”Toy” Paediatric Critical Care Unit: Building a computer simulation to improve patient flow in a Scottish PCCU

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Introduction

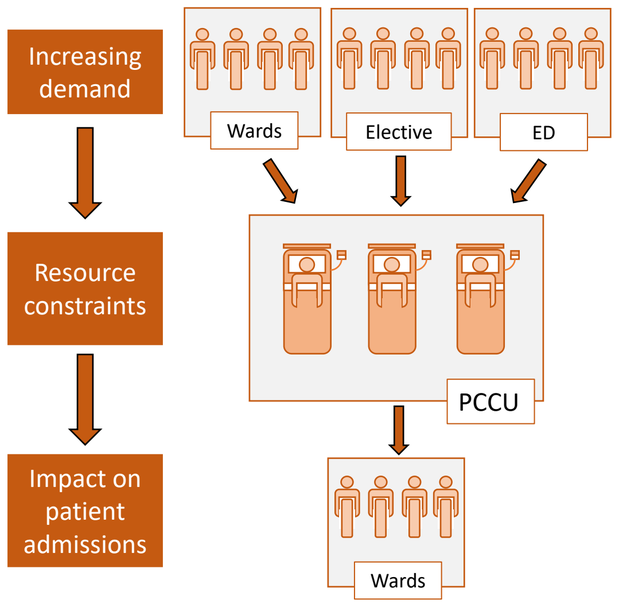
The Problem

In recent years, a Paediatric Critical Care (PCC) bed shortage has been reported[1]:

- Seasonal respiratory viral infections
- Increase in patients with multi-morbidities
- Staff shortages

The Solution

Computational simulation to model patient flows of patients requiring PCC.



AIMS

To create a computer simulation that:

- Is an accurate reflection of the real life operation of all units in the hospital directly relevant to PCC.
- Useable for bottleneck identification of patient flow through PCC and be flexible enough to be able to test different scenarios to remove/reduce bottlenecks.
- To be useable as a decision support tool in order to inform future planning.
- Useable for forecasting a short timeframe (24-48h) in advance to determine future patient flow/hospital capacity/staffing issues.

Simulation

The approach taken is that of a hybrid discrete event/agent-based simulation:

Structure

“Toy” simulation has been created to replicate RHSCE PCC (Fig. 1). Consists of a patient generator and two units: Paediatric Intensive Care (PICU) and the High Dependency Unit (HDU) as well as admissions and discharge.

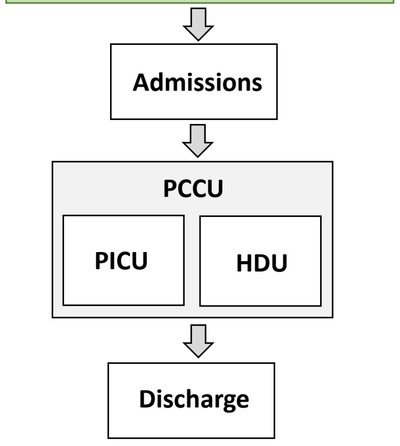


Figure 1: “Toy” simulation structure.

Simulation Controller

Discrete Event Simulation

System is modelled as a set of discrete events. Top-down approach to simulation:

- Handles high level tasks such as patient arrivals, staffing and scheduling.
- Allows for abstraction of some of the more complex tasks away from agent-based approach.

Patients

Uses real life arrival distributions.
Patient pathway generated on admission.
Assigned to staff on admission and during staff shift swaps based on staff skill sets.

Staffing

Staff scheduler developed to allow for realistic staffing patterns.

Agent Based Simulation

Simulation consists of “autonomous” agents and an environment. Bottom-up approach to simulation:

- Allows for more realistic modelling of human element[2].
- Agents make individual decisions and are required to communicated in order to complete tasks.

Agents

Clinicians, nurses, patients and equipment (e.g. beds).
Agents currently modelling as finite state machines although more complex models can be used.

Data

Project currently focused on using Royal Hospital for Sick Children Edinburgh (RHSCE) historical resource data.

Results

Simulated patient arrivals and Length Of Stay (LOS) inferred from routinely collected resource data.

Unit structure, resource allocation, staffing, communication and procedures currently developed using Subject Matter Expert (SMI) input.

The “Toy” simulation can be used to identify bottlenecks which may increase patient LOS/ reduce the number of patients able to access PCC and test scenarios to improve this in a reduced risk environment.

Next steps are to use routinely collected data to build the validated simulation of the RHSCE and to move to a more detailed set of clinical tasks as opposed to the highly aggregated tasks currently used.

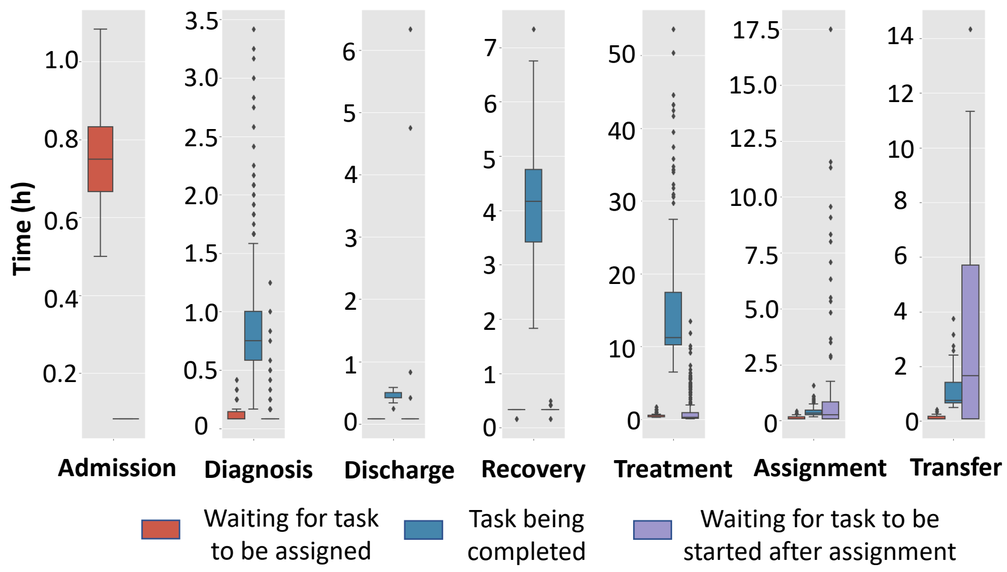


Figure 2: Example of “toy” simulation state execution times for each of the tasks in the individual patient admissions using synthetic simulation parameters over a three-month period.

Possible to identify bottlenecks to patient flow. In this example patients were unable to be efficiently transferred to the HDU and the root cause was identified as HDU staffing issues.

Conclusions

Patient flow is an important factor in overall hospital and hospital unit efficiency and improving it can increase the number of patients able to receive care while reducing key resource usages.

A hybrid DES/ABS is a good approach to incorporate more realistic human behavior and interaction without the challenges and drawbacks of using a pure agent-based approach.

Simulation can be used to understand and improve patient flow in a reduced-risk environment.

Further validation work needs to completed to prove the effectiveness of the approach.

References

[1] Wheeler DS, Dewan M, Maxwell A, Riley CL, Stalets EL. Staffing and workforce issues in the pediatric intensive care unit. Translational pediatrics. 2018 Oct;7(4):275

[2] Cabrera E, Taboada M, Iglesias ML, Epelde F, Luque E. Optimization of healthcare emergency departments by agent-based simulation. Procedia computer science. 2011 Jan 1;4:1880-9.

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