

Modelling the cost-effectiveness of strategies to treat end-stage heart failure using discrete event simulation

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Certificate of original authorship

I, Sopany Saing declare that this thesis, submitted in fulfilment of the requirements for the award of Doctor of Philosophy, Health Economics, in the Faculty of Business at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise reference or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis. This document has not been submitted for qualification at any other academic institution.

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Dissemination

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Abbreviations

ABM	Agent based modelling
ACT	Australian Capital Territory
AFT	accelerated failure time
AHF	advanced heart failure
AIC	Akaike's information criterion
AIHW	Australian Institute of Health and Welfare
ALOS	average length of stay
ANZCOTR	Australia and New Zealand Organ Transplant Registry
ANZOD	Australia and New Zealand Organ Donation
APDC	Admitted Patient Data Collection
AR-DRG	Australian Refined-Diagnosis Related Group
BIC	Bayesian information criterion
biVAD	biventricular assist device
BMI	body mass index
BTDB	British NHS Blood and Transplant Database
BTC	bridge to candidacy
BTR	bridge to recovery
BTT	bridge to transplant
C-Pulse	Extra-aortic counter pulsation device
CABG	coronary artery bypass grafting
CAV	cardiac allograft vasculopathy
CDRH	Center for Devices and Radiological Health
CHF	congestive heart failure
CRD	chronic renal dysfunction
CEA	cost-effectiveness analysis
CEAC	cost-effectiveness acceptability curve
CF	continuous-flow
CI	confidence interval
CRT	Cardiac Resynchronisation Therapy
CUA	cost-utility analysis
DCD	Donated after Circulatory Death
DES	Discrete event simulation
DPMP	Deceased organ donors per million population
DT	Destination Therapy
ECMO	extra-corporeal membrane oxygenation
EDDC	Emergency Department Data Collection
ESHF	End-Stage Heart Failure
EQ-5D	European Quality of Life-5 Dimensions
FDA	US Food and Drug Administration
GDP	Gross Domestic Product
HHT	Heterotopic heart transplants
HIV	Human Immunodeficiency Virus
HPV	Human Papilloma Virus
HR	hazard ratio
HRQOL	health related quality of life

HTx	Heart Transplant
HTA	Health Technology Assessment
HVAD	HeartWare™ HVAD™ System
IABP	intra-aortic balloon pump
ICD	Implantable Cardioverter Defibrillator
ICD-10-AM	International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Australian Modification
ICER	Incremental Cost-Effectiveness Ratio
ICU	intensive care unit
IDCM	idiopathic dilated cardiomyopathy
IDMT	inotrope-dependent medical therapy
IMACS	International Society for Heart and Lung Transplantation Registry for Mechanically Assisted Circulatory Support
INTERMACS	Interagency Registry for Mechanically Assisted Circulatory Support
IPD	Individual Patient Data
ISHLT	International Society for Heart & Lung Transplantation
ISPOR	International Society for Pharmacoeconomics and Outcomes Research
KCCQ	Kansas City Cardiomyopathy Questionnaire
KM	Kaplan-Meier
MCS	mechanical circulatory support
MedaMACS	Medical Arm of Mechanically Assisted Circulatory Support
MLWHFQ	Minnesota Living With Heart Failure Questionnaire
MM	Markov model
MSAC	Medical Services Advisory Committee
MVAD	HeartWare® Miniaturized Ventricular Assist Device (MVAD®)
n	number of observations
N	number of sample
N/A	Not Applicable
NHCDC	National Hospital Cost Data Collection
NICE	National Institute for Health and Care Excellence
NLG	Dutch Guilder
NS	not specified
NSW	New South Wales
NT	Northern Territory
NYHA	New York Heart Association
NZ	New Zealand
min	minimum
max	maximum
LVEF	left ventricular ejection fraction (%)
LTCS	long-term chronic support
LVAD	left ventricular assist device
LY	life year
LYG	life year gained
OHT	orthotopic heart transplant
OMM	Optimal Medical Management
PBAC	Pharmaceutical Benefits Advisory Committee
PF	pulsatile-flow
PH	proportional hazards

PMSI	Program for the Medicalisation of Information Systems
PPN	Project specific Person Number
PPP	purchasing power parity
PRA	panel reactive antibody
PSA	probabilistic sensitivity analysis
QALY	quality-adjusted life year
QALYG	Quality-adjusted life year gained
QLD	Queensland
QoL	quality of life
RCT	randomised controlled trial
REMATCH	Randomized Evaluation of Mechanical Assistance for the Treatment of Congestive Heart Failure
RR	Relative Risk
RVAD	Right ventricular assist device
UK	United Kingdom
UNOS	United Network of Organ Sharing
USA	United States of America
SA	South Australia
SD	Standard deviation
SE	standard error
SG	standard gamble
SHTAC	Southampton Health Technology Assessment Centre
SIMULATE	System, Interactions, Multilevel, Understanding, Loops, Agents, Time, Emergence
SMDM	Society for Medical Decision Making
SRTR	Scientific Registry of Transplant Recipients
SVHS	St. Vincent's Hospital Sydney
TAH	total artificial heart
TAS	Tasmania
TTO	time trade-off
VAD	ventricular assist device
VAS	visual analogue scale
VIC	Victoria
VOI	Value of Information
WA	Western Australia
WL	waiting list
WTP	willingness to pay

Abstract

The cost of providing healthcare is increasing due to an ageing population and new technologies, hence the assessments of value for money are becoming more important. Health Technology Assessment (HTA) is an approach to estimate the cost-effectiveness of treatment strategies to assist in decision-making.

However, resource constraints are not usually explicitly considered in HTA. For example, if a patient requires a new drug, it is assumed that that resource is available immediately, without delay to the patient. Queues and waiting lists are commonplace in health care; for instance, patients in an emergency department waiting room or the waiting list for elective surgery. Not incorporating queuing theory into HTA is likely to be an issue if the consequences of delayed treatment significantly affect a patient's morbidity and mortality.

A case-study in end-stage heart failure is utilised to explore the restrictions faced by patients as they enter the heart transplant (HTx) waiting list due to the shortage of donor organs. Unique to organ donation is the matching process, whereby patients are matched to a donor heart based on blood type and weight rather than a simple first-come first-served basis. Additionally, artificial implantable devices, such as a left ventricular assist device, can buy patients more time on the waiting list or allow patients to become eligible for a HTx when used as a bridge to candidacy.

This thesis explicitly considers a resource constrained HTA by applying queuing theory using discrete event simulation (DES). A dynamic simulation modelling method, DES models queues representing the competition between patients for resources. This study used real-world data from an Australian transplanting hospital to inform the modelling. The results of a DES model with and without queuing are compared with a traditional cohort Markov model to explore the impact of the modelling methods on decision-making.