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THE DEVELOPMENT AND VALIDATION OF A NOVEL DISCRETE EVENT SIMULATION TOOL FOR MODELING THE OPERATIONAL EFFICIENCY OF INPATIENT ELECTROPHYSIOLOGY SERVICES

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BACKGROUND AND OBJECTIVES

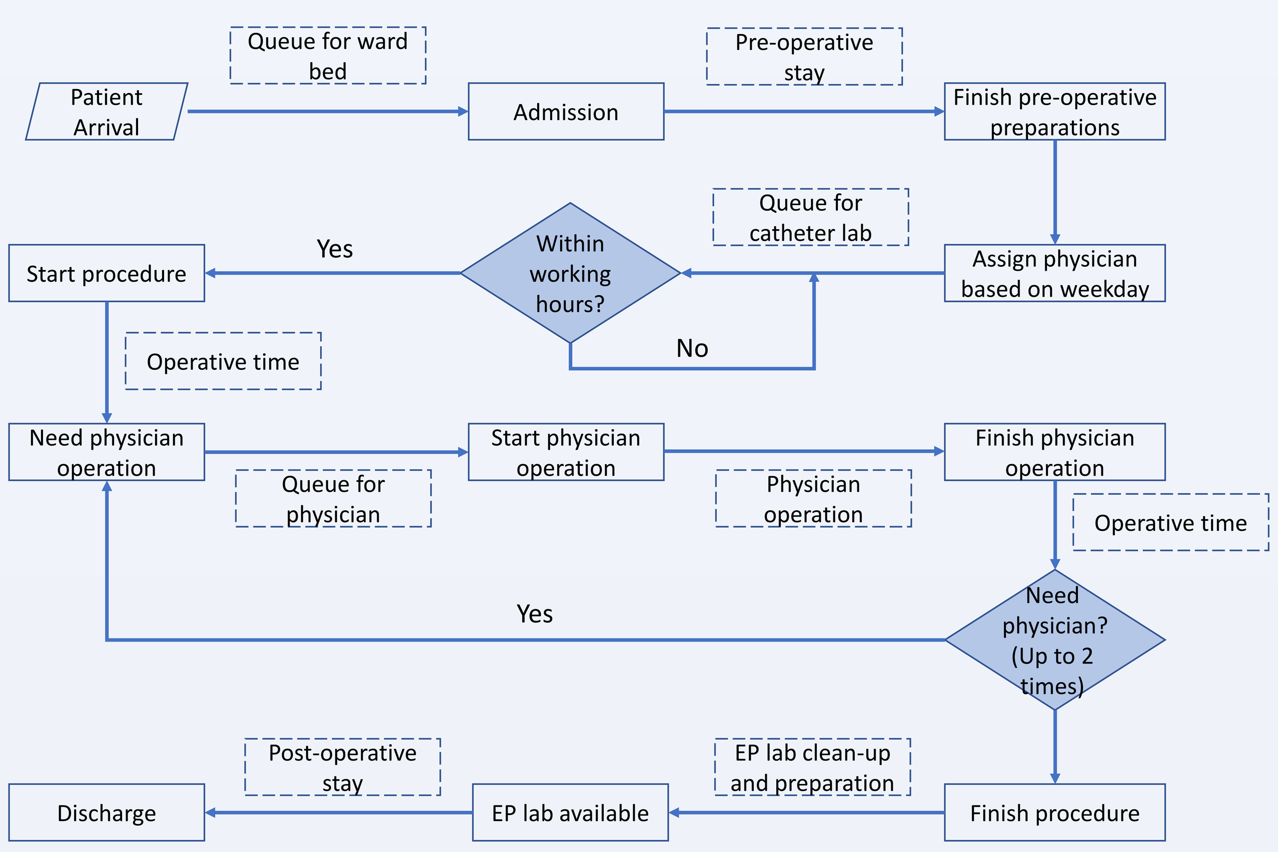
- Cardiac arrhythmias are irregularities in heart rate or rhythm, the severity of which range from asymptomatic to life-threatening, such as sudden cardiac arrest [1]. Cardiac arrhythmias can be treated by drugs, or electrophysiological (EP) treatment, such as ablation, cardiac pacing, and defibrillation [1]. The prevalence of major arrhythmias in the population is 1.7% in China [2].
- Atrial fibrillation (AFib) is the most common type of cardiac arrhythmias, and it is associated with increased risks of stroke, heart failure, dementia, and death [3-8]. The prevalence of Afib among the elderly population (>60 years) in China is projected to reach more than 8 million people by 2050 [9].
- Due to the aging population, the demand for inpatient EP treatment in China is proliferating, outpacing the growth of required healthcare resources. Overcrowding at large secondary and tertiary public hospitals has become a significant problem [10,11], while the rapid expansion of healthcare infrastructure is no longer feasible [12].
- Multiple operational and technological improvements may lead to different levels of operating efficiency improvement for EP centers.
- In this study, we developed and validated a discrete event simulation (DES) model for the inpatient care of EP patients. The model can track operational indicators, including the number of procedures, number of discharges, length of stay, etc. The model may serve as a tool for decision-makers to evaluate, compare, and prioritize different strategies to improve care delivery efficiency.

METHODS

Model Scope and Structure

- A DES model was built by incorporating and summarizing tertiary hospital clinicians' inputs to simulate the journey of the individual EP patient from admission through the EP procedure to discharge.
- Scheduling limited resources (beds, EP labs (assigned to EP procedures), electrophysiologists) was explicitly considered.
- EP patients who flow through the EP labs are the target EP patients. Other EP patients, who are treated in other labs not assigned to EP procedures, and non-EP patients compete for bed resources with the target EP patients.
- The process flow of target EP patients is shown in Figure 1.
- A randomly generated number of patients arrive each day before working hours. Patients are assigned to one of 8 EP procedures shown in Table 1.
- On the operative day, patients start to queue for an EP lab. Patients are assigned to an electrophysiologist according to the share of patients between different electrophysiologists on the weekday of the procedure.
- Once an EP lab is available, patients enter the lab to start the procedure.
- New procedures can only start during working hours, and no new procedures will begin after working hours. However, a procedure in process may run over working hours if it is not completed.
- After the procedure is completed, patients return to the ward. After clean-up and preparation for the next procedure, the EP lab becomes available again for the next patient.
- The patient is discharged after a period of post-operative recovery.

Figure 1. Target EP patient process flow



- For other EP patients and non-EP patients, the process is simpler. Patients are admitted if ward beds are available, and discharged after a hospitalization period.

Input data collection

- Model inputs were based on observed patient data from the Cardiology Department of the First Affiliated Hospital of Zhejiang University (CDFAHZU), collected from May 1st to May 30th, 2022.
- Collected data include dates of admission, procedure, and discharge; procedure types; assigned electrophysiologists; and start and end times of the procedures.
- Although patients were admitted daily, procedures were only performed on weekdays. We found that patients admitted on Thursdays and Fridays had a more extended total stay compared to other patients, with a difference of around two days. This was assumed to be caused by these patients having to wait two days over the weekend to receive the procedure. Therefore, the total length of stay and pre-operative stay parameters were based on patients admitted from Saturday to Wednesday.

Model validation

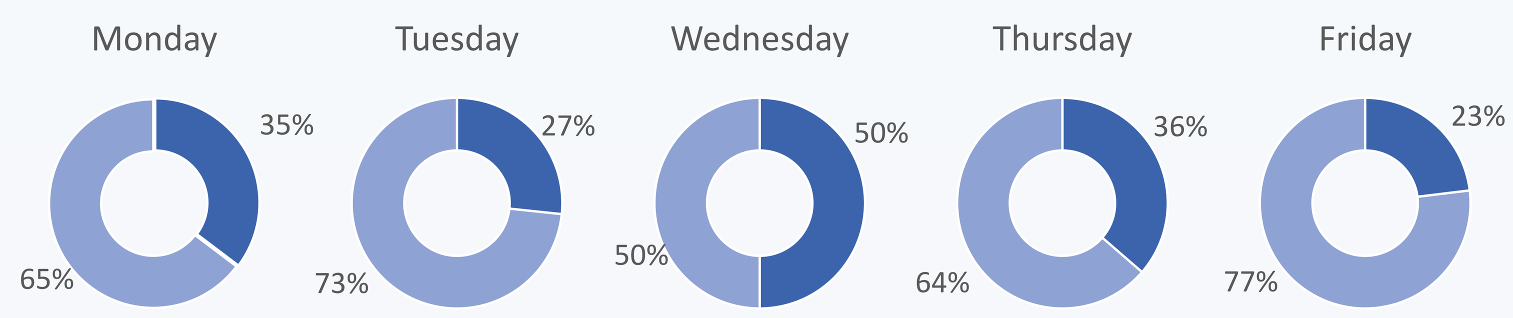
- The model tracked the daily number of procedures, the total length of stay of all target EP patients, and the total number of target EP patient discharges.
- Model validation was performed by comparing the mean simulation results from 1000 probabilistic runs with real-world target EP patient statistics from CDFAHZU.

RESULTS

Model parameters

- CDFAHZU has 87 beds and four catheterization laboratories, with two assigned to EP procedures. Beds are available 24 hours a day, while EP labs are only scheduled from 8:00-24:00 on weekdays.
- Two electrophysiologists (EPs) are on duty during the EP lab operation hours. The shares of patients between the two EPs each day are shown in Figure 2. Either EP on duty in the simulation may receive the heavier patient load randomly.

Figure 2. Average shares of patients between EPs on each weekday. EPs on duty in the simulation are equally likely to receive the heavier patient share on unevenly split days.



- Model parameters of the target EP patient's procedures are shown in Table 1. For other EP and non-EP patients, the means and standard deviations of their LOS are 4.32(2.79) and 3.31(1.95), respectively.

Table 1. Model inputs of target EP patient procedures

Procedure	Proportion	Total operative time, minutes Mean (SD)	Clean-up and preparation time, minutes Mean (SD)	Total length of stay, days Mean (SD)	Pre-operative stay, days Mean (SD)
Paroxysmal AFib ablation	23.19%	206.68 (61.68)	6.12 (5.42)	4.64 (1.63)	1.36 (0.67)
Persistant AFib ablation	8.70%	174.29 (23.35)	6.33 (4.41)	3.00 (0.00)	1.00 (0.00)
PVC ablation	23.19%	105.42 (40.84)	7.21 (5.18)	2.93 (1.33)	1.50 (0.65)
SVT ablation	15.94%	100.00 (41.12)	5.38 (2.79)	2.45 (0.69)	1.09 (0.30)
AFlutter/PAC/AT ablation	7.25%	225.86 (180.96)	10.40 (10.76)	2.25 (0.50)	1.00 (0.00)
Dual-chamber PM implant	2.90%	117.00 (12.53)	6.00 (5.66)	7.00 (0.00)	3.00 (0.00)
CRT PM implant	4.35%	224.00 (51.45)	5.00 (3.00)	6.67 (4.62)	3.00 (2.65)
Miscellaneous EP procedures	14.49%	91.33 (32.29)	6.36 (3.18)	3.00 (1.22)	1.40 (0.89)

AFib: atrial fibrillation; SVT: supraventricular tachycardia; PAC: premature atrial contraction; PM: pacemaker
PVC: premature ventricular complex; Aflutter: atrial flutter; AT: atrial tachycardia; CRT: cardiac resynchronization therapy

- The daily arrival inputs for the three patient types are shown in Table 2.

Table 2. Daily arrival number by patient type

Patient	Daily arrival, n Mean (SD)
Target EP patients	2.84 (2.58)
Other EP patients	3.12 (2.32)
Non-EP patients	14.16 (5.70)

Model Validation

- Simulated results are compared to real data in Table 3. All real-world average values used in the validation are within the 95% credible intervals (CrI) of simulation results.

Table 3. Validation results

Output	Simulated results		Real data
	Mean (SD)	95% CrI	Mean
Daily procedures, n	2.70 (0.45)	[1.87,3.58]	2.8
Total length of stay, days	3.79 (0.21)	[3.39,4.21]	3.89
Total discharges, n	76.42 (13.20)	[51.95,102.00]	77

CONCLUSIONS

- The DES model properly captured the cardiac EP patient journey, and the model simulation outputs were consistent with real-world observation.
- The DES model can be used as a strategic tool for evaluating initiatives to improve operational efficiency.

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DISCLOSURES

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