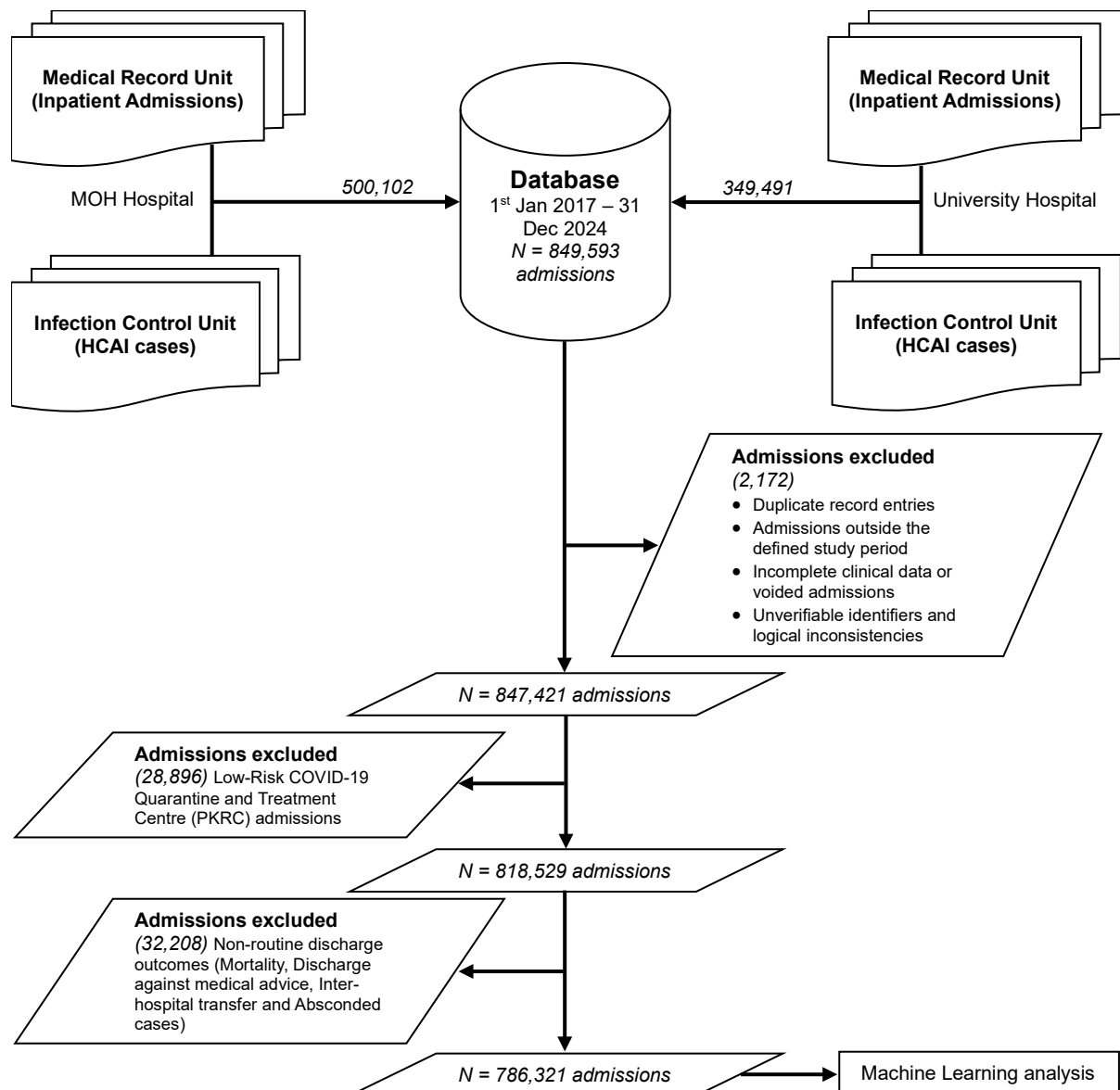
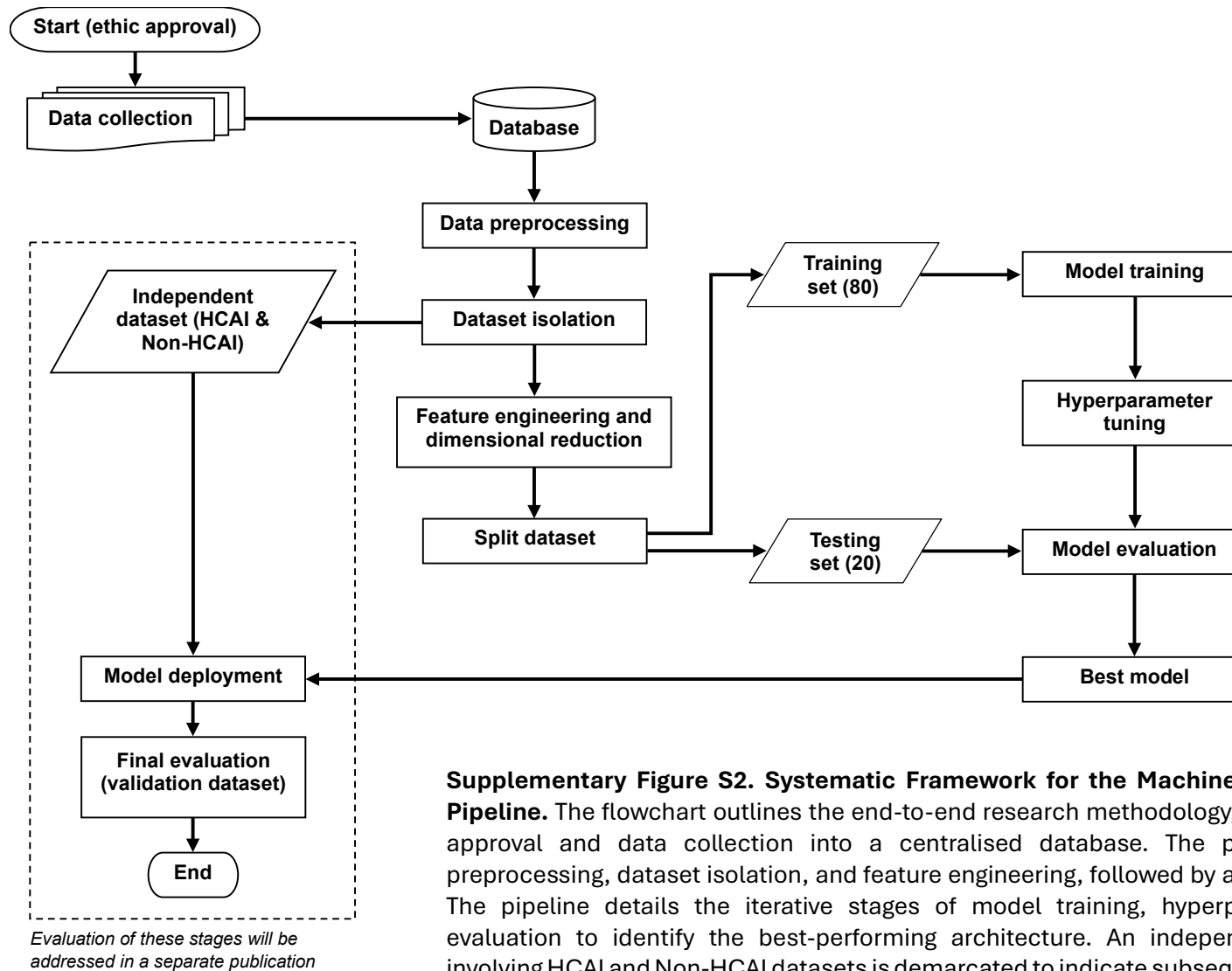


Supplementary Information



Supplementary Figure S1. Flowchart of the admissions data selection process. The diagram illustrates the systematic workflow of data acquisition and exclusion criteria applied to the 8-year retrospective dataset. Inpatient admission and healthcare-associated infection (HCAI) records were merged from the Ministry of Health (MOH) and University Hospital databases, yielding an initial cohort of 849,593 admissions. Following the exclusion of duplicate or incomplete records ($n = 2,172$), low-risk COVID-19 quarantine cases ($n = 28,896$), and non-routine discharge outcomes such as mortality or absconded cases ($n = 32,208$), a final analytic sample of 786,321 admissions was retained for machine learning analysis. *MOH* Ministry of Health, *HCAI* Healthcare-Associated Infection, *PKRC* Low-Risk COVID-19 Quarantine and Treatment Centre, *N* Number of admissions.



Supplementary Figure S2. Systematic Framework for the Machine Learning Regression Pipeline. The flowchart outlines the end-to-end research methodology, beginning with ethical approval and data collection into a centralised database. The process includes data preprocessing, dataset isolation, and feature engineering, followed by an 80/20 train-test split. The pipeline details the iterative stages of model training, hyperparameter tuning, and evaluation to identify the best-performing architecture. An independent validation stage involving HCAI and Non-HCAI datasets is demarcated to indicate subsequent evaluation phases addressed in related work.

Supplementary Table S1. ICD-10 Diagnosis Feature Blocks (215 Blocks)

No.	ICD-10 Block	Description
1	A00-A09	Intestinal infectious diseases
2	A15-A19	Tuberculosis
3	A20-A28	Certain zoonotic bacterial diseases
4	A30-A49	Other bacterial diseases
5	A50-A64	Infections with a predominantly sexual mode of transmission
6	A65-A69	Other spirochaetal diseases
7	A70-A74	Other diseases caused by chlamydiae
8	A75-A79	Rickettsioses
9	A80-A89	Viral infections of the central nervous system
10	A90-A99	Arthropod-borne viral fevers and viral haemorrhagic fevers
11	B00-B09	Viral infections characterized by skin and mucous membrane lesions
12	B15-B19	Viral hepatitis
13	B20-B24	Human immunodeficiency virus [HIV] disease
14	B25-B34	Other viral diseases
15	B35-B49	Mycoses
16	B50-B64	Protozoal diseases
17	B65-B83	Helminthiasis
18	B85-B89	Pediculosis, acariasis and other infestations
19	B90-B94	Sequelae of infectious and parasitic diseases
20	B95-B98	Bacterial, viral and other infectious agents
21	B99-B99	Other infectious diseases
22	C00-C97	Malignant neoplasms
23	D00-D09	In situ neoplasms
24	D10-D36	Benign neoplasms
25	D37-D48	Neoplasms of uncertain or unknown behaviour
26	D50-D53	Nutritional anaemias
27	D55-D59	Haemolytic anaemias
28	D60-D64	Aplastic and other anaemias
29	D65-D69	Coagulation defects, purpura and other haemorrhagic conditions
30	D70-D77	Other diseases of blood and blood-forming organs
31	D80-D89	Certain disorders involving the immune mechanism
32	E00-E07	Disorders of thyroid gland
33	E10-E14	Diabetes mellitus
34	E15-E16	Other disorders of glucose regulation and pancreatic internal secretion
35	E20-E35	Disorders of other endocrine glands
36	E40-E46	Malnutrition
37	E50-E64	Other nutritional deficiencies
38	E65-E68	Obesity and other hyperalimentation
39	E70-E90	Metabolic disorders
40	F00-F09	Organic, including symptomatic, mental disorders
41	F10-F19	Mental and behavioural disorders due to psychoactive substance use

42	F20-F29	Schizophrenia, schizotypal and delusional disorders
43	F30-F39	Mood [affective] disorders
44	F40-F48	Neurotic, stress-related and somatoform disorders
45	F50-F59	Behavioural syndromes associated with physiological disturbances
46	F60-F69	Disorders of adult personality and behaviour
47	F70-F79	Mental retardation
48	F80-F89	Disorders of psychological development
49	F90-F98	Behavioural and emotional disorders with onset usually in childhood
50	F99	Unspecified mental disorder
51	G00-G09	Inflammatory diseases of the central nervous system
52	G10-G14	Systemic atrophies affecting the central nervous system
53	G20-G26	Extrapyramidal and movement disorders
54	G30-G32	Other degenerative diseases of the nervous system
55	G35-G37	Demyelinating diseases of the central nervous system
56	G40-G47	Episodic and paroxysmal disorders
57	G50-G59	Nerve, nerve root and plexus disorders
58	G60-G64	Polyneuropathies and other disorders of the peripheral nervous system
59	G70-G73	Diseases of the myoneural junction and muscle
60	G80-G83	Cerebral palsy and other paralytic syndromes
61	G90-G99	Other disorders of the nervous system
62	H00-H06	Disorders of the eyelid, lacrimal system and orbit
63	H10-H13	Disorders of the conjunctiva
64	H15-H22	Disorders of the sclera, cornea, iris and ciliary body
65	H25-H28	Disorders of lens
66	H40-H42	Glaucoma
67	H43-H45	Disorders of vitreous body and globe
68	H46-H48	Disorders of optic nerve and visual pathways
69	H49-H52	Disorders of ocular muscles, binocular movement, accommodation and refraction
70	H53-H54	Visual disturbances and blindness
71	H55-H59	Other disorders of eye and adnexa
72	H60-H62	Diseases of external ear
73	H65-H75	Diseases of middle ear and mastoid
74	H80-H83	Diseases of inner ear
75	H90-H95	Other disorders of ear
76	I00-I02	Acute rheumatic fever
77	I05-I09	Chronic rheumatic heart diseases
78	I10-I15	Hypertensive diseases
79	I20-I25	Ischaemic heart diseases
80	I26-I28	Pulmonary heart disease and diseases of pulmonary circulation
81	I30-I52	Other forms of heart disease
82	I60-I69	Cerebrovascular diseases
83	I70-I79	Diseases of arteries, arterioles and capillaries
84	I80-I89	Diseases of veins, lymphatic vessels and lymph nodes, NEC
85	I95-I99	Other and unspecified disorders of the circulatory system

86	J00-J06	Acute upper respiratory infections
87	J09-J18	Influenza and pneumonia
88	J20-J22	Other acute lower respiratory infections
89	J30-J39	Other diseases of the upper respiratory tract
90	J40-J47	Chronic lower respiratory diseases
91	J60-J70	Lung diseases due to external agents
92	J80-J84	Other respiratory diseases principally affecting the interstitium
93	J85-J86	Suppurative and necrotic conditions of the lower respiratory tract
94	J90-J94	Other diseases of the pleura
95	J95-J99	Other diseases of the respiratory system
96	K00-K14	Diseases of the oral cavity, salivary glands and jaws
97	K20-K31	Diseases of the oesophagus, stomach and duodenum
98	K35-K38	Diseases of the appendix
99	K40-K46	Hernia
100	K50-K52	Non-infective enteritis and colitis
101	K55-K63	Other diseases of the intestines
102	K65-K67	Diseases of the peritoneum
103	K70-K77	Diseases of the liver
104	K80-K87	Disorders of the gallbladder, biliary tract and pancreas
105	K90-K93	Other diseases of the digestive system
106	L00-L08	Infections of the skin and subcutaneous tissue
107	L10-L14	Bullous disorders
108	L20-L30	Dermatitis and eczema
109	L40-L45	Papulosquamous disorders
110	L50-L54	Urticaria and erythema
111	L55-L59	Radiation-related disorders of the skin and subcutaneous tissue
112	L60-L75	Disorders of skin appendages
113	L80-L99	Other disorders of the skin and subcutaneous tissue
114	M00-M25	Arthropathies
115	M30-M36	Systemic connective tissue disorders
116	M40-M54	Dorsopathies
117	M60-M79	Soft tissue disorders
118	M80-M94	Osteopathy and chondropathy
119	M95-M99	Other disorders of the musculoskeletal system and connective tissue
120	N00-N08	Glomerular diseases
121	N10-N16	Renal tubulo-interstitial diseases
122	N17-N19	Renal failure
123	N20-N23	Urolithiasis
124	N25-N29	Other disorders of the kidney and ureter
125	N30-N39	Other diseases of the urinary system
126	N40-N51	Diseases of male genital organs
127	N60-N64	Disorders of the breast
128	N70-N77	Inflammatory diseases of the female pelvic organs
129	N80-N98	Noninflammatory disorders of the female genital tract

130	N99	Postprocedural disorders of the genitourinary system
131	O00-O08	Pregnancy with abortive outcome
132	O10-O16	Oedema, proteinuria and hypertensive disorders in pregnancy/childbirth
133	O20-O29	Other maternal disorders predominantly related to pregnancy
134	O30-O48	Maternal care related to the foetus, amniotic cavity and delivery problems
135	O60-O75	Complications of labour and delivery
136	O80-O84	Delivery
137	O85-O92	Complications predominantly related to the puerperium
138	O94-O99	Other obstetric conditions, not elsewhere classified
139	P00-P04	Foetus and newborn affected by maternal factors and complications
140	P05-P08	Disorders related to the length of gestation and foetal growth
141	P10-P15	Birth trauma
142	P20-P29	Respiratory and cardiovascular disorders specific to the perinatal period
143	P35-P39	Infections specific to the perinatal period
144	P50-P61	Haemorrhagic and haematological disorders of the foetus and newborn
145	P70-P74	Transitory endocrine and metabolic disorders specific to the newborn
146	P75-P78	Digestive system disorders of the foetus and newborn
147	P80-P83	Conditions involving the integument and temperature regulation of the newborn
148	P90-P96	Other disorders originating in the perinatal period
149	Q00-Q07	Congenital malformations of the nervous system
150	Q10-Q18	Congenital malformations of the eye, ear, face and neck
151	Q20-Q28	Congenital malformations of the circulatory system
152	Q30-Q34	Congenital malformations of the respiratory system
153	Q35-Q37	Cleft lip and cleft palate
154	Q38-Q45	Other congenital malformations of the digestive system
155	Q50-Q56	Congenital malformations of genital organs
156	Q60-Q64	Congenital malformations of the urinary system
157	Q65-Q79	Congenital malformations and deformations of the musculoskeletal system
158	Q80-Q89	Other congenital malformations
159	Q90-Q99	Chromosomal abnormalities, NEC
160	R00-R09	Symptoms and signs involving the circulatory and respiratory systems
161	R10-R19	Symptoms and signs involving the digestive system and abdomen
162	R20-R23	Symptoms and signs involving the skin and subcutaneous tissue
163	R25-R29	Symptoms and signs involving the nervous and musculoskeletal systems
164	R30-R39	Symptoms and signs involving the urinary system
165	R40-R46	Symptoms and signs involving cognition, perception and behaviour
166	R47-R49	Symptoms and signs involving speech and voice
167	R50-R69	General symptoms and signs
168	R70-R79	Abnormal findings on examination of blood, without diagnosis
169	R80-R82	Abnormal findings on examination of urine, without diagnosis
170	R83-R89	Abnormal findings on examination of other body fluids/organs
171	R90-R94	Abnormal findings on diagnostic imaging/function studies
172	R95-R99	Ill-defined and unknown causes of mortality
173	S00-S09	Injuries to the head

174	S10-S19	Injuries to the neck
175	S20-S29	Injuries to the thorax
176	S30-S39	Injuries to the abdomen, lower back, lumbar spine and pelvis
177	S40-S49	Injuries to the shoulder and upper arm
178	S50-S59	Injuries to the elbow and forearm
179	S60-S69	Injuries to the wrist and hand
180	S70-S79	Injuries to the hip and thigh
181	S80-S89	Injuries to the knee and lower leg
182	S90-S99	Injuries to the ankle and foot
183	T00-T07	Injuries involving multiple body regions
184	T08-T14	Injuries to the unspecified part of the trunk, limb or body region
185	T15-T19	Effects of a foreign body entering through a natural orifice
186	T20-T32	Burns and corrosions
187	T20-T25	Burns and corrosions of the external body surface
188	T26-T28	Burns and corrosions confined to the eye and internal organs
189	T29-T32	Burns and corrosions of multiple and unspecified body regions
190	T33-T35	Frostbite
191	T36-T50	Poisoning by drugs, medicaments and biological substances
192	T51-T65	Toxic effects of substances, chiefly nonmedicinal in source
193	T66-T78	Other and unspecified effects of external causes
194	T79	Certain early complications of trauma
195	T80-T88	Complications of surgical and medical care, NEC
196	T90-T98	Sequelae of injuries, of poisoning and of other consequences
197	U04-U86	Codes for special purposes (incl. COVID-19 and AMR)
198	V01-X59	Accidents
199	X60-X84	Intentional self-harm
200	X85-Y09	Assault
201	Y10-Y34	Event of undetermined intent
202	Y35-Y36	Legal intervention and operations of war
203	Y40-Y84	Complications of medical and surgical care
204	Y85-Y89	Sequelae of external causes of morbidity and mortality
205	Y90-Y98	Supplementary factors related to causes of morbidity/mortality
206	Z00-Z13	Persons encountering health services for examination and investigation
207	Z14-Z15	Genetic carrier and genetic susceptibility to disease
208	Z16-Z19	Resistance to antimicrobial drugs
209	Z20-Z29	Persons with potential health hazards related to communicable diseases
210	Z30-Z39	Persons encountering health services in circumstances related to reproduction
211	Z40-Z54	Persons encountering health services for specific procedures and health care
212	Z55-Z65	Persons with potential health hazards related to socioeconomic/psychosocial factors
213	Z66-Z68	Do-not-resuscitate status and Body Mass Index [BMI]
214	Z70-Z76	Persons encountering health services in other circumstances
215	Z77-Z99	Persons with potential health hazards related to family/personal history

Supplementary Table S2. ICD-9-CM Procedure Feature Blocks (16 Blocks)

No.	ICD-9-CM-Range	Description
1	00-05	Operations on the nervous system
2	06-07	Operations on the endocrine system
3	08-16	Operations on the eye
4	18-20	Operations on the ear
5	21-29	Operations on the nose, mouth, and pharynx
6	30-34	Operations on the respiratory system
7	35-39	Operations on the cardiovascular system
8	40-41	Operations on the hemic and lymphatic system
9	42-54	Operations on the digestive system
10	55-59	Operations on the urinary system
11	60-64	Operations on the male genital organs
12	65-71	Operations on the female genital organs
13	72-75	Obstetrical procedures
14	76-84	Operations on the musculoskeletal system
15	85-86	Operations on the integumentary system (Skin and Breast)
16	87-99	Miscellaneous diagnostic and therapeutic procedures

Supplementary Table S3. Feature Refinement via Elastic Net Regularisation

Rank	Top Positive Predictors (Increase LOS)	Weight (<i>B</i>)	Top Negative Predictors (Decrease LOS)	Weight (<i>B</i>)
1	F20-F29 (Schizophrenia & Delusional Disorders)	2.052	Type of ward	-1.300
2	Public Holiday Duration: 3 days	1.939	P50-P61 (Perinatal Haematological Disorders)	-0.668
3	Public Holiday Duration: 4 days	1.535	Z30-Z39 (Reproduction-related Health Services)	-0.617
4	Public Holiday Duration: 5 days	1.247	O80-O84 (Obstetric Delivery Outcomes)	-0.364
5	P05-P08 (Foetal Growth & Gestation Disorders)	1.014	U04-U86 (Emergency/Special Use (Including COVID-19))	-0.234

The table displays the top five positive and negative predictors of hospital Length of Stay (LOS) as identified through Elastic Net regression analysis. Positive weights (*B*) indicate features associated with increased LOS, such as specific ICD-10 diagnostic blocks and extended public holiday durations. Conversely, negative weights represent features associated with shorter hospital stays. This regularisation process served to refine the feature set by penalising less significant variables, contributing to the overall interpretability of the predictive model.

Supplementary Table S4. Optimised Hyperparameter Configuration for Predictive LOS Machine Learning Regression Models

DTR	ENR	RFR	XGBR
Criteria: squared error	alpha: 0.001	n_estimators: 200	n_estimators: 100
Min sample leaf: 0.00759	l1 ratio: 1.0 (Lasso)	Max features: 0.5	Learning rate: 0.3
Min sample split: 0.00183	Selection: cyclic Max iter: 1,000	Min samples leaf: 0.00508 Min samples split: 0.00631	Max depth: 6

This table details the specific hyperparameter settings selected for each machine learning algorithm to ensure optimal predictive performance and prevent overfitting during the model training phase. These configurations were determined through iterative tuning and evaluation of the training dataset. *DTR* Decision Tree Regression, *ENR* ElasticNet Regression, *RFR* Random Forest Regression, *XGBR* eXtreme Gradient Boosting Regression.