacy is interested in exploring the best way to allocate requests to the pharmacists and the robot given their constraints and operating procedures, subject to the following: the urgency of request, e.g. children and other more vulnerable patients such as urgent requests from outpatients, allocation of drug requests between different pharmacists and to the robot, the pick-up schedule for

completed drugs, the number of hospitals they produce drugs for, the pharmacy opening hours, the procedures and pathways, staff schedules and the robot's maintenance schedule.

A Discrete Event Simulation model has been combined with an Agent Based Model to evaluate suggested quality improvements, and evaluate specific research questions defined by the model stakeholders. Data was collected from January 2016 to May 2017. The data collected was a mixture of manually collected observations and data available from various hospital systems. The model will be validated against historical data and used to evaluate the effectiveness of alternative procedures, prior to implementation, to predict what affect these proposed changes would have on operations. The model will project forward over a 3-year time horizon.

Future work includes: designing mechanism(s) for collecting data for future research and quality control studies. To evaluate the accuracy of the model's predictions after changes have been implemented.

MO2.2-01 Parallel session: Diagnostic and screening management - 14:00-15:30

A review of demand and capacity for diagnostic services in Wessex

Richard Guerrero-Ludueña
University of Southampton

Presented by Richard Guerrero-Ludueña

Abstract

NHS hospital across are failing to meet the 62-day cancer standard time between a GP referral of a patient to a specialist and the beginning of any proposed cancer treatment. Performance against the national waiting times standards are considered an indicator of the quality of cancer diagnosis, treatment and care an NHS organisation deliver, and has been identified as a top priority at the national, regional and local level. The most challenging action identified by the NHS hospitals is demand and capacity modelling of the cancer pathways, specifically the diagnostics element.

This work aims to identify and address areas of improvement required across the 62-day cancer pathways. The project focusses on cancer diagnostic services for 11 cancers within 5 cancer specialities across 8 NHS hospital trusts in England.

We will share the mixed qualitative-simulation method approach used in this work. Interviews were conducted with cancer services representatives to collect data on their views on key issues at each provider and constraints on existing capacity. A review of national guidance on cancer diagnosis and waiting times, and analysis of publicly available cancer waiting time and diagnostic activity data was

carried out. Data provided by hospitals on activity and current capacity was collected. Information previously explained was used to develop a conceptual model of the current cancer diagnostic system. Finally, a simulation model was used to identify resource constraints and to evaluate potential service redesigns.

MO2.2-02 Parallel session: Diagnostic and screening management - 14:00-15:30

A hybrid approach using forecasting and discrete-event simulation for modelling endoscopy services in healthcare

Alison Harper, Nav Mustafee
University of Exeter

Presented by Alison Harper

Abstract

Efficient healthcare delivery relies on the coordination of demand and capacity, but forecasting studies often predict demand without regard for future capacity constraints. Likewise, capacity planning requires strategic decision-making, therefore planning tools should allow decision-makers to examine the consequences of changing demand and likely capacities required over time. Applications of hybrid simulation methodologies claim to increase insights into a problem area, and are an important research area within the field of modelling and simulation. The aim of the study is to evaluate a hybrid methodology using discrete-event simulation and demand forecasting in the healthcare domain. A case-study of Endoscopy services in one Clinical Commissioning Group in the UK investigates the application of official population projections with historical hospital demand data to forecast demand for a healthcare diagnostic service at the local level. The resultant forecasts, for three procedures over five years, are then used as inputs into a DES model in a hybrid systems modelling approach. This provides plausible demand forecasts for future capacity planning and resource allocation, and contributes to debates on the value of hybrid approaches.

MO2.2-03 Parallel session: Diagnostic and screening management - 14:00-15:30

Assessing the impact of different diabetic retinopathy screening policies using agent-based modelling

Steffen Bayer[1], Aastha Goel[2], Ecosse Lamoureux[3], David Matchar[2]
[1]University of Southampton, [2]Duke-NUS Medical School Singapore, [3]Singapore Eye Research Institute

Presented by Steffen Bayer

Abstract

While diabetes affects the eye in many ways including increased risk of glaucoma and cataract, diabetic retinopathy (DR) is the most common and serious ocular complication of diabetes. Since diabetic retinopathy remains a major cause of preventable loss of vision, regular screening of patients with diabetes has been widely advocated. While current guidelines typically recommend a yearlong interval between consecutive screenings for diabetic patients with no DR, there are a number of studies, which provide evidence that a longer screening interval for diabetics with no DR or a non-referable DR is safe, especially when risk factors are controlled.

In this paper, we report on an agent-based simulation model that allows examining the effect of prolonging screening intervals for lower risk-patients on disease progression and vision loss. We also consider the number of screenings, ophthalmologist consultations and ocular treatments (include laser photocoagulation, anti-VGEF and vitrectomy) under different screening policies.

The model has been developed using Anylogic simulation software. The Diabetes population is modelled as agents and each agent is assigned their respective baseline characteristics including demographic data as well as disease specific information (duration of diabetes, body mass index, hemoglobin A1c, systolic blood pressure, total cholesterol, baseline level of retinopathy and baseline presence or absence of clinically significant macular edema). Statecharts are used to model both the natural incidence and progression of diabetic retinopathy as well as diabetic macular edema in patients and screening and treatment interventions.

The work demonstrates the suitability of agent-based modelling to take into account individual disease processes when assessing the population level impact of health care policies and guidelines.

MO2.2-04 Parallel session: Diagnostic and screening management - 14:00-15:30

Modelling the Irish radiology service – a clinical perspective

Mary Conlon, Dr Owen Molloy
National University of Ireland, Galway

Presented by Mary Conlon

Abstract

Radiographers combine technical excellence, clinical decision making and patient care to produce diagnostic images that contribute to the management of the patient. This article details the experience of one radiographer and department as they model the delivery of CT (Computed Tomography) services in Portiuncula University Hospital (PUH), Galway. Ireland has a growing and ageing population, demands for CT and diagnostic imaging services are increasing and resources are finite.

Efforts must be made to optimise the utilisation of staff and equipment resources. Staff working on the clinical coal front, have a part to play in finding solutions. State of the art equipment and highly qualified staff are underutilised in some departments while over utilised in others. A generic DES model has been created in collaboration with staff at PUH.

A DES (discrete event simulation) model of the department is created to allow greater understanding of queues and processes. The model is based on a study of radiology data from 2014 and 2015 of individual patient arrival times. This paper describes ongoing research investigating how DES can facilitate a change of work practices allowing for better utilisation of CT scanners, radiographers and radiologists and ultimately allow for cost savings. The challenges associated with modelling for the non-programming clinical person are considered and an introduction to modelling for Radiographers provided.

Radiography is a changing profession; modelling and simulation can allow us to plan the future of radiology services in Ireland. In these new models, we need to ensure protected time for the profession, continuous professional development, role expansion and crucially patient care.

MO2.3-01 Parallel session: Workforce scheduling and allocation - 14:00-15:30

Optimal time allocation of an orthopedic surgeon

Eline Tsai
University of Twente

Presented by Eline Tsai

Abstract

In the Netherlands, an orthopedic surgeon can see patients either at the outpatient department (OD) or the operating room (OR). When patients arrive at the hospital they visit the OD for an initial consult first, after which they can either be dismissed or enter the OR queue. Per year, the amount of OR and OD sessions that can be distributed over the year is budgeted per surgeon. Hospitals aim at minimizing the waiting time of the patients while considering an efficient use of the ORs. The distribution of these sessions over the year influences the OR queue length. The optimal OR queue length is a tradeoff between the waiting time of the patients in the OR queue and the amount of unused OR time.
To analyze this system, we first model the orthopedic chain as a Markov chain. Then stochastic dynamic programming is used to determine the optimal OR queue length buffer and the optimal distribution of the OD and OR sessions of a surgeon per week throughout the year. Experiments are conducted using a case study of Sint Maartenskliniek in Nijmegen, The Netherlands, which shows the practical applicability of this approach.

MO2.3-02 Parallel session: Workforce scheduling and allocation - 14:00-15:30

Preference-based staff scheduling at hospitals

Kjartan Kastet Klyve, Henrik Andersson, Marielle Christiansen, Anders Gullhav
Norwegian University of Science and Technology

Presented by Kjartan Kastet Klyve

Abstract

Twice every year a work schedule must be created at Maternity Ward West (MWW) at St. Olavs Hospital. The planning problem involves allocating work shifts and off-days to 69 employees for a planning horizon of 27 weeks. Demand must be covered for health workers of different skill categories, while respecting numerous scheduling rules. The current manual planning process resembles typical self-scheduling, and is characterized by weeks of planning with all employees being included in the process through a three week period of negotiating and swapping shifts. Employees at Norwegian hospitals have significant influence on the scheduling process, and

respecting their preferences and ensuring perceived fairness is a decisive part of the scheduling problem.

By formulating a general mathematical integer linear programming model corresponding to the problem at MWW and developing a decision support tool using a commercial optimization software, we have created a complete schedule for a planning period at the ward. The level of details in the model is very high, as we have programmed all the preferences and practises that the ward manager at MWW was able to explicitly formulate.

We ran the model for a real-life planning period of 27 weeks in parallel with a schedule being created manually at MWW, in order to compare the two schedules. The results show that it is possible to respect significantly more of the employees' preferences using the scheduling model, while simplifying the planning process greatly. Furthermore, the manually created schedule does in some cases fail to respect all rules and regulations, as the employees who negotiate the schedules in some cases break the rules unintentionally. The schedule created by the model is also considered fairer than the manually created one by the ward manager, who prefers the model's schedule, due to its lack of bias in allocation of shifts.

MO2.3-03 Parallel session: Workforce scheduling and allocation - 14:00-15:30

Physician staffing and scheduling in an emergency department using optimization under uncertainty

Janaina Marchesi, Silvio Hamacher
PUC-Rio

Presented by Janaina Marchesi

Abstract

A challenging problem for Emergency Department (ED) managers is to determine the best mix and level of medical staff to promptly attend patients. This paper present two mathematical models for the Physician Scheduling Problem (PSP). First we propose a two-stage stochastic model with fixed recourse aiming to minimize the total number of patients in queue. Second we offer a min–max model that aims to minimize the largest queue. The models solve in an integrated manner the staffing and scheduling phases and consider uncertainty in ED´s demand to align physician scheduling with patient's arrivals. Moreover, the proposed models are able to facilitate and speed up the work of elaborating physician scheduling, guaranteeing all schedule requirements and contractual agreements. A case study with real data from an ED of a Brazilian hospital was carried out, considering over 80,000 medical encounters in a 16 months period. The proposed models allowed to better align service capacity and demand, since they consider the uncertainty in the arrival

of patients improving queue indicators. To estimate the benefits obtained using the models against the current situation, we rely on a simulation procedure to compare the schedules in terms of idle capacity and queue. The stochastic model decreases the total number of patients in queue for the period analyzed from 2,379 to 90. The maximum number of patients in queue was reduced from 77 to 6 patients with the min-max model.

MO2.3-04 Parallel session: Workforce scheduling and allocation - 14:00-15:30

An optimization model for staff scheduling at a Portuguese EMS

Joana N Rosa[1], Hendrik Vermuyten[2], Inês Marques[1], Ana Barbosa-Póvoa[1]
[1]CEG-IST, Instituto Superior Técnico, Universidade de Lisboa, [2]CEG-IST, Instituto Superior Técnico, Universidade de Lisboa and KULeuven,

Presented by Inês Marques

Abstract

In emergency medical services, personnel scheduling is extremely important for three main reasons. Firstly, meeting the required supply of qualified staff for each shift directly impacts the quality of the patients care. Secondly, frequent change of staff members shift patterns negatively impacts on their alertness, also known as 'jet fatigue'. Third, undesirable schedules are often cited as one of the reason for employees' unsatisfaction. In this paper a real-life personnel scheduling problem for the Instituto Nacional de Emergência Médica (INEM) is investigated. INEM consists of a dispatch center and ambulance provider, where resources to be schedule are subject to the same constraints. Currently, schedules are created manually in a three-phased approach, first on the individual level, then on the team level, and finally on the organisational level. This paper aims to develop an automated scheduling tool that can take into account simultaneously a wide range of constraints and preferences and significantly reduce the time spent on building the timetables, while simultaneously improving the schedule quality and employees satisfaction.

MO3.1-01 Parallel session: Geography, networks and resource allocation - 16:00-17:30

Measuring inequalities in the geographic distribution of multiple health resources

Martin Dlouhy
University of Economics Prague

Presented by Martin Dlouhy

Abstract

The existence of significant geographic differences in health resources, health expenditures, and the utilization of health services have been documented by many studies from various countries. Inequalities in the geographic allocation of health resources represent an important health policy problem even in the developed countries.

Let us assume that the objective is to measure inequality in geographical distribution in case of multiple health resources. By using traditional measures (Gini Coefficient, Robin Hood Index, decile ratios) separately for each health resource, the possibility of substitution between resources is missed. For example, the health resources as doctors and nurses are, at least to some extent, substitutes. Hence the region with fewer doctors may compensate such disadvantage by larger number of nurses. In order to cope with cases with multiple health resources, one can use multiple criteria decision making and set the nationwide resource weights. More flexible approaches to estimate resource substitution are econometric modelling and DEA. In this paper, we will concentrate on DEA.

Data envelopment analysis (DEA) is a method based on the mathematical programming and was originally developed to construct production frontier and evaluate technical efficiency of production units. The objective of this study is to show how a DEA model is able to measure the inequality in case of multiple health resources. For illustrative purposes, the Eurostat data on the NUTS 2 regions were used. The inequality measure based on DEA was calculated for selected countries.

MO3.1-02 Parallel session: Geography, networks and resource allocation - 16:00-17:30

Designing a regional-based healthcare logistics network

Ana Maria Anaya-Arenas[1], Valérie Bélanger[2], Angel Ruiz[1]
[1]Université Laval, [2]HEC Montréal

Presented by Valérie Bélanger

Abstract

In a healthcare network, several types of material need to be transported between the different healthcare facilities to provide the right service to the patients. On the one hand, medical items, including medications and sterilized equipment, are delivered to the healthcare facilities. On the other hand, some products such as biomedical samples and dirty laundry need to be collected from healthcare facilities or patients' home to be analyzed, cleaned, sterilized or disposed. Each product presents different characteristics, one of the most important being the biomedical sample short lifetime.

Recently, the Province of Quebec, in Canada, has undergone an important reorganization of the healthcare and social services network, creating regional clusters. This reorganization yield significant logistics challenges, but also offer the opportunity to optimise the network. The studied problem is inspired by the context of a regional organisation, which serves 422,000 inhabitants on a 17,500 km^2 territory. This organisation operates 108 healthcare facilities (such as local healthcare centres and nursing homes, all noted as HCFs) and several logistics centres, including laundry facilities, consolidation centers, and medical supply depots.

In this study, we focus on the design of a network to ensure an efficient flow of material from their origin to their destination. The network consists of two echelons: 1) healthcare facilities and 2) logistics centres. This study aims to propose a modelling framework to support the regional network design, including the location of consolidation centres (or hubs), the allocation of HCFs to hubs, as well as transportation decisions between all of them. Given the specific characteristics of the material to be transported, one of the main challenges comes from the synchronization of the activities from one echelon to the other. Several network structures and modelling approaches are explored and discussed based on the needs and the data from our partner.

MO3.1-03 Parallel session: Geography, networks and resource allocation - 16:00-17:30

Optimization approaches to the ambulance dispatching and relocation problem

Ana Sofia Carvalho[1], Maria Eugénia Captivo[1], Inês Marques[2]
[1]CMAF-CIO Universidade de Lisboa, [2]CEG-IST, Instituto Superior Técnico, Universidade de Lisboa

Presented by Ana Sofia Carvalho

Abstract

Emergency Medical Service (EMS) is one of the most important health care services. It plays an important role in the daily life of many people since its main goal is to provide basic medical care for any person in an emergency situation. EMS has to manage and mobilize several resources, e.g. high specialized equipment and highly skilled staff.

Operations researchers identified the EMS systems as a vibrant field of study since the mid 1970's. Both the great growth in computer technology and the modeling and algorithmic sophistication contributed to improve the first deterministic models proposed in this field. Through the years, approaches which include exact methods, heuristic algorithms and simulation have been developed to include real life features. The main challenge is the huge level of uncertainty involved namely in the emergencies' demand and severity, ambulances' availability, population density and traffic conditions.

In the EMS context, the decision-making process is very important as decisions made are usually closely related, having a direct impact in the service's quality. Three levels of decision can be identified: strategic, tactical and operational. This work focus on the operational level by solving the dispatching and relocation ambulance problems. The decision of which ambulance to send to each emergency is considered in the dispatching problem. The relocation problem includes two decisions focused on maximizing the system's coverage to face future emergencies: i) where to relocate ambulances that have finished the service and ii) whether additional relocations between bases are needed.

Since the importance of having an effective and efficient EMS response is an issue that concerns society, it is essential to have an optimized system. In Portugal, solving these problems has been a handmade task. This work presents optimization approaches to help managers in the decision-making process at the operational level tasks.

MO3.1-04 Parallel session: Geography, networks and resource allocation - 16:00-17:30

A geospatial analysis of the Nova Scotia emergency care network

Peter Vanberkel[1], Lauren McNamara[2]
[1]Dalhousie University, [2]Dalhousie

Presented by Peter Vanberkel

Abstract

The objective of this study is to measure how the Nova Scotian Emergency Medical System (EMS), consisting of Emergency Departments (EDs) and ambulance services, covers the population, and provide a tool to evaluate changes to the system. This study uses location-allocation models including the P-median problem (PMP), P-centre problem (PCP), maximal covering location problem (MCLP), and the location set covering problem (LSCP). Distance is measured in kilometres following the road network, and NS is divided into a grid where each square has a population and the potential to house a facility. We analyze the existing network by computing the weighted travel distance of the population to each facility, the maximum distance any person must travel, and the number of people within a specified distance from a facility. We also consider several proposed changes to the network and compute the degree of improvement expected using these metrics.

MO3.2-01 MO3.2 Parallel session: Costing and measurement - 16:00-17:30

Prediction of Patient Activation during Technology Enabled Continuity of Care Intervention

Carrie Queenan[1], Kellas Cameron[2], Alan Snell[3], Julia Smalley[4], Nitin Joglekar[2]
[1]University of South Carolina, [2]Boston University, [3]RISE Healthcare, [4]Hendricks Regional Health

Presented by Carrie Queenan

Abstract

Patients' skills, knowledge, and motivation to actively engage in their healthcare are assessed with the Patient Activation Measure (PAM) – a metric associated with positive healthcare outcomes. The literature on predicting PAM, when patient counseling is coupled with a technology enabled continuity of care intervention, is scant. This proof-of-concept study employs a two-phase framework to (i) posit a relationship between a technology enabled continuity of care intervention and enhanced patient activation; and (ii) link healthcare providers' operating decisions and patients' willingness to change with prediction of PAM. We test the framework using data from a randomized, controlled field experiment and find a relationship between technology enabled continuity of care and increased PAM. Further, the relevant PAM levels are predicted as a function of the strength of the information signals using a machine learning methodology. We show that these predictions are subject to under/over estimation biases, consistent with the behavioral concept of system neglect in signal detection theory.

MO3.2-02 Parallel session: Costing and measurement - 16:00-17:30

Segmentation of primary care patients by annual cost

Palvannan Rk
National Healthcare Group

Presented by Palvannan Rk

Abstract

Background: The aim is to segment primary care patients into groups with *distinct* and *homogeneous* annual medical *cost* using demographic and chronic disease variables. Combinatorial counting is infeasible, regression is algebraic and decision tree was seen as a good proposal, as it is visual, translatable to rules and addresses cost homogeneity within group. The annual mean cost per patient was $1.33k, with significant variation (s.d. = $5.2k).

Method: We used cross sectional patient administrative data and CHAID (IBM SPSS Modeler).

Results:

Order of variables. First 3 variables were heart failure followed by hypertension and access to government funds for help. There were 10 levels.

Prevalence and cost differentiation. The decision tree showed that low prevalence does not equate to cost differentiation. Heart failure (prevalence = 1.3%) was the top variable, while lipids (41%) was lower.

Hypertensive arms. The most important result was that we should divide the patients into hypertensive and non-hypertensive arms. The prevailing thinking was that diabetes will feature on top, but it was quite undifferentiated and appeared below. Next to hypertension, access to government help for funds featured, reinforcing that non-healthcare factors are determinants of health and cost.

Segments. Every path to a leaf node is potentially a cost homogeneous segment of patients while it could be 'rolled up' depending on purpose.

Disadvantages. The tree structure may change when data is changed, similar to change in regression coefficients, but more perceptible. And the mean cost of group is not directly comparable with the adjusted mean cost effect in the regression equation.

Conclusion: The decision tree was useful in highlighting the importance of hypertensive complications and social economic status as cost drivers and led to some rethinking in an ongoing exercise of bundle payment for patients. We complemented with standard regression.

MO3.2-03 Parallel session: Costing and measurement - 16:00-17:30

Simulation modelling and optimisation techniques in health technology assessment

Syed Salleh Abdul Rahman, Praveen Thokala
University of Sheffield

Presented by Syed Salleh Abdul Rahman

Abstract

Health technology assessment involves estimation of the costs and effects of all relevant technologies to estimate whether the new technology is cost-effective. Such analyses most commonly require the development of a mathematical model to synthesise relevant evidence from a range of sources to predict costs and health consequences associated with each technology. Typically, these models are Markov cohort models or simple decision tree models, which may be

associated with some limitations. The traditional health economic modelling techniques are not equipped to deal with differences in individual patient characteristics, interaction between patients, incorporating capacity constraints and modelling feedback loops.

There are other modelling techniques, typically found in the field of healthcare operational research (OR), such as discrete event simulation (DES), agent based simulation (ABM) and system dynamics (SD) which can help address these limitations. Furthermore, there are other techniques such as numerical optimisation methods which can help identify the best course of action rather than choosing a best option among a small number of alternatives.

Whilst these are very common in the OR community, these techniques are gaining popularity within the HTA field. This presentation will outline the principles of HTA, highlight the limitations associated with traditional HTA modelling methods and present how other modelling techniques (DES, SD and ABM) can help address these issues. Findings from a recent systematic literature review on how these techniques (DES, SD and ABM) have been used in HTA will be outlined. Furthermore, examples of simulation optimisation techniques in health care will also be presented. The presentation will conclude with highlighting the need for the OR and HTA community to work together.

MO3.2-04 Parallel session: Costing and measurement - 16:00-17:30

Portable, transparent markov modeling for medical cost-effectiveness

Gordon Hazen, Matthew Pilecki MD, MBA, James Carr, MD, Michael Markl
Northwestern University

Presented by Gordon Hazen

Abstract

Markov cohort models have become widespread as a tool for comparative effectiveness and cost-effectiveness in medicine. Although model transparency is a recognized goal in publication guidelines, complete model specification is uncommon in published applications. *StoTree* is a new and freely available Excel addin for finite-state continuous-time Markov modeling that facilitates transparency by allowing the user to specify a model in a graphical, decomposed form, under which model components can be separately formulated and linked. Decomposition of this type also facilitates model formulation, and allows *portability*, the potential re-use of model components in multiple applications. We review properties of *StoTree*, and illustrate its use in constructing a complex model of heart monitoring following cardiac transplant.

MO3.3-01 Parallel session: Policies and decision support - 16:00-17:30

Alternative policies to streamline the treatment of chronic patients in public hospitals

Mario Jorge Ferreira de Oliveira[1], Francisco Santos Sabbadini[2]
[1]Federal University of Rio de Janeiro, [2]State University of Rio de Janeiro

Presented by Mario Jorge Ferreira de Oliveira

Abstract

Management of chronic care capacity is a permanent challenge for emergency hospitals, since the hospital environment involves complex, high risk and high cost processes. Agility in patient referral is a critical factor for success in reducing waiting time and increasing the chance of patient recovery.

The path of the chronic patient to access health services is considered a strategic element to obtain a correct diagnosis and indication of the appropriate way to start medical care. The rules of access and prioritization of care is made through a monitoring system in order to reduce the waiting time for diagnosis and the continuity of treatment.

The objective of this article is to investigate alternative policies to streamline the treatment flow of chronic patients in a health service in the city of Resende, in the State of Rio de Janeiro. In this context, the principles of service capacity management and the treatment pathway for chronic patients is applied, using the theory of constraints. The complete experiment is conducted through a discrete event simulation model.

The model combines the allocation of material and human resources in the different stages of the admission system of chronic patients including access, diagnosis and treatment of patients in an integrated way. The structural mismatch between the supply of services and the demand for chronic patients generates a series of distortions such as the difficulty of scheduling appointments, the discontinuity in the processes of obtaining diagnosis and the interruption of therapeutic behaviors already started.

MO3.3-02 Parallel session: Policies and decision support - 16:00-17:30

Stratified breast cancer follow-up using a continuous-state POMDP.

Maarten Otten, Judith Timmer, Annemieke Witteveen
University of Twente

Presented by Maarten Otten

Abstract

Frequency and duration of follow-up for patients with breast cancer is still under discussion. Currently, in the Netherlands follow-up consists of annual mammography for the first five years after treatment and does not depend on the personal risk of developing a locoregional recurrence (LRR) or second primary tumor. The aim of this study is to gain insight in how to allocate resources for optimal and personalized follow-up. We formulate a discrete-time Partially Observable Markov Decision Process (POMDP) over a finite horizon with both discrete and continuous states in which the size of the tumor is modelled as a continuous state. In this decision process we aim to maximize the total expected number of Quality-Adjusted Life Years (QALYs). Transition probabilities were obtained from data from the Netherlands Cancer Registry (NCR). We show that the optimal value function for this POMDP is piece-wise linear and convex and provide an alternative representation of the optimal value function. With these results we show that Monahan enumeration suffices to obtain the supporting alpha-functions for the optimal value function. Under some reasonable conditions on the dynamics of the POMDP, the optimal value function can be obtained by only using the parameters of the underlying probability distributions. Finally we present results for a stratification of the patients based on their age to show how this model can be applied in practice.

MO3.3-03 Parallel session: Policies and decision support - 16:00-17:30

Evaluating the sustainability of complex health system transformation in the context of population ageing: a system dynamics approach

Gozdem Dural-Selcuk[1], Christos Vasilakis[2]
[1]Hacettepe University, [2]University of Bath

Presented by Gozdem Dural-Selcuk

Abstract

Demographic changes and in particular population ageing and rising morbidity from chronic conditions contribute to ever increasing pressures on the health and care systems in developed countries. Partly as a response, new transformative models of care and service innovations are introduced to reduce demand in the care system, contain costs and improve patient outcomes and experience. However, the effectiveness and sustainability of these complex health system

transformations is often not well understood. Although a number of systems modelling approaches has been suggested in the literature, no study has reported on a comprehensive approach that takes into account both population ageing and the organisation of the health and care services from a whole system perspective.

This study reports the development of a system dynamics model that combines population dynamics and flow of patients through different components of the care system in a local health economy. The development of the model was directly informed from a local care system transformation initiative in UK, which is designed to offer a different patient pathway for those patients with complex care needs.

We demonstrated the use of the model by populating its input parameters from empirical data and conducted a series of simulation experiments. Preliminary results show that the introduction of a complex care hub for patients with three or more comorbidities may have a differential impact on different patient groups. Under demographic changes, we also found that the number of individuals with three or more comorbidities in need of complex care will increase monotonically over the coming years, which should clearly have an impact on the sustainability of any new service redesign. In terms of sustainability, the critical parameters appear to be the hospital readmission rate and the length of stay for those patients with three or more comorbidities that are admitted to hospital.

MO3.3-04 Parallel session: Policies and decision support - 16:00-17:30

Clinical ambiguity and conflicts of interest in interventional cardiology decision-making

Tinglong Dai, Tinglong Dai
Johns Hopkins University

Presented by Tinglong Dai

Abstract

Conventional wisdom suggests more-precise diagnostic testing will help reduce overtreatment. However, the literature rarely recognizes that the decision about whether to perform these tests is itself endogenous. In this paper, we study the decision to perform advanced tests in a catheterization laboratory. One key driver of inappropriate usage of percutaneous coronary intervention (PCI) procedures is physician subjectivity in “eyeballing” a coronary angiogram. Advanced intracoronary tests such as fractional flow reserve (FFR) provide more precise and objective measures of PCI appropriateness, yet the decision to perform them is endogenous and not immune to clinical ambiguity and conflicts of interest associated with the angiogram- guided decision-making.

Among other results, we find that under a high conflict-of-interest level, the physician would perform the advanced test only when the visually assessed angiographic stenosis is sufficiently large, because of a financial disincentive: performing the advanced test may lower PCI revenue if the test results argue against the procedure. Surprisingly, despite this disincentive, a more revenue-driven physician can be more inclined to perform the advanced test. These results help to inform policy initiatives in several ways: (1) direct intervention in the conflict-of-interest level may backfire and lead to more PCI overuse; (2) reducing the risk of the advanced test has a behavior-inducing effect, yet a modest risk reduction may lower patient welfare; and (3) using parameter values based on interventional cardiology practice, we numerically illustrate the impact of increasing the FFR reimbursement rate on reducing overstenting and improving patient welfare.

Much effort in reducing overtreatment has been expended on “the first mile” (developing new diagnostic tools and therapies), yet “last mile problems,” such as an interventional cardiologist’s decision to perform the FFR test, have been little explored. Our research highlights the central importance of endogeneity of advanced intracoronary testing in policymaking surrounding interventional cardiology.

TU2.1-01 Parallel session: Primary and community care - 11:00-12:30

Referral propensity of out-of-hours doctors: analysis of Oxfordshire data

Honora Smith[1], Dan Lasserson[2], Sophie Garland[3], Gail Hayward[2]
[1]University of Southampton, [2]University of Oxford, [3]Oxford Health NHS Foundation Trust

Presented by Honora Smith

Abstract

Currently, the emergency departments (EDs) of UK acute hospitals are overloaded in terms of capacity to handle patients. This is an investigation of the variations in “referral propensity” of clinicians in the out-of-hours (OOH) service. Each clinician has a different probability of referring patients to more specialised care, such as to ED or another route of acute hospital admission. Data are being analysed concerning all patient contacts with the Oxfordshire OOH service over the period December 2014 to December 2015.

Initial results show lower average percentages of referrals to acute hospitals when comparing regular OOH General Practitioners (GPs) from Oxfordshire GP practices with registrars (trainees), non-regular GPs, and GPs from practices outside Oxfordshire. These results hold for all types of final contact with patients, whether base visits, telephone calls or home visits. Considerable variations have been found when comparing individual clinician referral rates, when taking numbers of consultations into consideration. Having established that variation exists in referral propensity of

OOH clinicians, simulation modelling will be undertaken to demonstrate the effects of changing referral propensity.

TU2.1-02 Parallel session: Primary and community care - 11:00-12:30

Modelling patient flow in community healthcare - a fluid approximation with patient health

Ryan Palmer, Martin Utley
Clinical Operational Research Unit, UCL

Presented by Ryan Palmer

Abstract

An ambition of UK healthcare policy has been to deliver more care in the community by moving acute services closer to patient homes. However, evaluating the impact of this shift is complicated due to a lack of comparable measures, nationally and locally, for evaluating quality across differing community services. One stand out challenge is how community healthcare may best be organised to provide co-ordinated care given the physical distribution of services, interrelated patient use and increased episodic use by patients with differing needs.

In this project, we extend a first order fluid approximation of a stochastic queueing system with reuse to include patient health to aid the evaluation of community services. In doing so we model dynamics of patient flow common to community care, such as re-entrant patients, patient mix and the use of multiple services. Patient health is modelled using states which patients may move between during a course of care and are used to model differentiated care. We use time and state dependent parameters to model the impact of patient mix on the performance of the system. In considering differentiated service, we implement a novel method for allocating servers across parallel queues and patient groups.

Finally, we develop the concept of “the flow of outcomes” – a measure of how individual services contribute to the output of patients in certain health states from the system over time – to provide insight and understanding into the clinical and operational performance of interrelated healthcare services.

TU2.1-03 Parallel session: Primary and community care - 11:00-12:30

Towards a concept for collaborative GP practices

Melanie Reuter-Oppermann[1], Jost Steinhäuser[2]
[1]Karlsruhe Institute of Technology, [2]University Hospital Schleswig-Holstein

Presented by Melanie Reuter-Oppermann

Abstract

General practitioner (GP) shortage is an internationally alarming issue. This is especially true for many (rural) regions in Germany. In Baden-Württemberg for example, a federal state located in south-west Germany, around 34% of all GPs (ca. 2000) will retire in the next ten years. These GPs therefore need a successor for their practices as well as their patients. It is expected that at least 500-1000 practices will close due to missing successors, leaving 750,000-1,500,000 patients with the need to find a new GP.

Different strategies against the shortage have already been applied including advertising the GP profession to medical students at the universities or offering an additional payment for taking over a practice in a rural district. We propose to open collaborative practices in which GPs would be employed rather than owning the practice. Due to several changes, newly qualified GPs often tend to work in teams rather than in single handed practices. Therefore, new practices offering this kind of working condition will be more attractive.

We propose a concept for the installation of collaborative GP practices that includes approaches for determining optimal locations and staff schedules. In addition, a layout was developed taking several different aspects (e.g., walking distances for staff and patients, and a set of soft factors) into account. The location models consider existing practices, patient demands and driving times now and in the future. A GIS-based decision support tool is used to visualize the solutions, e.g. for decision makers. For determining the staff schedules opening times, offered services and shift types are potential inputs.

The approaches were tested using data from several regions in Baden-Württemberg.

In future research additional services and appointment strategies will be added to the concept.

TU2.1-04 Parallel session: Primary and community care - 11:00-12:30

Simulation Model of Complex Continuing Care in a Rural Community Hospital

Alexander Rutherford[1], Sergei Gassan[1], Bojan Ramadanovic[1], Paul Rutherford[2], Heidi Dupuis[3], Emma Warren[4], Brent Boshart[3]
[1]Simon Fraser University, [2]North Perth Family Health Team, [3]Listowel Wingham Hospitals Alliance, [4]Listowel Memorial Hospital

Presented by Alexander Rutherford

Abstract

Complex continuing care (CCC) addresses the needs of clinically complex patients requiring hospitalization. Increasingly, CCC facilities are used to enhance the system's capacity to transition patients to lower levels of care or the community. Advances in surgical technology are changing the role of small community hospitals. Most minor to moderate surgery is now day surgery and small community hospitals require fewer active care beds. However, rural hospitals are now faced with restructuring to meet the healthcare needs of an aging population and demand for CCC is increasing. A discrete event simulation model has been developed of a community hospital with active care and CCC wards. Patients may be admitted to the CCC ward either directly or from the active care ward. Patients wait in active care, if CCC is full. They are discharged to longterm care (LTC), residential care, home with nursing support, or home. LTC is the only capacity limited discharge pathway in this application of the model. Patients waiting for LTC remain in CCC. Therefore, the CCC ward acts as a queue node with partial blocking-after-service. Patients are categorised into medically complex, restorative care, behavioural health, and end-of-life. Model calibration and validation use data from a rural hospital in Ontario, Canada. Performance metrics, such as beds in CCC blocked by patients awaiting discharge and timely admission to CCC, are evaluated relative to the number of patients discharged to home or residential care, number of CCC beds, and LTC capacity. Community hospitals may be more successful than large urban hospitals at engaging family and community support for patients discharged home. Particular attention is paid to leveraging this to deliver quality cost-effective CCC. For the hospital modelled, a 10% reduction in patients discharged to LTC would reduce the fraction of CCC occupancy blocked by patients waiting for LTC by 19.7%.

TU2.2-01 Parallel session: Location analysis and visualisation - 11:00-12:30

Optimization methods to handle uncertainty in healthcare location-allocation problems: a literature review.

Vittorio Nicoletta[1], Valérie Bélanger[2], Ettore Lanzarone[3], Angel Ruiz[1]
[1]Laval University, [2]HEC Montréal, [3]Istituto di Matematica Applicata e Tecnologie Informatiche (IMATI) Consiglio Nazionale delle Ricerche (CNR)

Presented by Vittorio Nicoletta

Abstract

In healthcare, several works dealing with home care, emergency medical systems, sample and organ transportation, blood supply chain, and disaster relief management can be modelled as Location-Allocation (LA) problems. These problems consist of locating a set of new facilities in an area of interest and deciding which facility has to serve each specific demand point. As for the objective, the most common is to minimize the transportation costs from facilities to customers, but several other objectives can be found (e.g., to maximize the ratio of served customers or to minimise the response time).

When applied to real-world situations, especially in healthcare, model parameters (e.g., demands, costs, and capacities) are prone to random fluctuations, or estimation errors may affect the considered values. Thus, optimization under uncertainty has received an increasing attention in the LA literature, and several approaches have been proposed.

Including uncertainty can be challenging, but the resulting solutions may outperform the deterministic ones over the realizations of the uncertain parameters. Indeed, these solutions guarantee the feasibility over a wide set of realizations, and the detriment of the objective function is usually limited.

In this work, we review and analyse the literature dealing with LA problems in healthcare under data uncertainty. Indeed, we classify the works based on the technique adopted to deal with uncertainty, the objective, and the type of service. Generally, two family of techniques are adopted to deal with uncertainty, i.e., robust optimization and stochastic programming. Nevertheless, fuzzy programming and ad hoc heuristics are also considered in some recent works.

We conclude our review outlining the gaps in the existing literature and highlighting possible future research directions.

TU2.2-02 Parallel session: Location analysis and visualisation - 11:00-12:30

Simulating hospitals' patient transit systems

Thomas Adams, Michael O'Sullivan, Cameron Walker
University of Auckland

Presented by Thomas Adams

Abstract

The patient transit system at North Shore Hospital in Auckland, New Zealand consists of staff called orderlies who are responsible for moving patients throughout the hospital in order to meet their appointments for procedures such as surgeries and scans. Late arrivals to appointments can lead to expensive resources being idle. Therefore, having a tool to determine the number of orderlies required to meet on-time targets, and how to best deploy those orderlies, is desirable.

A simulation model of the patient transit system at North Shore Hospital is presented. This model is able to accurately reflect the past performance of the patient transit system and evaluate changes to the system such as additional orderlies or a different method of dispatching orderlies. The results of operational changes being considered by North Shore Hospital are presented.

TU2.2-03 Parallel session: Location analysis and visualisation - 11:00-12:30

Centralising neonatal intensive care units in England

Emma Villeneuve, Michael Allen
NIHR PenCLAHRC

Presented by Emma Villeneuve

Abstract

Question: Are the neonatal intensive care units (NICUs) of England located in the right place?

Data: In England there are 161 existing neonatal units, 45 of which are intensive care units.

Straight line distances were computed using a Geographic Information System software, between the mothers' home location (by country divisions LSOAs) and the existing units. Travel times were predicted from a Geographic Information System (Maptitude).

The numbers of very-low birth weight (VLBW) infants (<1500 g) in LSOAs were derived from a regression analysis of the Badger neonatal database (2012-2015).

Method: A genetic algorithm based on NSGA-II was used to explore solutions, with varying numbers of NICUs, that best met a number of objectives:

- Three access objectives aimed at aligning facility locations with the population distribution:
  - Minimise the average and maximum travel times from mother to unit,
  - Maximise the proportion of mothers within 30 minutes from closest unit.
- Three objectives focus on the number of admissions:
  - Maximise the minimum number of admissions to any unit,
  - Minimise the maximum number of admissions to any unit,
  - Maximise the proportion of births occurring in units with more 100 VLBW infants per year.

Some objectives conflict in areas with sparse population.

In the first stage we restricted location to existing NICUs. In a second stage, we extended the location optimisation to all existing neonatal care locations.

Results: Analyzing the Pareto Front of solutions, we show that changing the location of NICUs (while keeping the same number) could increase the proportion of parents within 30 minutes from 64% to 73%. Furthermore, we highlight which locations are more likely to build a resilient optimal neonatal network.

TU2.2-04 Parallel session: Location analysis and visualisation - 11:00-12:30

Home care hospitalization for newborn infants in Ile de France (IDF) region

Catherine Crenn-Hebert[1], Claudie Menguy[2], Elodie Lebreton[3], Chloe Poulain,[3], Marina Martinowsky[4]
[1]Assistance Publique Hôpitaux de Paris, [2]Medical Information Dept, CHI A. Gregoire, [3]PERINAT-ARS-IDF, [4]ARS- Ile de France

Presented by Catherine Crenn-Hebert

Abstract

Background: Home care hospitalization of extremely and very preterm infants should improve their future cognitive and emotional balance, through an earlier return to their family environment. Shortened length of hospital stay after intensive care requires a paradigm shift and a better health system organization.

Perinatality and health inequalities reduction is a priority field for Regional health authority in the next Regional health plan.

Material and Methods: Use of Perinatal health Information System data.

Hospital discharge summaries, which contain more clinical informations, are linked to home care hospitalization discharge summaries to explain their case-mix. Length of stay is measured, taking into account gestational age at birth.

Results: IDF maternities registered 181 331 live birth stays in 2015, 1,5% were very pretem, increasing since 2012.

Among 172420 linkable living birth stays, 24126 newborns have been hospitalized in neonatalogy units. 1481 infants went home with home care hospitalization (6,1%).

In some districts no home care hospitalization has been used.

Compared with infants who went out directly home, home care hospitalized infants have longer length of stay in neonatalogy services. They were more often very preterm infants with higher frequency of intensive care.

Discussion: Home care hospitalization is used for very preterm infants but not in all districts, even those with high rate of preterm births. No decrease in length of stay is observed for these infants, but they had heavier pathology and higher care level.

Conclusion: Linkage between hospitalization and home care hospitalization improves perinatal pathways description for regional health plan. We will focus on regional disparities in health system organization for very preterm infants.

TU2.3-01 Parallel session: Demand, capacity and resource allocation - 11:00-12:30

Mathematical and practical challenges in scheduling medical residents

Amy Cohn
University of Michigan

Presented by Amy Cohn

Abstract

Scheduling medical residents (or any trainees) in the U.S. introduces a number of both mathematical and practical challenges. First, these problems face many of the same challenges as other personnel scheduling problems in terms of size, fractionality, and computational complexity. In particular, because residency schedules must address two often-competing goals (providing patient care and providing medical education), the number of rules can be large, and many of them difficult to pose in

a mathematical model. Second, these problems often do not have a single, well-defined objective over which to solve but instead have many different criteria of importance, some more qualitative than quantitative. Third, each institution and often even each program within an institution have unique characteristics that must be captured, with the added difficulty that the historical knowledge lies with Chief Residents who rotate out every year. We present lessons learned from several years of building both block and shift schedules for a number of residency programs at the University of Michigan Health System.

TU2.3-02 Parallel session: Demand, capacity and resource allocation - 11:00-12:30

A resource allocation model as a vehicle for translating research into practice in postnatal care

John Bowers, Helen Cheyne
University of Stirling

Presented by John Bowers

Abstract

Many studies have examined the provision of postnatal care. However their impact on practice has often been disappointing. This project synthesised research and guidelines on postnatal care creating a decision support tool. The Postnatal care Resource Allocation Model (PRAM) uses a combination of multi-criteria decision analysis with programme budgeting and marginal analysis, incorporating various sub-models that capture the understanding established in previous research. PRAM estimates of the effects of reallocating resources, both along care pathways and between mothers and babies with different needs. Redesign options are analysed considering cost and a variety of quality domains to provide a comprehensive assessment and the capability to explore various trade-offs. Postnatal care has been under particular pressure to reduce costs while improving quality and there is evidence that shifting the balance of care from the hospital into the community may offer a significant contribution to this objective. PRAM helps identify specific actions, and also highlights the consequences of poorly considered reductions in the provision of postnatal care. Experience in one NHS Trust suggests that PRAM can encourage a structured debate about service redesign and the reallocation of resources, bringing the key results from research to local decision making.

TU2.3-03 Parallel session: Demand, capacity and resource allocation - 11:00-12:30

The Affine Accumulating Priority Queue: a model which prioritises based upon acuity and waiting time

Maryam Mojalal[1], Richard Caron[2], David Stanford[1], Peter Taylor[3], Ilze Ziedins[4]
[1]Western University, [2]University of Windsor, [3]University of Melbourne, [4]University of Auckland

Presented by David Stanford

Abstract

Previous accumulating priority queues (APQ) in the literature have assumed that all arriving customers accumulate priority credits over time starting from an initial value of 0. The affine APQ model introduces a new element in terms of an initial class-dependent credit level, from which the accumulated priority grows linearly over time. In this presentation, we consider a two-class APQ, for which class-1 customers receive a positive initial credit upon arrival. (Without loss of generality the class-2 customers continue to have an initial credit of 0.) We assess the impact of the initial priority score upon the waiting time distributions for the lower class of customers, and hopefully the higher class as well. Numerical examples will be presented to illustrate the trends we observe.

TU2.3-04 Parallel session: Demand, capacity and resource allocation - 11:00-12:30

Waiting times in outpatient clinics: what needs to be understood to match demand and capacity

Doris Behrens[1], John Boulton[2]
[1]Aneurin Bevan University Health Board / Cardiff University, [2]Aneurin Bevan University Health Board

Presented by John Boulton

Abstract

The length of time a patient waits to be seen by a doctor or receive treatment is a subject pertinent to many healthcare providers. Lack of capacity to meet demand frequently results in delays. Delays to healthcare delivery means patients wait longer, potentially exposing them to excess morbidity and harm, and results in a reduction in the quality of care they receive.

Aneurin Bevan University Health Board (ABUHB) in South Wales is in the process of redesigning their outpatient services. The performance measure for outpatient management in Wales is to reduce the time from referral to commencing treatment (RTT). Whilst RTT targets clarify understanding new patient backlog, they fail to consider that for several conditions, such as Diabetes or Rheumatoid arthritis, many patients require regular on-going follow-up.

We seek to gather insight into the dynamic behaviour of outpatient queues and the capacity needed to avoid unplanned patient waiting by building and analysing a three-state nonlinear dynamical model of an outpatient clinic. Among others, we found that it is counterproductive to shift backward follow-up appointments to enable bringing in more new patients (e.g. to meet RTT targets) as altering the follow-up interval does not change the steady state number of patients that can be seen per week – it however destabilises the system and makes patients wait longer for their follow-up appointments.

Moreover, we show that the number of follow-up patients that can be sustainably seen every week critically depends upon discharged rates and the proportions of patients not attending their appointments, while running initiative clinics (a very common management practice) for new patients is often counter-productive. Dividing available resources flexibly and in response to the current number of new and follow-up patients is key to sustainable outpatient management. Different rules of resources allocation and their (unintended) consequences are discussed.

TU3.1-01 Parallel session: ED attendance and flow models - 14:00-15:30

Statistical analysis of routinely collected and openly reported NHS Trust data, to explain the decline in Accident & Emergency 4-hour target performance

Brad Keogh, Thomas Monks, David Culliford
University of Southampton

Presented by Brad Keogh

Abstract

It is widely reported that pressures on Acute NHS Trusts across England have been steadily increasing in recent years. This is often reported in the media as rising numbers of breaches of the '4-hour target', which is calculated as the percentage of patients being treated within 4 hours of arriving at an Accident & Emergency (A&E) department. Concerns over the number of 'cancelled elective-operations' at Trusts, as a result of increasing emergency pressures, have also been highlighted more frequently. Some analyses and commentary have suggested that high rates of bed-occupancy and delayed transfers of care within a Trust can increase waiting times in A&E departments. However, there is currently limited statistical evidence showing the relationship between these factors and routinely collected measures of pressure on Acute Trusts.

This work outlines the current state of pressure on Acute NHS hospital services and puts in context some of the factors which might explain why performance targets have reduced in recent years. It presents the results of a statistical analysis using open-data to investigate the impact of: bed occupancy, delayed transfers of care, and other operational factors on the '4-hour target' as well as

'cancelled elective operations'. This approach of using open-data also highlights the opportunities for using routinely collected performance measures in a constructive way to provide greater understanding of the demands on NHS services.

TU3.1-02 Parallel session: ED attendance and flow models - 14:00-15:30

Using real-time data in nudging patients' emergency department (ED) attendance behaviour

Navonil Mustafee[1], John Powell[1], Susan Martin[2], Andrew Fordyce[2], Alison Harper[1]
[1]University of Exeter, [2]Torbay & South Devon NHS Foundation Trust

Presented by Alison Harper

Abstract

We investigate the use of healthcare operations data and business intelligence for reducing overcrowding in Emergency Departments (EDs). The work has been carried out with the Torbay & South Devon NHS Foundation Trust (subsequently referred to as 'TSDFT' or 'The Trust').

TSDFT's urgent care network comprises of one acute/ED hospital at Torbay and several community hospitals at Brixham, Dawlish, Newton Abbot, Paignton and Totnes. The community hospitals have MIUs that are equipped to provide services for minor conditions such as broken bones, muscle injury, minor head injury, cuts and wounds (dressing), minor burns, skin infections, etc. However, users are unaware of the availability of these centers which may be appropriate to meet their needs close to where they are located. Therefore they usually choose to go to ED as they are confident they will be seen and have their medical needs met. This has led to overcrowding with the rate of ED attendance at Torbay hospital now above the national average with 39,419/100,000 population, compared with 30,041/100,000 in England (Turner, 2015). Another factor contributing to the overcrowding is the increased demand from tourists during the summer (by one estimate the catchment population of the trust increases by over 100,000 during this period).

The aim of this research is to provide information transparency on ED/MIU waiting times and patient numbers across the network to both providers and users. This would allow recipients, including, significantly, patients who are in need of urgent medical attention, to make informed decisions as to the health care facility that could best serve their needs. This work will contribute towards reducing pressure in ED by redistributing demand for minor ailments among the MIUs, since the MIUs have facilities for the treatment of minor injuries and the ED exists mainly for emergency and life-threating conditions.

TU3.1-03 Parallel session: ED attendance and flow models - 14:00-15:30

Using OR to help hospitals reduce emergency department waiting times: examples and impact

Thomas Monks, Rudabeh Meskarian
University of Southampton

Presented by Thomas Monks

Abstract

In recent years, all acute hospitals in the UK have experienced unprecedented emergency department waiting times and hospital bed pressures. The consequences are overcrowded emergency departments, ambulance shortages, cancelled elective operations, low staff morale and financial penalties. To deal with the increasing numbers of patient admissions and delayed discharges hospitals must turn now to modelling and simulation to help increase their flexibility and ability to deal with demand variation. Hospitals face several issues that reduce their flexibility including the need for extreme value-for-money and specialization of care. This talk presents three ED case studies undertaken by an analytics team in the UK. The talk considers the impact of the work and challenges arising from their experiences of modelling in acute hospitals. Final thoughts consider the future of ED simulation.

TU3.1-04 Parallel session: ED attendance and flow models - 14:00-15:30

What is the required size of a Clinical Decision Unit for an Emergency Department? - Insights from a knowledge transfer project

Sebastian Rachuba[1], Alaric Moore[2], Laura Custerson[2], Martin Pitt[3]
[1]NIHR PenCLAHRC, [2]Royal Devon & Exeter Hospital, [3]University of Exeter

Presented by Sebastian Rachuba

Abstract

The Accident & Emergency Department at the Royal Devon & Exeter Hospital in England sees approximately 100,000 patients per year. Attendance levels have increased over the last twenty years and both clinicians and managers agreed to introduce a Clinical Decision Unit (CDU) to help streamline patient flow in the department. The demand for cubicles in the CDU is dependent on the admission policy, i.e. which patients are admitted to the unit, and on opening hours. In order to determine the required size for this new unit, a discrete event simulation model was developed and parametrised with historic data. We analysed different admission policies and opening hours and captured the utilisation of the CDU over time assuming infinite capacity. Contrary to most research projects or programmes such as Researcher in Residence, the majority of this project's work was undertaken by a Performance Improvement Manager based at the hospital in Exeter. This project

was part of a 'Health Service Modelling Associates' scheme set up between healthcare providers in the South West of England and the Peninsula Collaboration for Applied Leadership in Health Research and Care. After introductory training sessions in model development and use, the modelling associate's work was overseen and mentored by an operational researcher based at the University of Exeter. We present insights from this inter-disciplinary research project work and discuss how the interaction between research and practice developed over time. In particular, we share how the process of model development and use brought together analysts, researchers, clinicians, and hospital managers to make a difference and initiate evidence-based changes to existing structures in the department. Finally, we discuss the potential impact of this work and highlight how it informs policy around a major investment for the hospital's Accident & Emergency Department.

TU3.2-01 TU3.2 Parallel session: Obesity and dementia - 14:00-15:30

Modelling the future of dementia care in Wessex

Dave Evenden, Sally Brailsford, Bronagh Walsh, Paul Roderick
University of Southampton

Presented by Dave Evenden

Abstract

I am researching service demands and care costs for persons with dementia in the Wessex area over the coming decades.

Dementia is an irreversible progressive condition affecting memory and cognitive ability, associated with high levels of care burden as severity worsens. Appropriate services to care for people with dementia will need to be provided in a challenging context of an ageing population, changing patterns of dementia incidence and prevalence, constrained health and care service resources, and a rapid pace of organisational change in health and social care delivery.

A computer simulation model is being developed - using a hybrid modelling approach - that captures key drivers, known modifiable risk factors, potential interventions, and the effects of these on future care burden.

The simulation model includes dementia prevalence estimates and projected regional population growth, along with symptom severity progression driving care costs. The simulation includes intervention and lifestyle scenarios, allowing uncertainties in model parameters to be explored to determine outcomes in relation to dementia severity and care need.

Stocks and flows are used for mortality and disease incidence; ageing is implemented in java code; and disease severity progression attributes are captured using agent-based approaches.

Current medical treatment interventions have only modest progression-slowing effects and there is no known cure, meaning that adequately planned care provision and timely delivery will continue to be very important.

Results from the computer simulation model will be used to present scenarios to identify key capacity issues in service planning and delivery. The model itself is critically informed by current evidence of epidemiological and clinical understanding of dementia.

TU3.2-02 Parallel session: Obesity and dementia - 14:00-15:30

Modelling the increase in BMI (obesity) in England since the early 1990s

Roger Brooks
Lancaster University

Presented by Roger Brooks

Abstract

There is very strong evidence linking obesity with various long term health conditions such as diabetes, hypertension and arthritis. One common measure of body type is body mass index (BMI), with categories established for a healthy range, overweight and obese. The main aim of this research is to gain a better understanding of the precise changes in the distributions of BMI for men and for women in England since the early 1990s, by finding simple and plausible transformations that would produce the observed changes in the BMI distributions. Estimated distributions were derived for 1993 and 2013 using data from the Health Survey for England (HSE) for 1991-1994 and 2011-2014 and applying a smoothing algorithm. It was found that linear scaling transformations worked well in being able to model the changes in the distributions. Probability distributions were also applied that model greater variability within the population, and very close matches to the 2013 distributions were achieved. The pattern of the increases was higher 1993 BMI values having a higher increase in BMI in a mainly linear pattern. Finally, the BMI changes were converted into calories using energy balance equations to give an estimate of what they mean in terms of dietary changes. Interpreting the increases as due to the effects of different lifestyles and behaviours in the different time periods, the results imply that those with a higher BMI adopted more lifestyle changes. The same method was then applied to model the changes in four year periods from 1993 to 2013, which showed that the rate of BMI increase was greater before 2001 than after 2001. The analysis and results give an insight into past changes as well as what is required to return to the better BMI levels of the past and so may be useful in informing policy.

TU3.2-03 Parallel session: Obesity and dementia - 14:00-15:30

Using hybrid simulation to model the spread of obesity through social networks

Mark Tuson[1], Paul Harper[1], Daniel Gartner[2], Doris Behrens[2]
[1]Cardiff University, [2]Cardiff University and Aneurin Bevan University Health Board

Presented by Mark Tuson

Abstract

According to Christakis and Fowler (2007), obesity spreads through face-to-face social networks. In our research, we will explore the following research questions:

- What is the nature of the interaction between social networks and obesity?
- How does this vary for different sub-groups of the population?
- What intervention strategies might be effective in modifying this interaction?
- Which sub-groups might have the most impact on resources in the future?

These are being addressed through the development and application of a hybrid simulation. The model is parametrised using values taken from both the literature and data from a local health board in South Wales, U.K. The overall aim of the model is to help the health board explore cost-effective services that reduce the level of obesity within the population they serve.

This paper will outline aspects of the model such as:

- The generic design and specification process used to define the content and key outputs of the simulation.
- The processes used to simplify the current complex models used by the healthcare community to set strategy in this area, in order to represent the impact of environmental factors in a System Dynamics model.
- The development of an agent-based model to simulate the influence and impact of social networks.
- Modelling the individual decision-making processes that individuals use in relation to food consumption.
- Combining these three models into a hybrid simulation.
- Calibration and validation of the simulation.
- Strategies for scenario testing and exploration.

TU3.2-04 Parallel session: Obesity and dementia - 14:00-15:30

The use of telecare to support people with dementia to remain living within their own homes

Katherine Penny
University of Southampton

Presented by Katherine Penny

Abstract

There are currently 820,000 people in the United Kingdom living with dementia and around 670,000 partners, family members, and friends providing them with support. The behavioural disturbances and memory loss, that typify dementia, can make the role of caregiver incredibly challenging. The consequent burden that many of these carers experience is closely associated with admission to institutional care. Due to the UK's ageing population, the number of people with dementia is set to rise to over one million by 2021. Consequently, the UK government is keen to explore different options to support carers and to meet the increasing demand on care services. One such option is telecare, which uses information and communication technology to help manage the risks of community living for people with dementia and support care delivery.

In order to explore telecare's influence on the number of people with dementia able to remain living at home, this research uses a hybrid modelling approach. The success of discrete event simulation (DES) for modelling multifaceted care systems has been well documented. Using this trusted OR tool to model the care pathway in combination with statecharts, enhances its capability for capturing the complexity of this human centric system. Statecharts, a common component of agent based simulation (ABS), are used to convert the passive entities associated with traditional DES, into autonomous beings that exert control over the system. These transformed entities are better equipped to reflect the people they represent; capturing disease progression, level of dependency, and carer burden. These factors then govern the person's movement through the social care system. The TeleDem Simulation models the potential experiences of thousands of hypothetical telecare service users. This enables the testing of different scenarios to inform planning decisions for the provision of telecare services for people with dementia.

TU3.3-01 Parallel session: Stroke care modelling - 14:00-15:30

Supporting decisions around the organisation of anticoagulation services for patients with atrial fibrillation with operational research

Neophytos Stylianou, Christos Vasilakis
University of Bath

Presented by Neophytos Stylianou

Abstract

Atrial fibrillation (AF), an arrhythmia characterized by chaotic electrical activity in the atria, is a public health problem affecting countries experiencing aging population and increases the risk of stoke five-fold. Historically, Warfarin and aspirin have been the treatments of choice for AF, but recent guidance states that aspirin should not be used as a monotherapy. In the recent years a new class of drugs was developed, Novel Oral Anti-Coagulants (NOACs) which aim to treat AF avoiding some of the disadvantages of Warfarin. However, each treatment comes with costs and benefits for both the patient and care system which need to be taken into account when planning the organisation of stroke prevention services at a regional or national level

Currently in the UK, there is no standardised approach in the management of AF. Our research aims in developing a tool that will allow the examination of what-if scenarios for the management of AF, providing evaluation of the potential impact those scenarios will have on patient and system level outcomes. This tool aims to eventually be used nationally by NHS and local authority commissioners to help with the decision making for anticoagulation and stoke prevention services.

In this talk we will describe our approach to developing stochastic simulation models that will be used to evaluate the likely impact of different options on patient and system-level outcomes. The model is based on extensive data collected as part of a major regional quality improvement initiative and data that was found in the literature. The outcomes from the tool are numbers of strokes, number of bleeding events, mortality attributed to stroke, costs to the systems and DALYs over a time period of one, five and 10 years.

TU3.3-02 Parallel session: Stroke care modelling - 14:00-15:30

Optimising the stroke pathway through discrete event simulation: Assessing the credibility of a centralised hyper-acute stroke unit

Richard Wood
Bristol, North Somerset, and South Gloucestershire NHS CCGs

Presented by Richard Wood

Abstract

Stroke is one of the leading causes of death in the UK and puts a great strain on NHS services, especially the relationship between hospital and social care. Recent clinical guidance suggests that some health systems may benefit from a centralised hyper-acute stroke unit, providing a specialist 24 hours a day service and a singular point of access to downstream localised secondary and tertiary care. However, assessing the suitability of such a transformation for a particular system, alongside the optimal configuration of bed capacity, is not a straightforward task. In order to support these assessments a discrete event simulation is constructed, modelling patient flows through the acute and rehabilitation units as well as through the early supported discharge teams, which play a key role in reducing delays to discharge in the upstream bedded facilities. The model itself, built in R (a free software, gaining traction in the NHS), is a queuing network based on the Markov property, where discharges are only possible if capacity is available at the appropriate downstream service. This allows any potential bottlenecks to be identified, alongside other operational performance measures for each of the modelled units, such as mean/95% waiting times, throughputs, and quantiles of beds blocked to total occupied. Costs are estimated as a function of unit capacities and the respective distributions of occupancy. Whilst the solution has been constructed and calibrated for stroke, it has been developed to be versatile and so can be readily used to model a whole host of inpatient service pathways.

TU3.3-03 Parallel session: Stroke care modelling - 14:00-15:30

Survival of the fittest? Frailty modelling of stroke incidence.

Mathias Barra, Kim Rand-Hendriksen, Kashif Faiz, Joe Viana, Fredrik A Dahl
Akershus University Hospital

Presented by Mathias Barra

Abstract

Modelling of patient arrivals often relies on projections of future incidence rates; in particular when one is tasked with informing policy makers about the future demand on health services. One important, but challenging, problem is how to obtain good estimates on incidence rates in the older

cohorts. It is important because these cohorts will likely be larger in the future. It is challenging for the same reason: they are relatively sparsely populated at the present. In Norway, the absolute number of persons at or above the age of 70 is projected to double towards 2045.This work focuses on how to model future incidence rates for cerebrovascular disease. We adapt methodology from the field of so-called frailty modelling in survival modelling, to data on stroke incidence collected at a major Norwegian hospital. Frailty modelling is capable of incorporating the paradoxical fact that it is possible for a population to exhibit a non-accelerating, or even abating, incidence rate (as a function of age), even when each individual in that population has an accelerating individual risk throughout life. This phenomenon manifests because, during any given year, those individuals at age *n* with the lowest individual risk are most likely to survive into the next year. In this way, under certain conditions, the cohort of *n+1* year olds may as a cohort be at less risk than one would expect from considering the individual risks alone. Based on our data, we explore several functional forms for the population-risk function, and demonstrate how to build custom R-regression models based on Poisson and Negative Binomial regression. Our results show that signs of “frailty” is present in stroke-incidence data, and that incorporating this mechanism may produce lower incidence projections for the future senescent cohorts than more standard methodology.

TU3.3-04 Parallel session: Stroke care modelling - 14:00-15:30

Operations Research Modelling to Understand Patient Progression in Stroke Rehabilitation

Leonid Churilov[1], Hannah Johns[2], John Hearne[3], Julie Bernhardt[1]
[1]Florey Institute of Neuroscience and Mental Health, [2]RMIT University & Florey Institute of Neuroscience and Mental Health, [3]RMIT University

Presented by Leonid Churilov

Abstract

Stroke is a debilitating illness which can lead to death and life-long disability. While the pre-hospital and acute phases of stroke care became a point of research interest in a number of Operations Research (OR) publications, to date there has been little OR work to address uncertainties in stroke rehabilitation.

The recent AVERT rehabilitation clinical trial is the largest study conducted in stroke rehabilitation. It included 2104 patients across three continents, and its data provided a fertile ground for investigation and modelling beyond the analyses pre-specified in the trial’s protocol. However, further analyses are challenging due to the multifaceted and hierarchical nature of the treatment data, the multi-dimensional nature of the intervention, differences in intervention length between patients, and

the non-trivial links between patients' day-to-day performance and their final outcome measured at 90 days post-stroke.

We report on efforts to overcome these challenges and identify clinically meaningful treatment pathways and outcomes, focusing on the use of various cluster analysis techniques, including novel measures of distance inspired by "edit distance between strings" used in computer science domain. The outcomes of this study provided important inputs into clinical deliberations about optimization of treatment regiments in stroke rehabilitation.

Thursday 3rd August

TH1.1-01 Parallel session: General issues and methods in health OR - 09:00-10:30

Objectives, objectives – developing reflections

Penelope Mullen
Independent

Presented by Penelope Mullen

Abstract

There is widespread recognition that there is no single 'correct' objective in healthcare. Nevertheless, cost-effectiveness, with the aim of maximising health gain, remains central to many approaches, especially within health economics and, increasingly, within operational research. This approach is based on the assumption, implicit or explicit, that health is the primary, or even sole, objective of healthcare systems. However, maximising health gain (QALY maximisation) can have a number of undesirable consequences, including reinforcement of inequalities and discrimination against those with rare diseases, against those with pre-existing disabilities and against those needing more costly interventions. As a result, modifications have been proposed to attempt to mitigate these problems, for example, weighting QALYs or adjusting funding thresholds, but all without questioning the underlying assumptions of the pursuit of health-gain maximisation.

In challenging the apparent primacy of health-gain maximisation, an earlier paper suggested that it would be helpful to make a clearer distinction between health-related interventions and healthcare systems. In the case of the latter, in particular, it was argued that trust and security are under-recognised as important, and possibly primary, objectives. This paper develops those arguments and reflects on their implications, exploring whether and how the objectives of security and trust could be operationalised for use in analysis, decision making and resource allocation. In this it examines whether lessons can be drawn from a range of sources ranging from the global health security movement, at one end of the spectrum, to the needs and wishes of patient carers, at the other.

TH1.1-02 Parallel session: General issues and methods in health OR - 09:00-10:30

Modelling patient flows through municipal acute units in South-Eastern Norway

Meetali Kakad, Fredrik Dahl
Akershus University Hospital Trust

Presented by Meetali Kakad

Abstract

Introduction

As of 1st January 2016, all 426 municipalities in Norway were required to have a municipal acute unit (MAU). MAUs were established to shift care away from hospitals towards municipal health care services. Our project will develop simulation models of patient flows through MAUs and propose how these may be optimised.

Study design and participants

The study population includes all adult patients admitted to 9 MAUs and 4 hospitals in Akershus and Oslo counties, in the period between January 2009 and December 2019. We propose to use a mixed-methods design using Soft Systems Methodology (SSM) and Discrete Event Simulation (DES) to model patient flows through MAUs. The study population includes all adult patients admitted to 9 MAUs and 4 hospitals in Akershus and Oslo counties, in the period between January 2009 and December 2019.

Data collection

We will obtain individual level data for all MAU patients ever admitted to the units included in the study, together with individual level data for all patients admitted to the 4 hospitals in the period 2009-2019.

Analysis

We will develop and validate DES model(s) of patient flows through municipal A&E - MAU- hospitals, including individual level patient trajectories based on linked data for MAU and hospital admissions. We will assess whether frequent users of MAUs are frequent users of hospital services and whether use of hospital services is reduced following the introduction of MAUs. We will use the model to test the effects of alternative forms of organisation, including merging smaller MAU units. SSM will be used as a framework for presenting and discussing the results of our modelling with key stakeholders.

Conclusion

As the project is in its initial stages, we are keen to get input on our analytical approach.

TH1.1-03 Parallel session: General issues and methods in health OR - 09:00-10:30

A research agenda for Operations Research Applied to Health Services (ORAHS) in South Africa

Liezl Van Dyk, Liezl Van Dyk, Maria Van Zyl, Hanneke Botha
North-West University

Presented by Liezl Van Dyk

Abstract

ORAHS has long been a mature discipline in many countries in terms of practice and research. Although the number of research publications (conference contributions, articles, dissertations and theses) concerning OR in South African healthcare is gradually increasing, much still have to be done. The purpose of this study is to propose a research agenda for ORAHS in South Africa in order to expedite much needed improvements to the healthcare system by means of OR.

South Africa has a legacy of a fragmented health system, with vast differences between the public healthcare sector and the private healthcare sector in terms of the availability and quality of healthcare. Primary health care in the public system is mainly nurse-driven and focuses on preventative healthcare and health promotion. Regional hospitals provide secondary healthcare services and specialists services are provided in the tertiary system by academic hospitals. In the Annual South African Health Review five categories of challenges are addressed: Leadership and Governance, Human Resources, Service Delivery, Financing and Information. This provide a framework for the potential contribution of OR to improvements in the South African healthcare system.

Against this framework, the following South African literature corpus are analyzed: All recent South African Bachelors, Masters and Doctoral theses and dissertations in Industrial Engineering and Operations Research related to health services as well as publications the Southern African Journal for Industrial Engineering, the conference proceedings of the Southern African Institute for Industrial Engineering as well the journal and conference proceedings of the Operations Research Society of South Africa.

A research agenda for ORAHS in South Africa will be proposed, based on an analysis of the gap between existing research the potential contribution of OR as framed above.

TH1.1-04 Parallel session: General issues and methods in health OR - 09:00-10:30

Teaching Modelling & Simulation to Medical Students

Sally Brailsford
University of Southampton

Presented by Sally Brailsford

Abstract

Numerous literature surveys since the 1980s have reported a lack of take-up of Operational Research by healthcare organizations, despite the massive academic literature in this area. Numerous theories have been proposed over the years to explain why this should be the case, and numerous people have tried to address the problem through a wide variety of initiatives, networks and schemes. Despite nearly 30 years in health OR, I do not claim to have found the answer! However, in this talk I shall describe one very small initiative, an elective module offered to final-year medical students at Southampton in which we present a whistle-stop tour of modelling and systems thinking, illustrated by case studies and guest talks by OR-friendly clinicians who explain why they think it is important for doctors to know something about modelling. The thinking behind the module is to educate future doctors about OR while they are still young (and hopefully receptive to new ideas), so that when they go out into the real world of clinical practice, they have already been exposed to the benefits that modelling can offer.

This talk will be interactive, as I am keen to find out if any other ORAHS members are doing anything like this and if so, what topics they include and how they deliver the material. I am also keen to get people's views on what the content of such a module should be, bearing in mind that medical students will have had limited practical experience compared with the majority of healthcare practitioners on similar training courses.

TH1.2-01 Parallel session: Scheduling applications - 09:00-10:30

Scheduling interval planning considering no-shows and cancellations

Gréanne Leeftink[1], Ingrid Vliegen[2], Erwin Hans[1]
[1]University of Twente, [2]Eindhoven University of Technology

Presented by Gréanne Leeftink

Abstract

Patient no-shows and cancellations are a significant problem to healthcare clinics, as they compromise a clinic's operational efficiency. Therefore, it is important to account for both no-shows and cancellations into the design of appointment systems. To understand the no-show and

cancellation behavior, we present an analysis of clinic data from two healthcare providers in the USA and the EU. In line with the literature, no-show and cancellation rates increase with longer scheduling intervals. We also analyze the temporal behavior of cancellations for multiple scheduling intervals, which shows to follow a bimodal distribution.

To improve the operational efficiency of clinics, we determine the optimal scheduling interval such that the impact of no-shows and cancellations is minimized, against a cost of rejecting patients. Where the majority of the literature only includes a fixed no-show rate, we include both a cancellation rate and a time-dependent no-show rate. We use an analytical queuing model with balking and reneging in the queue, to determine the optimal scheduling interval. Furthermore, simulation experiments show that the assumptions of this model are viable. Computational results demonstrate general applicability of this model by case studies of outpatient clinics of two hospitals in USA and EU health systems.

TH1.2-02 Parallel session: Scheduling applications - 09:00-10:30

Dynamically accepting and scheduling patients for home healthcare

Mustafa Demirbilek[1], Juergen Branke[2], Arne Strauss[2]
[1]University of Warwick, [2]Warwick Business School

Presented by Mustafa Demirbilek

Abstract

The importance of home healthcare is growing rapidly since populations of developed and even developing countries are getting older quickly and the number of hospitals, retirement homes, and medical staff do not increase at the same rate. We consider the Home Healthcare Nurse Scheduling Problem. In this problem, arrivals of patients are dynamic and acceptance and appointment time decisions have to be made as soon as patients arrive. The objective is to maximise the average number of daily visits for a single nurse. For the sake of service continuity, patients have to be visited at the same day and time each week during their service horizon. We propose a new heuristic based on generating several scenarios which include randomly generated and actual requests in the schedule, scheduling new customers with a simple but fast heuristic, and analysing results to decide whether to accept the new patient and at which appointment day/time. We compare our approach with two greedy heuristics from the literature, and empirically demonstrate that it achieves significantly better results compared to these other two methods.

TH1.2-03 Parallel session: Scheduling applications - 09:00-10:30

A mathematical programming model for efficient resource allocation in radiotherapy with uncertain demand

Bruno Vieira[1], Erwin Hans[2], Jeroen van de Kamer[1], Derya Demirtas[2], Wim van Harten[1]
[1]NKI-AVL, [2]University of Twente

Presented by Bruno Vieira

Abstract

As the number of people diagnosed with cancer increases, demand for radiotherapy (RT) services has been continuously growing. In RT, delays in the start of treatment has shown to increase the risk of tumor progression in at least some cancer types, and patients experience greater psychological distress and prolonged symptoms when subject to longer waiting times. The RT process, which involves imaging and treatment planning before treatment, is subject to uncertainties and complexities that hamper resource planning and control. On the demand side, it is known that the amount of workload verified at each operation depends on the highly variable patient inflow. On the supply side, radiation therapy technologists (RTTs) have multiple skills, rotation needs and partial availability, which makes the planning of RTTs a complex task that often leads to situations of under-staffing, jeopardizing the fulfillment of the patients' waiting time standards.

In this work, we propose a stochastic mixed-integer linear programming model that optimizes the tactical allocation of RTTs to the key operations in RT over a set of scenarios of patient inflow and care pathways. The scenarios are generated from historical data, and the final RTT allocation is robust enough to accommodate the workload differences between scenarios. The goal is to maximize the (expected) number of patients finishing the pre-treatment stage within the waiting time standards while satisfying operational and capacity constraints.

Results for a case study in the RT department of the NKI, a comprehensive cancer center in the Netherlands, show that, on average, the number of patients finishing the pre-treatment stage within the maximum waiting time standards may increase from 85.9% to 98.7% for subacute patients, and from 95.6% to 99.1% for regular patients. In addition, the number of RTTs needed to cover the expected demand in all scenarios can be reduced by 10%.

TH1.2-04 TH1.2 Parallel session: Scheduling applications - 09:00-10:30

Scheduling Surgical Instrument Decontamination: Reducing Lead Times for High Priority Contaminated Goods

Daniel Gartner[1], John Boulton[2], Tracey England[1], Doris Behrens[2], Paul Harper[1]
[1]Cardiff University, [2]Aneurin Bevan University Health Board

Presented by Doris Behrens

Abstract

In the age of multiple drug resistance, surgical instrument sterilization and decontamination has a vital impact on hospital-acquired infections. In a hospital sterilization and disinfection unit (HSDU), contaminated equipment arrives from the surgery rooms or wards. They are unpacked, checked, inventoried, washed, dried and packed. Each processing step requires human and material resources. Their inefficient management can lead to increasing lead times for items to be processed. Failure to process instruments quickly leads to two undesirable effects: i) the risk that contaminated items leave the HSDU and ii) scarce medical equipment is unavailable for surgical procedures. We develop a discrete-optimization model and a greedy heuristic to schedule personnel and machine downtimes in the HSDU. Our discrete-event simulation model evaluates lead times for high and low priority items to be processed. Based on data from our collaborating hospital in the U.K., we evaluate our approaches. The current scheduling policy of the HSDU reveals that only 67% of high priority items leave the system within the 5-hour target. Using our proposed schedules based on our heuristic approach, more than 80% of high priority items leave the system within 5 hours.

TH1.3-01 Parallel session: Demand and capacity management - 09:00-10:30

System dynamic models by estimates the needed number of beds for each ward of the hospital

Paula Andrea Velásquez Restrepo[1], Sebastián Jaén Posada[2]
[1]IPS Universitaria - Universidad de Antioquia, [2]Universidad de Antioquia

Presented by Paula Andrea Velásquez Restrepo

Abstract

The lack of inpatients flow and discharge, are among the causes of the emergency department overcrowding, the increase of nosocomial diseases, the deterioration of inpatients wellbeing, the availability of beds and the increasing of cost in the health care system. The required number of beds per hospital ward is one of the main factors influencing the formation of inpatients bottlenecks or the inefficient use of beds. These problems and the need of a better assessment for determining the required number of beds and their allocation among the wards are commonly perceived in acute

hospitals in the Medellin city of Colombia, given the city's large population and their increasing demand for hospital care. In this work, it is presented two system dynamic models of two acute hospitals in the city of Medellin, which share the same methodology for modeling the hospital and estimating the required number of beds in each ward. The methodology uses the first order information delays for adjusting the current bed capacity in to the demanded one, considering a desired goal of occupancy. The results show how by adjusting the capacity in beds the model estimates the needed number of beds for each ward uncloging the bottleneck in the emergency department.

TH1.3-02 Parallel session: Demand and capacity management - 09:00-10:30

Online discrete event simulation for the management of inpatient beds

Dave Worthington, David Oakley, Stephan Onggo
Lancaster University

Presented by Dave Worthington

Abstract

The potential benefits of using discrete event simulation (DES) models in healthcare are well established, and they are often preferred to other modelling approaches because of their ability to emulate randomness seen in real systems at a level of detail that is often necessary for models to be convincing. However their use is often limited to strategic or tactical decision making, and few have attempted to produce models which can help hospitals with short-term decision making – which is becoming increasingly important as hospitals try to cope under higher and higher occupancy levels.

An Online Discrete Event Simulation (ODES) (also known as symbiotic simulation) takes all the components of a DES model, and adds the ability to load the state of the real system at simulation run-time. ODES has been made possible with the increasing availability of real-time and semi real-time data from various sources (e.g. wireless sensor networks, information systems) and the ability of simulation software to read data during runtime.

DES models used in strategic and tactical decision making are typically interested in long-term (or steady-state) behaviour. They start empty and run through a warm-up period before the collection of results begins, with the warm-up period behaviour disregarded. However in an ODES model, an operational state is loaded at initialisation, data collection begins immediately, and the interest is often in understanding the short-term consequences of the starting conditions, be they describing the state of the system or the decisions under consideration.

In this talk we consider the problem of inpatient bed management and describe research into the model building process for ODES, including model validation; and outline some of the potential applications to short-term decision making.

TH1.3-03 Parallel session: Demand and capacity management - 09:00-10:30

Restructuring existing ward structures at a public hospital

Sebastian Rachuba[1], Nalan Gulpinar[2], Elvan Gokalp[2]
[1]NIHR CLAHRC South West Peninsula (PenCLAHRC), [2]University of Warwick

Presented by Sebastian Rachuba

Abstract

Ward structures and sizes at hospitals have grown historically and only few changes are made to the allocation of beds to wards and departments. Although restructuring of existing allocations appears to be promising towards a more efficient bed utilisation, the resulting changes cause disruption and would affect daily working practice. With more changes to an existing allocation, an increasing amount of organisational changes will become necessary which will likely affect the effectiveness of service delivery, although cost savings might be significant. In this paper, we present a two-stage stochastic optimisation model for the ward restructuring problem at a public hospital. The optimisation model assigns beds to wards and departments and takes into account demand uncertainty per department and various room sizes. The effects of restructuring are demonstrated in a case study using real world data. We analyse the trade-offs between restructuring effort, the resulting costs and the quality of new structures. Finally, both operational and managerial implications of our research are discussed.

TH1.3-04 Parallel session: Demand and capacity management - 09:00-10:30

Capacity planning for a healthcare network with outsourcing

Nalan Gulpinar, Elvan Gokalp, Vinh Doan
Warwick Business School

Presented by Nalan Gulpinar

Abstract

Outsourcing is a growing trend in the healthcare sector due to an increasing demand for cost effective services. A healthcare outsourcing network consists of several hospitals sharing a patient population based on a pre-specified contract. In this paper, we are concerned with the capacity

planning problem for a healthcare outsourcing network involving different uncertainties such as patient arrivals and service times. We assume that the service providers (hospitals) offer a fixed capacity with a certain price to a central authority. The central authority needs to allocate a fixed budget and distribute demand (patients) among the service providers while ensuring certain criteria such as the maximum waiting time not to be violated. We introduce an alternative optimization based algorithm to solve the underlying non-linear integer optimization model. The computational results are presented to illustrate the performance of the model with different network structures.

TH2.1-01 Parallel session: Routing, transit and tele-health - 11:00-12:30

Operations-based healthcare service innovation: an example of tele-health

Jiun-Yu Yu
National Taiwan University

Presented by Jiun-Yu Yu

Abstract

Service innovation involves considerable degree of collaborations between the service providers and the receivers. To make the service innovation successful, the operations that create and shape user experiences along the customer journey must be carefully designed and studied. Data collected, either quantitatively or qualitatively, from these operations fuels the essential analytics to obtain insights on the user needs and the points for innovation. The dynamic and complex nature of healthcare services makes such operations-based innovation studies even more important and challenging.

Some scholarly attempts have been made in this field of operations-based healthcare service innovation, particularly focusing on business model and service design for tele-health. Studies on user behavior and user experience for current and potential users have been carried out, and the impacts from urban and rural differences have been discovered. In addition, an operations strategy analysis reveals the potential direction of further development for tele-health service model. It is hoped that some feasible and self-sustainable health service innovations are to be developed from these operations-based studies.

TH2.1-02 Parallel session: Routing, transit and tele-health - 11:00-12:30

Benchmarking online dispatch algorithms for Emergency Medical Services

Caroline Jagtenberg[1], Pieter van den Berg[2], Rob van der Mei[1]
[1]Centrum Wiskunde & Informatica, [2]Rotterdam School of Management

Presented by Pieter van den Berg

Abstract

Providers of Emergency Medical Services (EMS) face the online ambulance dispatch problem, in which they decide which ambulance to send to an incoming incident. Their objective is to minimize the fraction of arrivals later than a target time. Today, the gap between existing solutions and the optimum is unknown, and we provide a bound for this gap.

Motivated by this, we propose a benchmark model (referred to as the offline model) to calculate the optimal dispatch decisions assuming that all incidents are known in advance. For this model, we introduce and implement three different methods to compute the optimal offline dispatch policy for problems with a finite number of incidents. The performance of the offline optimal solution serves as a bound for the performance of an - unknown - optimal online dispatching policy.

We show that the competitive ratio (i.e., the worst case performance ratio between the optimal online and the optimal offline solution) of the dispatch problem is infinitely large; that is, even an optimal online dispatch algorithm can perform arbitrarily bad compared to the offline solution. Then, we performed benchmark experiments for a large ambulance provider in the Netherlands. The results show that for this realistic EMS system, when dispatching the closest idle vehicle to every incident, one obtains a fraction of late arrivals that is approximately 2.7 times that of the optimal offline policy. We also analyze another online dispatch heuristic, which manages to reduce this gap to approximately 1.9. This constitutes the first quantification of the gap between online and offline dispatch policies.

TH2.1-03 Parallel session: Routing, transit and tele-health - 11:00-12:30

Comparison between alternative decomposition methods to solve the assignment and routing problems in home health care

Semih Yalçındağ[1], Nadia Lahrichi[2], Ettore Lanzarone[3]
[1]Yeditepe University, [2]Polytechnique Montreal, [3]CNR-IMATI

Presented by Semih Yalçındağ

Abstract

Home Health Care (HHC) is a relatively new service system, which plays an important role to reduce hospitalization costs and improve the life quality for patients. HHC is one of the recent service systems where human resource planning has a great importance, and the service providers have to deal with several operational issues such as the assignment problem of the operators to patients together with their routing process. In the literature, either these problems have been simultaneously solved or decomposed by first solving the assignment problem and then the routing one. Recently, we proposed an alternative approach, where the decomposition is based on the First Route and

Second Assign (FRSA) approach. Briefly, in the FRSA approach, daily giant tours are first generated by solving a Periodic Vehicle Routing Problem; then, these tours are split and assigned to the operators (nurses) while taking into account continuity of care, capacities and workload balancing; finally, a post assignment process is included to guarantee feasibility and to improve the solution of the splitting process. In this work, we perform a comparison between this new decomposition approach and the existing alternatives, to analyze the efficiency and quality of the solutions under different HHC service settings. To test the approach in a wide range of instances, an instance generation mechanism is adopted, which generates instances inspired from real HHC providers. Results show some advantages of the FRSA approach, especially in instances characterized by a large territory and long travel times.

TH2.1-04 Parallel session: Routing, transit and tele-health - 11:00-12:30

Stochastic routing for relief efforts

Maria Elena Bruni, Patrizia Beraldi, Sarah Khodaparasti, Demetrio Laganà
University of Calabria

Presented by Maria Elena Bruni

Abstract

In the last decades, several disasters have caused worldwide millions of victims. Seismic and flood events have affected an enormous number of people. It is therefore evident the need to address the challenge associated with managing a humanitarian relief chain.
An efficient coordination and management of disaster operations, which are the set of activities that are performed before, during, and after a disaster, might prevent loss of human lives, reduce material, economic and environmental losses. An important logistical issue in disastermanagement is the determination of transportation routes for providing first aids, rescuing people and saving lives. A large number of destination nodes, geographically spread out over the disaster region should be reached in a time effective fashion since the arrival time clearly has an impact on mortality and morbidity.
The aim of this talk is to study a stochastic version of a routing problem arising in the context of disaster management in which the travel times are uncertain and the objective function minimizes the arrival time at nodes. It is easy to recognize that this interesting variant allows to address many real-life situations, where travel speed is not constant since depends on many factors among which roadway capacity and traffic fluctuations.
We study the problem under ambiguity supposing that only the first and the second moment of the probability distribution of the travel times are known.
The introduction of the uncertainty leads to additional severe computational difficulties that need to be addressed from a computational standpoint.

We present tailored heuristic solution approaches able to efficiently solve the problem. Preliminary computational results are presented and discussed.

TH2.2-01 Parallel session: Workforce allocation - 11:00-12:30

Pooling nursing staff in an intensive care setting with two units

June Lau, Ilze Ziedins
University of Auckland

Presented by June Lau

Abstract

A large city hospital has recently consolidated nursing rosters for an intensive care unit and a step down unit. Motivated by this, we examine the effects of pooling servers. Previous literature has shown that pooling is beneficial in tandem cases, but unintuitive results occur in more general network structures. We present models for a specialised model, a consolidated model with pooled nurses and compare these approximations with discrete event simulation models. These simulation models have been validated against historical data and with clinicians. The unit's setting of non-stationary queues and multiple patient classes with individual service time distributions add to the intractability of a closed form solution. Blocking probability and server utilisation are of importance to the clinical team. We discuss these differences between specialised and consolidated model based on numerical results from the simulation and theoretical models. This study gives insight into the impact of pooling nursing resources and would be relevant to teams considering integration of intensive care units and step down units, or those introducing a step down unit to assist with demand management in an intensive care setting.

TH2.2-02 Parallel session: Workforce allocation - 11:00-12:30

A stochastic knapsack approach for the individual surgeon loading problem

Troels Martin Range[1], Dawid Kozlowski[2], Niels Christian Petersen[2]
[1]Hospital of South West Jutland, University of Southern Denmark, [2]Department of Business and Economics, University of Southern Denmark

Presented by Troels Martin Range

Abstract

Assigning elective patients to surgeons and days of surgery is a common task in the hospital sector. It can be stated as a generalized assignment problem which can be decomposed into a set partitioning problem and a number of knapsack problems - each representing the loading of a surgeon on a given day - which we denote individual surgeon loading problems.

The focus of this presentation is on how to solve the stochastic knapsack problem when having only estimates for mean and variance of the completion time of each of the surgeries conducted by a

specific surgeon. As the completion time is not deterministic we penalize the expected overtime by a non-decreasing convex penalty function. If the penalty is linear it corresponds to the overtime payment of the surgical staff while in the case of a strictly convex penalty function it represents a proxy for the risk of failure due to e.g. fatigue of the surgeon.

We can formulate the knapsack problem as a resource constrained shortest path problem on an acyclic graph. This formulation lends itself to generalizations of the knapsack problem where multiple resource constraints or where generalized upper bound constraints (GUB) are present. The knapsack problem is solved by dynamic programming and the algorithm is augmented by a bounding procedure eliminating a significant number of states. In addition we show that dominance between states can be applied without calculating the expected overtime explicitly.

To access the characteristics of the algorithm a computational study has been conducted on a large set of randomly generated instances. This study shows that the algorithm is reasonably fast e.g. cases with 250 potential surgeries with mean between 10 and 50 and a regular time of 250 (after which it is overtime) solves within seconds.

TH2.2-03 Parallel session: Workforce allocation - 11:00-12:30

Reconstructing Disrupted Nurse Rosters

Toni Ismael Wickert, Pieter Smet, Greet Vanden Berghe
KU Leuven

Presented by Toni Ismael Wickert

Abstract

The Nurse Rostering Problem (NRP) is a well-known problem within the field of operational research which seeks to assign nurses to shifts during a time period subject to a set of hard and soft constraints.
While hard constraint violations make a potential solution infeasible, soft constraint violations only penalize the objective function.
The Nurse Rerostering Problem (NRRP) occurs when one or more nurses already scheduled to work cannot be present due to, for example, illness.
Such events may render an existing solution infeasible and changes are thus necessary to reschedule other nurses to remedy the absences.
This work proposes an integer programming formulation to address the NRRP.
Three primary research questions are addressed, namely:

- Is it necessary include all original hard and soft constraints from the NRP when attempting to generate good quality solutions for the NRRP?
- What is the difference, in terms of computation time and solution quality, between solving the full NRRP model and a surrogate model which only considers disruption minimization objectives?
- What is the best scheduling horizon to consider when rerostering? Should only those days where nurses are absent be considered? The complete scheduling horizon? From first absent day until the last absent day? This restricted period could be extended with some days before and after.

Computational experiments were conducted by employing adapted instances from the Second International Nurse Rostering Competition.
Several scenarios were generated to test different approaches to find the best alternatives to solve the NRRP according to the preferences of each health care institution.
Experimentation reveals that all the instances were quickly solved to optimality when using the proposed integer programming formulation.

TH2.2-04 Parallel session: Workforce allocation - 11:00-12:30

Effects of stroke on labour force participation for patients and family caregivers

Fredrik A. Dahl, Kim Rand-Hendriksen, Joe Viana, Mathias Barra, Tone Berines Simonsen
Akershus University hospital

Presented by Fredrik A. Dahl

Abstract

The focus of this work in progress is the indirect economic impact of stroke through reduces labour participation of patients and family caregivers. Our goal is to estimate the average impact that a case of stroke has on the contribution to economic production for the patient and family caregivers, as a function of age at onset, sex, family situation and stroke severity. The analysis relies on registry data from several national sources. The case part of the cohort consists of all patients admitted to a Norwegian hospital with acute stroke from 2009 until today. We include one control for each patient, matched on age, sex and municipality residence. For all of cases and controls our cohort also includes spouses and children. For this cohort we acquire socio-demographic variables, including income history data. This will enable us to estimate the reduction in labour force participation for patients and their family carers, which is attributable to the stroke event. We will utilize all relevant data available in regression models, in order to eliminate confounding factors, and isolate the causal link between the stroke and changes in labour force participation, as accurately as possible. We will

compare the income trajectories of cases and controls (and their families). If these are similar prior to the stroke event, and then diverge, it will support the conclusion that the event has a causal effect on the income development. The primary framework for this analysis will be the human capital approach, which builds on the assumption that the economic value of labour is equal to the wages that are paid. We will also consider the main alternative approach, which focuses on friction cost, under the assumption that a lost employee can be replaced, and the only relevant cost runs until a replacement is found.

TH2.3-01 Parallel session: Patient appointment scheduling - 11:00-12:30

Outpatient appointment scheduling

Eduardo López Aguilar[1], Yannick Kergosien[1], Vincent Boyer[2], Jean-Charles Billaut[1]
[1]Laboratoire d'Informatique, Polytech Tours, [2]Universidad Autónoma de Nuevo León

Presented by Eduardo López Aguilar

Abstract

To improve its outpatient department, the Assistance Publique – Hôpitaux de Paris (APHP) is rebuilding its organization. They plan to merge several outpatient departments into one located in only one site. This new service should provide care to patients according to 25 pre-defined care plans or clinical pathways. A clinical pathway is a sequence of activities that the patient has to follow in order to get a diagnosis or a treatment. To manage the appointments of patients and the schedule of their activities during a day, a decision-making software is being developed. Our study focus on the scheduling problem related to their appointment process. All the patients that should come during a given day are known in advance. The problem consists in scheduling all care activities of the patients in order to minimize their total waiting time, considering all the constraints: sequences of the clinical pathways, resource requirements for each activity (human, materials and rooms), availability of the resources, patient preferences, and time restrictions of certain activities. This problem is an extension of the resource constrained multi-project scheduling problem (RCmPSP). We formulate the problem as a mixed integer linear problem model and we propose an Adaptive Large Neighborhood Search (ALNS) as a solution method. In order to evaluate our approach, we generated a set of instances based on real data.

TH2.3-02 Parallel session: Patient appointment scheduling - 11:00-12:30

A new appointment-scheduling policy: a case study in a bariatric surgery clinic.

Igor Peres, Sílvio Hamacher, Fernando Cyrino
PUC-Rio

Presented by Sílvio Hamacher

Abstract

Traditional appointment-scheduling systems book patients at fixed intervals, resulting, either in server idleness at certain times of the day, or long queues at other times. In this context, first, we performed an extensive systematic literature review, where 17 appointment-scheduling policies were found. Afterwards, we conducted a case study and proposed a new appointment-scheduling policy, called DOME CYCLE, which considers the following complexity factors: stochastic service times, patient unpunctuality, lateness and interruptions of the provider and presence of no-shows. We also offer a framework to straightforwardly compare policies. The case study was conducted in a bariatric surgery clinic located in Rio de Janeiro (Brazil). We analyzed scenarios with overbooking for four different work shifts, including periods of low, medium and high demand, and tested the 18 policies using a discrete event simulation model. The DOME CYCLE policy outperformed the other ones, increasing by 30% the daily number of consultations, and maintaining the provided service level.

TH2.3-03 Parallel session: Patient appointment scheduling - 11:00-12:30

Analysis of indirect waiting times for medical practices considering different patient types and appointment policies

Anne Zander
Karlsruhe Institute of Technology

Presented by Anne Zander

Abstract

Indirect waiting times or access times of patients are an important indicator for the quality of care in a medical practice. In the literature queueing models have been proposed to calculate the indirect waiting time distributions when considering only panel patients or only non-panel patients, where the panel is defined as the group of patients visiting the practice regularly.

In the first part of the talk, we will investigate the indirect waiting time when a practice treats a mix of panel and non-panel patients. The important modeling aspect here is that non-panel patients request appointments at a constant rate whereas panel patients' request rate depends on the length of the indirect queue (the virtual queue representing the schedule). This is because we assume that panel

patients do not make new appointments if they already have an appointment at some time in the future.

The model helps to decide on a maximal panel size and a maximal acceptance rate for non-panel patients in order to maintain a predefined service level with respect to indirect waiting times.

At present, more and more medical practices use online appointment booking software. However, at the same time many practices also continue to use their old appointment management software leading to the situation of having to handle two separate appointment schedules. To prevent double booking, time capacities are often divided between the two schedules.

In the second part of the talk, we will discuss the influence of unsynchronized schedules on the indirect waiting times of patients compared to the case of one schedule.

This enables us to calculate the benefit of having one schedule in terms of indirect waiting time and to give recommendations on how to divide time capacities if two schedules have to be used.

TH2.3-04 Parallel session: Patient appointment scheduling - 11:00-12:30

Decision support for appointment scheduling of MRI examinations

Anders N. Gullhav, Marielle Christiansen, Bjørn Nygreen, Anders R. Eilertsen, Hanna M. Selvaag
Norwegian University of Science and Technology

Presented by Anders N. Gullhav

Abstract

With the increasing demand for magnetic resonance image (MRI) examinations, the manual scheduling of patients at the MRI labs of hospitals becomes complicated without the right decision support. We study the appointment scheduling problem, which is a dynamic problem where randomly arriving examination requests are to be mapped to an MRI machine at a specific time and day in the future. The patients that request examinations have different urgency levels and require MRI examination procedures of various durations. While the requests arrive according to stochastic processes, we assume that the procedure durations are deterministic.

The planners that perform the scheduling should guarantee that there is enough available time at any given day to schedule urgent patients, while maintaining a high utilization. If there are too few time slots for urgent patients, delays and rescheduling will occur. On the contrary, too many time slots reserved for urgent patients will lead to inferior utilization.

The objective of our study is to define policies for efficient patient scheduling, which can be used by the planners at the hospital. An important part of the decision support is to help the planners to ensure that there is an appropriate amount of available time for urgent patients. Some requests must be scheduled at once due to urgency, while others can be delayed. Therefore, we develop different types of scheduling rules; both simple rules that allocate requests one by one, and more advanced rules that are less myopic and allocate multiple request simultaneously.

We simulate and analyze the performance of the scheduling rules in computational experiments based on real data from a major Norwegian hospital. We also compare the scheduling rules with an integer program run in a rolling horizon framework.

TH4.1-01 Parallel session: Modelling blood and transplant services - 16:00-17:30

A simulation-optimization approach to single-cycle inventory policies between one blood center and multiple hospitals

Maria Carlina Poveda[1], Daniel Vargas Cabezas[1], Juan David Urrego[1], David Barrera-Ferro[1], Elena Valentina Gutierrez[2], Andres Felipe Osorio[3], Sonia Patricia Forero[4], Bernardo Camacho[4]
[1]Pontificia Universidad Javeriana, [2]Universidad de Antioquia, [3]Universidad ICESI, [4]Instituto Distrital de Ciencia Biotecnología e Innovacion en Salud

Presented by David Barrera-Ferro

Abstract

Blood banks play a key role in the blood supply chain as they are responsible for collecting, processing and distributing donated blood. However, the design of inventory policies for blood products presents important challenges due to three main characteristics: demand uncertainty, low collection rates and perishable nature of the products. This work studies inventory policies at IDCBIS (*Instituto Distrital de Ciencia Biotecnología e Innovacion en Salud*) which is the main blood center at Bogotá, Colombia. IDCBIS caters to public network hospitals and some private clinics near 5900 units per month. Currently, although the service level is approximately 85%, historical data shows that between 5% and 20% of units sent to hospitals are wasted.

A simulation-optimization approach is proposed to design single-cycle inventory polices considering a network of one blood center and multiple hospitals. Firstly, a total cost model is constructed that takes into account shortage for this supply chain setting. For the optimization phase, a well-known heuristic is used and the objective function is estimated using Montecarlo Simulation and Common Random Numbers. Finally, a solution frontier, considering service levels between 70% and 95%, is constructed. Preliminary results show costs savings by including variability in the optimization process.

TH4.1-02 Parallel session: Modelling blood and transplant services - 16:00-17:30

UK Living Kidney Sharing Scheme

Matthew Robb, Rachel Johnson
NHS Blood and Transplant

Presented by Matthew Robb

Abstract

There are currently over 5000 patients in need of a kidney transplant in the UK. The average waiting time for a deceased donor kidney is over 2.5 years. This can be much longer in difficult to match patients. Over this period of time the health of the patient deteriorates further. If a patient has a willing living donor, either a relative, friend or partner, this eliminates waiting time. However, in many cases even if a patient has a willing living donor a transplant may not go ahead due to a blood group or tissue type incompatibility. The UK Living Kidney Sharing Scheme was set up in 2007 and gives patients with a willing but incompatible living donor an additional route to get a transplant. This allows donor-patient pairs to enter a quarterly 'matching run' that looks at possible exchanges between the donor of one pair and the patient in another to facilitate transplants for both patients. All possible matches are calculated and transplants are identified using an optimisation algorithm developed in collaboration with colleagues at the University of Glasgow. This algorithm maximises the total number of transplants in line with criteria developed with the transplant community. Over 1800 donor-patient pairs have now entered the sharing scheme and this has helped facilitate over 680 transplants which would otherwise not have been possible. A simulation study has also enabled development of a patient tool to give patients more information on their expected chance of transplant through the scheme based on their relevant characteristics.

TH4.1-03 Parallel session: Modelling blood and transplant services - 16:00-17:30

Blood type specific issuing policies to improve inventory management

Joost van Sambeeck, Sem van Brummelen
CHOIR University of Twente / Sanquin

Presented by Joost van Sambeeck

Abstract

The challenges faced by blood transfusion services are becoming more complex and are changing continuously over time due to growing economic pressure, new technologies and increasing customer expectations. The Dutch blood supply is currently exploring the feasibility to order extensively typed red blood cell units directly from stock. Currently, all units are issued according to

the first-in-first-out principle, irrespective of their typing. These kind of issuing policies lead to unnecessary shortages of rare blood units. Such shortages can easily be limited by using more advanced issuing policies for rare blood types. However, such policies also increase the risk of wastage due to outdating. To balance outdating and shortages a trade-off between the age and rarity of a specific typed blood unit in stock must be made.

Due to specific features of the inventory management of red blood cell units, traditional (perishable) inventory allocations models do not apply. We modelled the allocation of inventory as a circulation flow problem, in which decisions about which unit to issue, given a specific blood type requested, are based on the age and rarity of the units in stock.

The model was evaluated for various input parameter settings whereby varying stock size, trade-off ratios between age and rarity, and the number of decision moments per day. As expected, we can show that whenever a relative limited number of donors are typed for combinations of antigens, shortages can be avoided by saving rare blood products without introducing excessive outdating. Moreover, this can be achieved without affecting the average products' issuing age.

TH4.1-04 Parallel session: Modelling blood and transplant services - 16:00-17:30

Modelling the impact of extended shelf life platelets

John Blake
Dalhousie University and Canadian Blood Services

Presented by John Blake

Abstract

Background: The regulatory shelf life for platelets in many jurisdictions is five days. Platelet shelf life can be extended to seven days with an enhanced bacterial detection algorithm. Enhanced testing, however, comes at a cost, which may be offset by reductions in wastage due to longer shelf life. This paper describes a method for estimating system wide reductions in platelet outdates after platelet shelf life is extended.

Study design and methods: A simulation was used to evaluate the impact of an extended platelet shelf life within a national blood network. A network model of the Canadian Blood Services platelet supply chain was built and validated. Platelet shelf life was extended from 5 days to 6, 7, and 8 days and runs completed conducted to determine the impact on outdates.

Results: Results suggest that, in general, 16.3% reduction in platelet wastage can be expected with each additional day that platelet shelf life is extended. Both suppliers and hospitals will experience

fewer outdating units but that wastage will decrease at a faster rate at hospitals. No effect was seen by blood group, but there was some evidence that the topology of the regional distribution networks influences both the number of units to waste and the network ability to benefit from extended shelf life platelets.

Conclusion: Extended shelf life platelets will reduce wastage within a blood supply chain. At 7 days, an improvement in wastage of 38% reduction in wastage can be expected with outdates being equally distributed between suppliers and hospital customers.

TH4.2-01 Parallel session: Surgery and operating room scheduling 1 - 16:00-17:30

Optimizing the master surgery schedule in a private hospital

Nara Barros, Inês Marques, Maria Eugénia Captivo
Universidade de Lisboa

Presented by Maria Eugénia Captivo

Abstract

A multiobjective mixed-integer linear programming (MILP) model to create cyclic master surgery schedules (MSSs) for a case study in a medium-sized Portuguese private hospital is developed. The hospital performs around 8000 surgeries yearly but this number is growing. Thirteen surgical specialties and more than 200 active surgeons compete in each trimester for Operating room (OR) time. OR time blocks are assigned to surgical services or to individual surgeons. A target OR time per surgical specialty is not an input of the model as it is often assumed on other studies available in the literature. Four objectives are considered: (1) to assign surgeons and surgical specialties to the available OR time, while reducing the variability at the care units, in order to level the workload in these units as much as possible; (2) to concentrate surgeons from the same surgical specialty as much as possible in the same room, in order to reduce turnover time; (3) to allocate OR time blocks to the surgical specialties with the highest number of available surgeons; and (4) to renew the MSS based on recent historical data. Since the surgeries' duration is dependent on the type of surgery, on the surgeon, and on the surgical specialty, the empirical distribution of the surgeries' duration is incorporated into the model. Solutions are computed considering a weighted sum of the multiple criteria presented. The model provides different solutions for different criteria weight assignments: 35 weight assignments are tested and the results are analyzed, although it is up to the decision maker to choose the solution that s/he prefers, after visualizing and evaluating different schedules. This approach enables the surgical suite to be more efficiently managed and helps to get a better understanding of the trade-offs on the relevant criteria for building a schedule.

TH4.2-02 Parallel session: Surgery and operating room scheduling 1 - 16:00-17:30

Approximate dynamic programming for the surgery room allocation problem under uncertainty

Elvan Gokalp, Nalan Gulpinar, Vinh Doan
University of Warwick

Presented by Elvan Gokalp

Abstract

The real-time surgery room allocation under uncertainty is a complex and dynamic problem. Duration of surgeries cannot be known until they are completed. Besides, some disruptions like equipment failure or arrival of a non-elective patient may occur simultaneously. Thus, the initial surgery assignment needs to be updated over time to minimize the possible effect of disruption. In this study, we present a stochastic dynamic programming model for allocating surgeries to multiple operating rooms during a day. The optimization model minimizes the number of cancellations and emergency rejections as well as overtime and elective waiting times while taking different surgery types into account. Due to the curse of dimensionality in real-size instances, we introduce an approximate dynamic programming algorithm that simulates future paths and iteratively updates the state values. The computational results illustrating performance comparison of different policies obtained by the approximate dynamic programming algorithm and a myopic heuristic approach are presented.

TH4.2-03 Parallel session: Surgery and operating room scheduling 1 - 16:00-17:30

Optimal allocation and evaluation of operating room hours

Lisa Koppka, Lara Wiesche, Matthias Schacht, Brigitte Werners
Ruhr University Bochum

Presented by Lisa Koppka

Abstract

On a tactical level, decision makers in hospitals are faced with a given case mix and given resource capacities. Handling of those capacities in order to support different stakeholder's interests is a huge challenge. A large part of revenue and costs in the hospitals emerges in the operating theater. Therefore, we support decision makers to optimally allocate operating room capacity and to determine operating hours for the individual operating rooms. In cooperation with one of the biggest heart centers in Germany, an innovative optimization model was developed which uses the probability for a perfect day without overtime as goal criterion. Hence, the solution obtained has a

maximum probability for no overtime in all operating rooms while all patients initially assigned are treated. An extensive simulation study demonstrates that optimal operating hours for operating rooms can significantly influence key performance indicators such as overtime, rescheduling of patients and utilization.

TH4.2-04 Parallel session: Surgery and operating room scheduling 1 - 16:00-17:30

Using buffer capacity in operating room planning: a good idea?

Carla Van Riet, Erik Demeulemeester
KU Leuven

Presented by Carla Van Riet

Abstract

Many inpatient surgical departments experience a large amount of uncertainty in the required daily operating room (OR) time. A large part of this uncertainty is due to the arrival of non-elective patients.

One way to take the uncertainty of the non-elective patients into account is to assign capacity to them or in other words, to use buffers in the schedule. Unfortunately, this reduces the amount of capacity available for planning elective patients.

Having implementable policies to deal with this trade-off is essential in order to provide timely and reliable care to patients (i.e., minimal cancellations) at a reasonable cost. Current models that are dealing with this trade-off suffer from several limitations, resulting in contradicting managerial advises. First, although the importance of integrated solutions (i.e., including both the capacity planning phase and the patient scheduling phase) is widely recognized, these types of solutions are still lacking for hospital settings with a mix of both elective and non-elective patients. Second, current models including both patient groups, are not validated on a real setting by either being implemented or by being data-driven (i.e., the modelling choices are motivated by real-life data).

Using discrete-event simulation with detailed data from a large university hospital, this talk discusses whether and in which cases it is reasonable to install capacity buffers, which type of buffer (i.e., dedicated OR or a fragmented buffer per OR) results in the best performance and how buffers influence the capacity allocation between disciplines.

We discuss the impact of different policies related to capacity planning and access policies using a wide set of performance measures (related to staff, patient and hospital management). Moreover, we

focus on the applicability of both existing (traditional) and new (partial) policies and explain the cause of the current contradiction in managerial advises.

TH4.3-01 Parallel session: Disaster and emergency planning - 16:00-17:30

Assessment of physicians stress in emergency departments

Marta Cildoz, Amaya Ibarra, Fermin Mallor
Public University of Navarre

Presented by Marta Cildoz

Abstract

An Emergency Department's physicians may be exposed to severe and variable stress most of the time owing to the stochastic nature of the demands (unpredictable arrivals, emergencies, etc.). The physicians in a Spanish Emergency Department (ED) reported their feelings of large inequities among them regarding the stresses from the workload assigned to each of them, which is increased as a new patient comes to the ED. A big share of these inequalities are due to the patient flow management rules used at triage. However, the introduction of the physicians' stress as a criterion to manage the patient flow requires the assessment of the stress experienced by physicians in real time, which cannot be measured by any of the existing methods.

The main purpose of this presentation is to introduce a novel methodology developed to provide a function that allows the dynamic assessment of the stress experienced by a physician in real time during the work-shift.

Our approach takes into account not only physician's workload (pending patients' priority and quantity) but also uncertainties (phase of attendance, unpredictable arrivals, patients' illness not seen, etc.), and time pressure (overcrowding, waiting time) of that workload. It considers the importance the physicians have consensually given to the different stress factors for aggregating each patient's contribution to the workload. The methodology involves factor stress analysis, design of stress questionnaires, and a statistical data analysis of opinions elicited from experts.

This new methodology facilitates the investigation of new patient flow management rules in order to reduce stress variability among physicians during the work shift and consequently, improve patients' quality of medical care and avoid the physicians' health problems.

TH4.3-02 Parallel session: Disaster and emergency planning - 16:00-17:30

Emergency event forecasting: a spatial-temporal approach

Niki Matinrad, Krisjanis Steins, Tobias Andersson Granberg
Linköping University

Presented by Niki Matinrad

Abstract

One aim for emergency medical services is to provide quick and efficient medical treatment and transportation to out-of-hospital patients. To achieve this, proper resource management is necessary, and a key factor is to have information about the expected demand for service. By having a reliable and realistic prediction of events, it is possible to proactively plan for an optimized management of the resources that need to be utilized.

In this study, a spatial-temporal forecasting model for daily medical emergencies is presented. In order to achieve high precision, influencing variables such as socio-economic aspects and population distribution are taken into account. Furthermore, the model is developed so that it can incorporate real-time data such as weather forecasts and road and traffic conditions, if such data is available.

The data utilized for training and testing the model is ambulance calls to SOS Alarm Sweden (Swedish Public Safety Answering Point) between years 2010 and 2014, for three counties with varying demographic and geographic characteristics. The model is tested and compared to historical data, as well as to the forecasts currently used by the emergency services.

TH4.3-03 Parallel session: Disaster and emergency planning - 16:00-17:30

Emergency Readmission for Integrated Care (ERIC) Model - Using an Automated Feature Generation and a Multi-Task Learner

Thierry Chaussalet, Mohsen Mesgarpour, Philip Worrall, Salma Chahed
University of Westminster

Presented by Thierry Chaussalet

Abstract

Predictable hospital readmissions can be avoided with preventive interventions, and healthcare commissioners are looking for more powerful predictive models to target the high-risk patients. The predictive risk tools in clinical decision-making can help to improve care quality and reduce the costs of inappropriate admissions to hospital and A&E.

Considerable work has been carried out in this subject area, especially in the USA and the UK, which lead to the development of tools, like PARR, PARR++ and the Combined Predictive Model. However, these tools quickly become obsolete, due to continuous changes in care sectors and population characteristics. Also, they usually have poor formal mechanisms for finding and generating features, and substantial research and development works must be carried out every time a model update is required.

The project is funded by the Innovate UK, in which we seek to develop novel predictive risk tools and dashboards to assist commissioners in understanding the complex needs of individuals, to optimise integrated care.

In this research, we developed a decision support system for prediction of hospital emergency admission, using primary and secondary care. The developed model, Emergency Readmission for Integrated Care (ERIC), uses an automated feature generation framework to first create a large pool of features from inpatient, outpatient, A&E and GP. Then, the features are ranked, combined and aggregated using multiple methods. Afterwards, the ERIC model implements a multi-task learning approach, to facilitate personalisation of the decision support system for each care sector more efficiently and accurately.

TH4.3-04 Parallel session: Disaster and emergency planning - 16:00-17:30

Improving interoperability of major disasters: main tasks, materials, equipment, EU civil protection modules and responders: a decision support system

Marion Rauner[1], Helmut Niessner[1], Karen Neville[2], Andrew Pope[2], Odd Steen[3], Simon Woodsworth[2], Niklas Holmberg[3]
[1]University of Vienna, Austria, [2]University of Cork, [3]Lund University

Presented by Marion Rauner

Abstract

In the S-HELP (Securing Health.Emergency.Learning.Planning) fp7-project a Decision Support System (DSS) was developed leaded by the University of Cork, Ireland (http://www.fp7-shelp.eu/). The main aim was to improve the preparedness, response, and interoperability of health stakeholders involved in emergency situations. Especially, multi-agency cooperation and cross-border disaster scenarios are most challenging.

First, we briefly outline the general functionality of the S-HELP DSS. The core parts include: situation module, situation log module, current recognized situation module, casualty module, **decision**

support module, action module, charting module, geographic information system, **knowledge management system**, twitter module, and weather module.

Second, we present the contribution of University of Vienna to the S-HELP DSS. We investigated in detail emergency response performed by emergency responders (skills taxonomy) using emergency material/equipment and EU Civil Protection Modules (resources taxonomy) under consideration of different disaster scenarios (skills/disaster taxonomy). In addition, European emergency responder systems are analyzed including incident command and control roles and responsibilities.

Finally, we illustrate how these taxonomies are embedded in the knowledge management system (KMS) and decision support module of the S-HELP DSS which facilitates individual and inter-group and intra-group decision-making and learning in crisis management.

Friday 4th August

FR2.1-01 Parallel session: Surgery and operating room scheduling 2 - 11:00-12:30

Admission control in an intensive care unit with readmission

Faruk Akın, E. Lerzan Örmeci
Koç University

Presented by Faruk Akın

Abstract

We consider an Intensive Care Unit (ICU) where we focus on the effects of early discharge decisions and possible readmissions on the hospital bed management. The system may admit, reject or admit an arriving patient by early discharging a current patient in the ICU. Arrivals to the system occur from two sources: 1) *first-time patients* from the outside population and 2) *recurring patients* who have previously visited the ICU but seek another admission, i.e. readmission. To represent such a setting, we developed a discrete-time Markov Decision Process with the aim of minimizing the total expected β-discounted cost over an infinite horizon. Each discharged patient may join the environment and cause readmission, where we assume that early discharged patients are more likely to join the environment than regularly discharged patients. Arrival process for both patient types occurs according to a Poisson process where the rate of normally discharged patients is constant whereas the rate of recurring patients depends on the number patients in the environment. Length of stay for all patients is an exponentially distributed random variable with the same rate, i.e. once admitted to the ICU, patients are treated as one type. We use event-based dynamic programming to model a framework, which seeks policy implications in the existing problem as well as in similar systems that can be modeled by these operators. Using these operators we investigate the structure of the optimal admission control policy. Further, we prove that when there is an empty bed it is never optimal to reject an arriving recurring patient. We also analyze the model as an M/M/1 feedback queueing system and derive analytical results.

FR2.1-02 Parallel session: Surgery and operating room scheduling 2 - 11:00-12:30

Surgical procedure type scheduling incorporating semi urgent patients

Nardo Borgman[1], Erwin Hans[1], Ingrid Vliegen[2]
[1]University of Twente, [2]Eindhoven University of Technology

Presented by Nardo Borgman

Abstract

In operating room (OR) scheduling, a tactical (cyclic) block schedule in which OR blocks are assigned to surgical specialties is often used. Once surgical demand is realized, surgical cases are scheduled into the allocated OR blocks. In practice, this results in planning periods having many of the same type of surgical cases being scheduled, with slight variations due to changes in demand. Additionally, changes often take place as processes within the OR are stochastic in nature.

A source of uncertainty often not accounted for, is the arrival of semi-urgent patients. Unlike emergency patients that must be treated on the day of arrival, semi-urgent patients may be postponed for some limited time (e.g., several days or weeks). To accommodate these semi-urgent patients, surgical case schedules are often changed to ensure timely treatment. In order to reduce the rescheduling of patients after semi-urgent patient arrivals, an approach is sought that accounts for these patients on a tactical level.

In this research we aim to create a surgery type schedule (STS) that can hierarchically be positioned between the tactical block schedule and operational surgical case assignment. We account for both elective and semi-urgent surgery demand such that the waiting time of semi-urgent patients is minimized, as well as required OR capacity.

To solve this planning problem a stochastic model considering uncertain semi-urgent arrivals and surgery durations is formulated. Following this, we adopt a decomposition approach wherein first sample average approximation (SAA) is used to allocate semi-urgent surgery capacity to days in the planning horizon. Second, a STS is constructed using a column generation (CG) based heuristic approach, in which elective and semi-urgent surgeries are combined into OR schedules and placed in the planning horizon. In this approach the number of required operating rooms is minimized, while ensuring the probability of overtime is limited.

FR2.1-03 Parallel session: Surgery and operating room scheduling 2 - 11:00-12:30

Parametric and nonparametric models for next day operating room scheduling

Enis Kayis, Omer H. Sevindik
Ozyegin University

Presented by Enis Kayis

Abstract

Effective operating room (OR) scheduling when surgery durations are uncertain requires accurate surgery duration estimates. True surgery duration distributions are not known in practice and hence estimates are used as a proxy. Unfortunately, these estimates are developed using limited past data. In this paper, we model parametric and non-parametric models for next day OR scheduling, quantify and analyze the effect of limited past data on generating OR schedules. We find that the number of data points may not be practically available in most settings to generate near-optimal schedules.

FR2.1-04 FR2.1 Parallel session: Surgery and operating room scheduling 2 - 11:00-12:30

A generic simulation model for operating room scheduling and planning

Michael Carter[1], Daphne Sniekers[2], Carolyn Busby[1]
[1]University of Toronto, [2]Cancer Care Ontario

Presented by Michael Carter

Abstract

Decisions regarding bed capacity and allocation, surgical block schedules and patient mix have an effect throughout the hospital. Many factors need to be considered when making these decisions, such as the effect on bed occupancy levels, Emergency Department boarding times, surgical cancellation rates, Operating Room efficiency, off-servicing rates, staffing flexibility, seasonal variation, and future demand. In addition, decisions must be made regarding the number of beds to staff and budget for, and how many physical "flex" beds to have in reserve that can be staffed in times of surge. A discrete event simulation tool has been developed to help administrators consider all of these factors. The simulation was constructed with the intention of being reused across a variety of hospitals without modifying the simulation code. The model used successfully at more than two dozen hospitals in Canada. We will discuss a variety of applications and the results.

FR2.2-01 Parallel session: ED optimisation and performance - 11:00-12:30

Synchronisation and optimisation of emergency department patient flow

Guvenc Dik[1], Erhan Kozan[1], Michael Sinnott[2]
[1]Queensland University of Technology, [2]Princess Alexandra Hospital

Presented by Guvenc Dik

Abstract

The emergency department (ED) is a dynamic and complex system interacting with hospital units. Flow of the admittance-required emergency patients in the ED can be blocked due to unsynchronised use of scarce hospital resources. Blocked patients still consume scarce ED resources and reduce the ED performance in delivering quality and timely emergency care to new arrivals. A multi-machine constrained flexible blocking job shop scheduling model is developed for optimising patient flow. The model is solved under different parameter settings. Results show that ED length-of-stay times are decreased when the occupancy of hospital resources are considered while optimising ED care process.

FR2.2-02 Parallel session: ED optimisation and performance - 11:00-12:30

Sequentially assigning and prioritizing patients at emergency departments

Maartje van de Vrugt[1], Ilze Ziedins[2]
[1]Universtiy of Twente/Leiden University Medical Centre, [2]University of Auckland

Presented by Maartje van de Vrugt

Abstract

Emergency departments (EDs) often experience severe overcrowding, which may put patient lives at risk. Typically, doctors at EDs use multiple rooms in parallel; while one patient awaits test results in a treatment room, the doctor visits other patients. The assignment of rooms among the doctors is often unbalanced, which affects the blocking probability and waiting and sojourn time of patients. Doctors typically follow a policy that prescribes the sequence in which the patients are treated. We investigate extreme cases, from which we conclude that it is unlikely that there exists a policy that is optimal for all ED systems. We optimize the priority policy of each doctor and the patient-doctor assignments in each state of the ED system using a mixed integer programming model in a rolling-horizon approach, in which we incorporate time-varying arrival rates and that each phase of treatment may have different characteristics that depend on the type of doctor and patient. Numerical experiments indicate that our policy performs similar to the policy that gives priority to the patient with

the longest length of stay. As this heuristic policy is easy and performs well, these results are of significant practical relevance.

FR2.2-03 Parallel session: ED optimisation and performance - 11:00-12:30

Using the "floating patients" method to balance crowding between the hospital emergency department and other departments

Guy Wachtel, Amir Elalouf
Bar Ilan University

Presented by Guy Wachtel

Abstract

Overcrowding in hospital emergency departments (EDs) that arises from long length-of-stay (LOS) is an unfortunate common occurrence all over the world. In our research, we propose a model and a scheduling algorithmic approach to reduce crowding in the EDs, and to provide faster and better service. This approach relies on the "Floating Patients" (FP) method, in which the ED triage can send patients directly to hospitalization departments instead of providing them with full examinations in the ED. In contrast to previous work in this vein, our technique is based on a holistic approach, considering crowding not only in the ED but also in other departments in the hospital. It also considers the extent to which information has been made available about the patient's condition (e.g., through referring physicians), in addition to other factors such as the severity of the patient's condition and the effect of crowding on treatment time. A benefit of this method is that it enables triage staff (the decision maker) to control and balance the EDs' crowding with crowding in other departments. We define the model and propose an efficient Fully Polynomial Time Approximation Scheme (FPTAS). When dealing with a system in which large numbers of patients arrive from a variety of sources (e.g., are brought in by ambulances, referred by clinics, or sent by other hospitals), the FPTAS produces a close-to-optimal solution in a short time. First application of the FP is scheduled for June and July 2017. During the application, we will record numerical indexes (such as LOS, number of tests, etc.), ask the patients to fulfill a survey regarding the influence of the FP method on the service quality from the patients' point of view, and will interview the medical staff in the ED. First notes from the application will be shared and discussed.

FR2.2-04 Parallel session: ED optimisation and performance - 11:00-12:30

Using discrete event simulation with Coxian phase-type regression models to understand patient flow through emergency departments

Laura Boyle[1], Adele H. Marshall[1], Mark Mackay[2]
[1]Queen's University Belfast, [2]Flinders University

Presented by Laura Boyle

Abstract

High attendance adds strain to increasingly pressurised emergency departments (EDs) in Australia, which saw an upsurge of 14% in patients presenting for treatment between 2011 and 2016. This, combined with 'boarding' patients (those awaiting beds for inpatient admission), contributes to ED overcrowding and results in reduced capability of units to treat patients within government performance targets. The most recent figures, from 2016, show that the proportion of patients seen within the four-hour National Emergency Access Target (NEAT) in South Australian EDs was just 66%.

This study presents a discrete event simulation (DES) model for the ED of a major South Australian hospital, utilising administrative data spanning a two-year period. It begins by identifying patient attributes which are influential on length of stay (LoS) at each stage of their treatment, such as age, acuity level and arrival method. These are then incorporated as covariates in Coxian phase-type regression models, which evaluate the covariate effects on rate of flow through the system. The DES model operates using embedded regression models to estimate LoS at each stage of ED treatment, providing a unique approach as the individual patient attributes are considered. The study is extended to consider the impact of ED system state variables, e.g. occupancy, upon ED LoS, using an adaptation of the above method. The benefit of the model is that it is capable of identifying patient-types who are likely to have a longer stay within the unit and consequently permit more informed allocation of resources. The DES model will be practically implemented for the purpose of scenario testing – for example, the simulation of an unanticipated increase in patients presenting with a particular attribute. Further work will consider the application of the modelling framework to an alternative ED to validate its generalisability.

FR2.3-01 Parallel session: Model validation and participation - 11:00-12:30

Overcoming common critical mistakes in building composite indices through the MACBETH socio-technical approach

Monica Oliveira[1], Teresa Rodrigues[1], João Bana e Costa[2], Ana Vieira[1], Ângela Freitas[3], Liliana Freitas[1], Paula Santana[3], Carlos Bana e Costa[1]
[1]Universidade de Lisboa, [2]Bana Consulting, [3]CEGOT - University of Coimbra

Presented by Monica Oliveira

Abstract

Composite indices have been used as formal assessment tools, but are often built with *ad hoc* processes and suffer from theoretical meaningfulness. Departing from common critical mistakes of composite indices, in this presentation we show how these can be avoided by following the principles of multi-criteria value modelling. Specifically we describe how the MACBETH socio-technical approach has been devised to overcome these problems and to assist population health indices construction in the context of the EURO-HEALTHY H2020 and of the GeohealthS FCT projects. Under this technical framework, the added value to health of improving performance on a criterion is measured by a value-function (or by a conditional value-function in case of interdependencies) and the relative importance of performance improvements in different criteria is measured by relative weights. The judgemental information to define value-functions and weights can be elicited with MACBETH through two-stage participatory processes: a Delphi panel formed by a large number of experts and stakeholders to agree upon value-functions shapes and “qualitative” weights, which then informs a decision conferencing process with a small strategic group. We describe how this approach was successfully applied to build indices at the municipality level in Portugal and at the regional level in Europe.

FR2.3-02 Parallel session: Model validation and participation - 11:00-12:30

A novel participatory approach to scenario building: application to the evolution of population health inequalities in Europe

António Alvarenga, Ana Vieira, Liliana Freitas, Mónica Oliveira, Carlos Bana e Costa
Universidade de Lisboa

Presented by Liliana Freitas

Abstract

Scenarios are key to capture uncertainty and inform strategy and policy evaluation. Recognised cross-cutting challenges in scenario building are the involvement of a large and diverse number of participants and the combination of their opinions with evidence. We present a new approach for scenario building that entails a sequence of face-to-face and non-face-to-face participatory

processes: a two-round Delphi process with a large panel of experts and stakeholders describing, in a first idea-generation round, causes for future changes, which are subsequently worked into drivers that are then assessed by participants in a second Delphi round; next, in a two-workshop process with a strategic small group, drivers are organized into scenario structures reinforced by future-oriented evidence, for which scenario narratives are developed. Technically, a protocol is devised to convert causes into drivers; and the Extreme-World method is used to build extreme but plausible scenarios, with a third interim scenario being set. We show how this approach was applied in the H2020 EURO-HEALTHY project to develop scenarios to appraise the evolution of population health inequalities in Europe.

FR2.3-03 Parallel session: Model validation and participation - 11:00-12:30

Validating clinical hybrid OR models: what can go wrong (and probably will)?

Hannah Johns[1], Leonid Churilov[2], John Hearne[1], Julie Bernhardt[2]
[1]RMIT University, [2]Florey Institute of Neuroscience and Mental Health

Presented by Hannah Johns

Abstract

Hybrid OR Models are a promising method for handling the complexities of real-world health systems, due to both the ability to compartmentalise the model into more approachable sub-problems, and the ease with which the model can be extended. However, the approach is relatively young and there is little literature on how these models can best be applied, developed and validated.

In this study, we report on a hybrid OR model developed in the domain of stroke rehabilitation, aiming to link day-to-day physiotherapy activity to the progression of functional recovery and a final clinical outcome measured 3 months after stroke. In the development process, we used the data from the largest stroke rehabilitation clinical trial (AVERT), that included 2104 patients from three continents. The developed hybrid model consists of three sequential predictive models: The model to predict functional ability of a patient at the start of the process (based on clinical and sociodemographic characteristics); the iterative model to predict functional ability of a patient on a given day (based on functional ability on the day prior); and the model to predict final clinical outcome at 90 days (based on functional ability at the end of the hospital in-patient episode).

While each of the component models performed extremely well under validation, the hybrid model failed to perform as expected. We discuss how conventional validation approaches were insufficient to ensure that the hybrid model was fit for purpose, and how this need for more stringent validation procedures may be addressed.

FR2.3-04 Parallel session: Model validation and participation - 11:00-12:30

Opening the door: inviting patient and family perspectives on pediatric mental health emergency department use in Nova Scotia

Leslie Anne Campbell[1], David Lovas[2]
[1]Dalhousie University, [2]IWK Health Centre

Presented by Leslie Anne Campbell

Abstract

Youth are seeking mental health care at Emergency Departments (EDs) at steadily increasing rates. This trend is likely a result of several complex factors, including gaps or access problems in primary care or community mental health services, increasing awareness of mental disorders, and associated fear of potentially harmful outcomes (e.g. suicide, self-injury, addictions) with resultant expectations of need for urgent specialist care. These putative explanations have largely been offered by clinicians, researchers, and health system administrators. However, we recognize patients' and families' perceptions and reasons for use of the ED may differ, and to date have been underrepresented.

Therefore, we are consulting with youth and families to inform a program of research designed to improve mental health outcomes, and to reduce non-urgent ED use through improving the development and awareness of effective adjunctive or alternative crisis interventions. We aim to ensure we are posing the "right" research questions and identifying outcomes of value to patients and families.

A current key strategy of the Canadian Institutes of Health Research (CIHR) is the engagement of patients as research partners, focusing on patient-identified priorities with the expectation of improving translation of research to clinical settings with resultant improvements in patient-oriented outcomes. While patient engagement in clinical decision making is not new, its application in research and decision analysis is an emerging field, and as such there is little guidance for researchers. Challenges arise in prioritizing and optimizing potentially competing objective functions for decision modelling.

We present our work to date in engaging patients and families in prioritizing research directions and identifying key outcomes for a program of research aimed at optimizing outcomes of child and youth mental health services, drawing upon lessons learned from shared decision making in the clinical context.

Poster Abstracts

1. Modelling mental health care pathways and services for capacity planning and policy decisions

Sarie Brice[1], Paul Harper[1], Daniel Gartner[1], Doris Behrens[2], Mark Mackay[3], Nigel Bean[4]
[1]Cardiff University, [2]Aneurin Bevan University Health Board - Aneurin Bevan Continuous improvement (ABCi), [3]Flinders University, [4]The University of Adelaide

Presented by Sarie Brice

Abstract

Mental health problems are a growing public health concern and are one of the main causes of the overall disease burden worldwide. Major depression is thought to be the second leading cause of disability and a major contributor to the burden of suicide and ischemic heart disease. It is estimated that 1 in 6 people in the past week experienced a common mental health problem.

Mental health is a complex condition that affects and is affected by various factors such as financial, social relationship, and physical health. Treating the disease involves several health care providers and resources. This complexity couples with issues such as lack of mental health literacy and results in a complex patient pathway accessing the service.

Unlike with other physical illnesses, people with mental health conditions often experience difficulty in accessing the health care services. This may due to stigmatisation, institutionally and socially, or simply not enough resources that can accommodate people with mental health conditions.

Many studies have used OR methods such as simulation to model healthcare services to optimise the flow of patients. However, only a few studies around mental health care services exist. The current study attempts to incorporate a range of health services from community level to acute care in hospital. The model will be designed using a combined paradigm. The human element will be modelled using an Agent-Based Modelling method. This will represent the patients with their mental health conditions. Their conditions will be linked to a network of services where the patients receive the treatment. Data is taken from Adelaide, Australia, as well as a local Health Board in South Wales, U.K. This will allow for a comparative study.

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2. Development of a scorecard for measuring care home quality

Philip Worrall, Thierry Chaussalet
University of Westminster

Presented by Thierry Chaussalet

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3. Emergency Readmission for Integrated Care (ERIC) Model: Using an Automated Feature Generation & a Multi-Task Learner

Mohsen Mesgarpour, Thierry Chaussalet, Philip Worrall, Salma Chahed
University of Westminster

Presented by Thierry Chaussalet

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4. Progression modelling of clinically-determined severity for dementia patient care planning

Dave Evenden[1], Chris Kipps[2], Sally Brailsford[1], Bronagh Walsh[1], Paul Roderick[2]
[1]University of Southampton, [2]University Hospital Southampton

Presented by Dave Evenden

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5. An exploration of standardised processes in a knowledge-intensive (healthcare) operation: Implementing the acute stroke care pathway

Marianna Frangeskou, Christos Vasilakis, Michael Lewis
University of Bath

Presented by Marianna Frangeskou

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6. Discrete Event Simulation of a Complex Continuing Care Ward with Bed Blocking

Sergei Gassan, Bojan Ramadanovic, Alexander Rutherford
Simon Fraser University

Presented by Sergei Gassan

Abstract

A discrete event simulation model was developed to understand the impact of resource allocation on access and quality of complex continuing care (CCC) in a community hospital. As opposed to following the mainstream approach of using a high-level simulation package, we developed a customized queue-based, event-driven simulation engine following the object-oriented paradigm. Such an approach offers much greater flexibility compared to standard simulation packages. This includes the ability to model arbitrary stochastic processes, such as non-Markovian processes, implement arbitrary queue priorities, and incorporate complex behaviour of agents. An additional benefit is that the simulation code can be used as a separate library module (black-box objective function) to build an optimization pipeline. Elimination of the overhead imposed by standard

simulation packages results in substantially better performance, which is crucial for such an optimization pipeline to run in reasonable time.

We applied our discrete event simulation engine to complex continuing care in a rural community hospital. Patients staying in a CCC ward can be discharged to longterm care (LTC), residential care, or to their own homes with or without nursing support. LTC is the only discharge location with limited capacity. Patients waiting for LTC continue to occupy CCC hospital beds for the duration of their wait, which is called bed blocking. This increases the wait times for admission to the CCC ward. Bed blocking may be reduced by redirection of some patients to other discharge locations. Our model was applied to analyze the combination of this approach with other strategies for improving access to care. As an example of our results, a 5% reduction in patients discharged to LTC leads to an improvement in access to CCC, which is equivalent to adding one extra bed in CCC.

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7. Evaluating the cost benefit of a remote cancer patient monitoring system in a single NHS Institution

Penny Kechagioglou
University Hospital Coventry and Warwickshire

Presented by Penny Kechagioglou

Abstract

Background: The study aims at evaluating a remote monitoring system for the care of cancer patients undergoing chemotherapy, in terms of its cost saving benefit for the National Health Service, based on data from a single healthcare organization. The rationale for this study is the increasing incidence of unnecessary cancer patient admissions to hospital during chemotherapy treatment, with significant economical burden for the NHS.

Methods: The standard model of care involving hospital in-patient monitoring is compared to the proposed model of care, which utilizes a remote patient monitoring (RPM) system. Secondary quantitative data collected from the organization under study are combined with published financial data and data from the RPM manufacturing company, in order to perform a forecast analysis of the financial benefit of the proposed model of care.

Results: The proposed RPM model of care is more cost-effective than the standard model of care, at least in the short-term (5 years), which is the limit of the forecast analysis in this study. Beyond the forecasted period, the sustainability of its economic benefit depends on volatile external factors, such as other technological innovations and economic circumstances.

Conclusion: Further research into the development of such remote monitoring model of care is needed, including qualitative analyses regarding patient quality of life and clinician satisfaction with the model.

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8. Decision making under uncertainty: A health care infrastructure scenario

Rudabeh Meskarian
CLAHRC Wessex, University of Southampton

Presented by Rudabeh Meskarian

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9. Novel mapping methods to visualise and understand referral data within community healthcare

Ryan Palmer, Martin Utley
University College London

Presented by Ryan Palmer

Abstract

Working alongside the North East London Foundation Trust (NELFT) we developed and applied novel mapping methods to better understand referrals within community services. Important dynamics to understand included, how patients concurrently used services, whether common patterns of referrals existed and how sequences of referrals occurred over time. Visually depicting this information helped to communicate this insight.

We first created a network depiction of referrals which highlighted the intensity and frequency of patient activity within the system as well as its complexity and vastness. In support, we plotted the time distribution of concurrent patient referrals at a population level – looking at how long patients remained in one, two, three, four, five and six or greater referrals at the same time. This showed how the number of patients requiring multiple treatments evolved over time and how subsequent referrals overlapped. Next, we analysed common sequences and patterns of referrals, looking at the mixture and order of services used by patients in groups of three, four and five referrals. This highlighted groups of services with high activity and correlation of referrals. Finally, we analysed how subsequent referrals developed for patients first referred to a given service.

In applying these methods, we helped to inform the design of NELFT's single point of access, providing insight into how referrals may be streamlined to improve patient access in considering areas of high activity formed of multiple services and the large volume of low activity referral paths.

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10. Modelling the benefits of radiographer-led discharge in emergency departments

Sebastian Rachuba[1], Lucy Ashton[2], Karen Knapp[2], Martin Pitt[2]
[1]NIHR PenCLAHRC, [2]University of Exeter

Presented by Sebastian Rachuba

Abstract

Diagnostic imaging services are essential to the diagnosis pathway for many patients arriving at hospital emergency departments with a suspected fracture. Commonly, if an X-Ray image has been taken, these patients need to be seen again by a doctor or emergency nurse practitioner in order finalise the diagnosis. This follow-up consultation also determines the next stage in the patients' pathway. Although the vast majority of patients are discharged, significant waiting times can accrue for these follow-up consultations after radiographic imaging because staff availability is highly constrained. Research evidence from pilot studies suggests that patients with minor appendicular injuries could be safely discharged by a qualified radiographer directly after imaging avoiding queues for repeated consultation. Our work links directly with an assessment of image interpretation competences of radiographers, emergency nurse practitioners and consultants in ED. In this study, we model patient pathways through an emergency department (ED) at a hospital in the South West of England using process mapping, interviews with ED staff and discrete event simulation (DES). The DES model provides a means to compare the current practice at the hospital's ED with scenarios of radiographer-led discharge of patients directly after imaging and assess the reduction in patients' length of stay in ED. We also quantify trade-offs between the provision of radiographer-led discharge and its effects, i.e. reduction in waiting times and ED workload. Finally, we discuss how this decision support tool can be used to support understanding for patients and members of staff.

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11. Generating virtual patients for discrete-event simulation from a small sample with categorical characteristics

Christina Saville, Honora Smith, Katarzyna Bijak
University of Southampton

Presented by Christina Saville

Abstract

Context: Healthcare services are increasingly tailored to individual patient needs in order to make the best use of limited resources. For example, risk tools assess the risk of a patient having a certain disease, based on their characteristics. One way of tailoring services in this case is to send those patients deemed at higher risk straight for diagnostic tests, while those at lower risk may be offered

an additional consultation. But how do such service changes affect costs and operational measures such as waiting times?

Need: Discrete-event simulation is commonly used to test the potential impact of service changes on performance measures. For the situation described above, it is necessary to generate virtual patients with different combinations of characteristics. The characteristics used in risk tools are typically categorical variables, for example age group or urgency, and are not necessarily independent. A further complication is that the available patient data may not contain all possible combinations of characteristics. Hence there is a need for methods that can create virtual patients with previously unseen combinations of categorical characteristics, where these variables may be dependent on each other.

Method: We propose an approach that meets this need. For this we demonstrate how a Poisson regression model can be fitted to counts in the contingency table of combinations. In particular, since we cannot use the large-sample chi-squared approximation for the Pearson goodness-of-fit statistic, we instead simulate distributions of this statistic. We illustrate our approach on a case study of a breast diagnostic clinic.

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12. Is it possible to plan and improve patient flow in a post term pregnancy clinic?

Tone Breines Simonsen[1], Hildegunn E. Faraas[1], Nina Schmidt[1], Joe Viana[2], Fredrik A. Dahl[1]
[1]Akershus University Hospital, [2]Oslo University Hospital and Akershus University Hospital

Presented by Tone Breines Simonsen

Abstract

Norwegian guidelines for post term pregnancies were changed in 2011. A pregnancy is defined as post term when the gestation period exceeds week 42. All women should be offered an ultrasound examination 7 – 9 days over the due date. The obstetrics department wanted to evaluate changes in patient flow in the post term pregnancy clinic due to introduction of these guidelines, especially the use of subsequent appointments.

It is a challenge to deliver the clinic due to variations in the length of the list, it can vary greatly, from 0 to >10 pregnant women each day. This variation arises due to many of the appointments being unused due to the expectant mothers giving birth before the appointment

In this ongoing project we will collect data on the patient flow from the hospitals electronic medical records system (DIPS). Data will be analysed to produce: i) patient arrival pattern, ii) process time distribution, and iii) staff schedules. This historical data will also be used to validate the simulation model. We are developing a hybrid simulation model, consisting of an agent based model

representation of the mothers and healthcare professional and discrete event simulation of the clinic's processes.

Preliminary results will be presented relating to three distinct periods: i) how it was before the guidelines were changed, ii) how it was after the guidelines changed and iii) the future, relating to selected "what-if" scenarios analyses. What-if scenarios such as: changes in the patients' demographic variables and arrival patterns, the proportion of mothers who are induced (linked to changes in the clinical criteria) and length of stay changes. Addition analysis at an organisational level will be performed focusing on for example: changes in the number health care staff and their skill mix and in the pathways and processes followed in the clinic.

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13. Are medical outliers associated with worse patient outcomes? An analysis of routinely collected data within a regional NHS hospital

Neophytos Stylianou[1], Robin Fackrell[2], Christos Vasilakis[1]
[1]University of Bath, [2]RUH

Presented by Neophytos Stylianou

Abstract

Background: Faced with ever increasing pressures, hospital bed managers often resort to placing patients on wards that are not designed for the type of care the patient requires. Evidence associating medical outliers, as these cases are often called, with patient outcomes are scarce with some small scale studies pointing towards a range of negative impacts on patient outcomes. This research aims to explore the quality of patients' healthcare provision by identifying whether being a medical outlier is associated with worse patient outcomes.

Methods: This is a retrospective cross-sectional observational study. Secondary data from a district general hospital were provided for the financial years 2013/14-2015/16. The data included 71,038 medical patient spells for the three year period. Univariate analysis was used to investigate any potential association and multivariate logistic regression and zero truncated negative binomial regression were used to explore patient outcomes (in-hospital mortality, 30-day mortality, readmissions and length of stay) while adjusting for several confounding factors

Results: Univariate analysis indicated that an outlying medical in-hospital patient has higher odds for readmission, double the odds of staying longer in the hospital but not significant difference in the odds of in-hospital and 30-day mortality. Multivariate analysis indicates that being a medical outlier

does not affect mortality outcomes or re-admission but is associated with longer length of stay in hospital.

Implications: This is the first quantitative study in England's NHS that investigates potential associations between medical outliers and patient outcomes. After adjusting for other factors, medical outliers are associated with an increased LOS while mortality or readmissions are not worse than patients treated in appropriate specialty wards. Hospitals may need to revisit their policies regarding outlying patients since increased length of stay is associated with an increased likelihood of harm events, worse quality of care and increased healthcare costs.

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14. Modelling the TB epidemic in South Africa

Riley Wishart[1], Alexander Rutherford[1], Brian Williams[2], Jf Williams[1]
[1]Simon Fraser University, [2]South African Centre for Epidemiological Modelling and Analysis

Presented by Riley Wishart

Abstract

Tuberculosis ranks alongside of HIV/AIDs as one of the deadliest infections in the world, killing 1.4 million people in 2015. The UN and the Stop TB Partnership have set goals to eliminate the TB epidemic by 2035. These goals require a 90% reduction in incidence and a 95% reduction in TB deaths from the 2015 baseline. As South Africa had one of the highest incident counts in 2015, significant progress is needed here to achieve the set targets.

To assess the strategies for epidemic control in South Africa, the Tuberculosis Incidence and Mortality Estimates (TIME) model was implemented in Matlab. The TIME model is a compartmental system of differential equations which was first developed in the Spectrum modelling suite to make disease burden predictions. This system separates the population into fifteen compartments to model the flow between the susceptible, latent, and infected populations. The latent and infected populations are subdivided by treatment history and by multi-drug-resistant status. The model also makes the distinction between sputum smear negative and sputum smear positive infections. This level of detail allows for relevant disease dynamics and control strategies to be captured in a realistic manner.

The TIME model was calibrated against the TB endemic in South Africa. The calibration used Matlab's pattern search algorithm to optimize a least squares fit between the model output and data obtained from the World Health Organization. Initial results indicate that increasing the TB screening rate would realistically drop incidence by at most 50% and mortality by at most 75% over the next 20 years. Consequently, additional improvements to the TB treatment and care continuum are required

to meet the Stop TB targets. Further analysis is ongoing to determine strategies for meeting these targets.

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15. Interactions between naturalistic decision making and computer simulation modelling in managing patient flow in hospitals

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