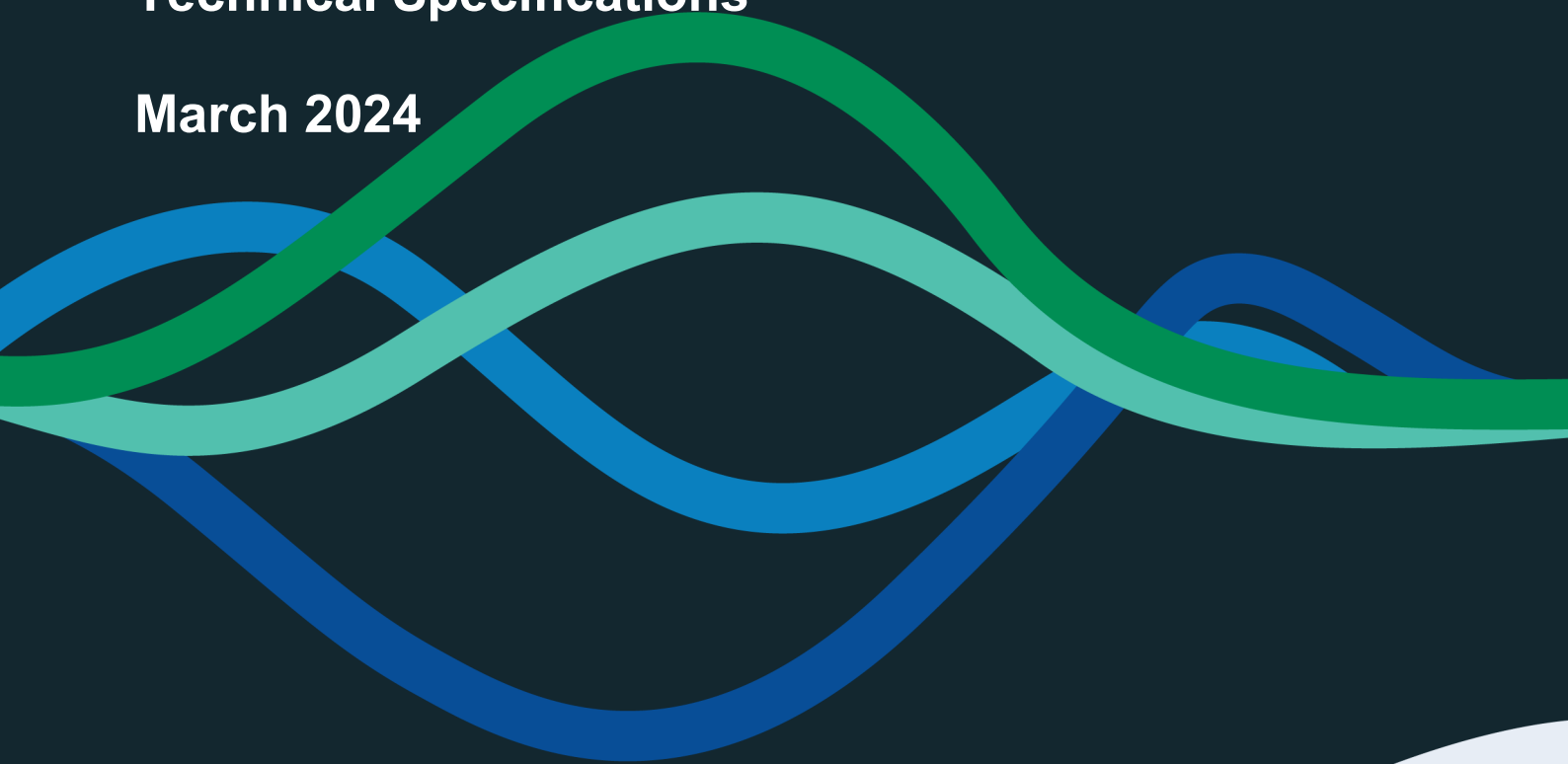
National Pricing Model 2024-25

Risk adjustments for avoidable hospital readmissions

Technical Specifications

March 2024



IHACPA

National Pricing Model 2024-25 – Risk adjustments for avoidable hospital readmissions – Technical Specifications – March 2024

1. Executive Summary

1.1. Purpose

This document has been produced as an accompaniment to the National Efficient Price 2024-25 (NEP24). It provides the technical specifications for how the Independent Health and Aged Care Pricing Authority (IHACPA) developed the avoidable hospital readmissions funding approach and risk adjustment methodology. It also provides guidance to hospitals, local hospital networks (LHNs) and state and territory health authorities on how to apply these to hospital activity.

1.2. Risk adjustment

In accordance with the Addendum to the National Health Reform Agreement 2020-25 (the Addendum), IHACPA was required to develop a pricing model for avoidable hospital readmissions for implementation from 1 July 2021, following approval from the Council of Australian Governments (COAG) Health Council.

1.2.1. Scope

Following analysis and consultation with jurisdictional stakeholders, IHACPA developed the risk model with the intention of it applying the funding adjustment to readmissions that have occurred within the same jurisdiction, using the available Medicare PIN until a nationally consistent Individual Healthcare Identifier (IHI) is available. Medicare PIN is a unique identifier for individuals that is used as a key by IHACPA when determining which hospital episodes are readmissions. Identifying readmissions occurring at a jurisdictional level will allow for the best coverage of readmission episodes and a more robust validation of available data.

1.2.2. Funding option

IHACPA undertook analysis of the funding impacts of several options presented in the 'Consultation paper for the pricing framework for Australian public hospital services 2021-22'. Following the results of this analysis and stakeholder feedback, IHACPA has determined that the readmission funding adjustment will be to deduct the cost of the readmission episode from the index episode. The meaning of this is discussed in further detail in this specification.

1.2.3. Risk adjustment model

The initial risk adjustment model used in development of the readmissions pricing model was a logistic regression model, similar to the hospital acquired complications (HACs) risk adjustment model. To improve the model, IHACPA evaluated logistic regression modelling, and developed and trialled a new risk adjustment model based on gradient boosting decision trees. Using existing and refined performance metrics, this new model showed substantial improvement in performance and better fit to data than the previous logistic regression model.

The final gradient boosting decision tree model has been endorsed by the University of Melbourne and IHACPA has implemented this model. A risk adjustment model has been derived for each readmission condition, which assigns the risk of being readmitted for each episode of care, based on 'feature importance', that is, the most clinically significant and best performing risk factors.

1.2.4. Inclusions/exclusions

The Commission initially developed the specification for a hospital level approach using facility-specific identifiers, leading to transfers not being flagged as readmissions. However, during

IHACPA's assessment of funding impacts with an expanded scope, episodes where patients were transferred elsewhere after the index admission were being flagged as a readmission.

Due to this, IHACPA will continue utilising the definition and specifications developed by the Commission, but will trim transfer episodes from the readmissions. IHACPA will also provide data to the jurisdictions indicating how many episodes are affected and the specific episodes trimmed from the readmission counts.

1.2.5. Risk factors

A set of risk factors has been developed for each individual readmission category in the risk adjustment model. This means each readmission category has a tailored risk adjustment model based on risk factors that are highly relevant to the readmission condition. The risk factors for each readmission category were selected based on clinical relevance and statistical performance, using the feature importance breakdowns. The risk factors are discussed further in Section 7.

Contents

Acronyms and abbreviations

APC NMDS	Admitted patient care national minimum data set
AR-DRG	Australian refined diagnosis related group
COAG	Council of Australian Governments
COF	Condition onset flag
Commission	Australian Commission on Safety and Quality in Health Care
GWAU	Gross weighted activity unit
HACs	Hospital acquired complication, as defined by the Commission
LHN	Local hospital network
ICD-10-AM	International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Australian Modification
ICU	Intensive care unit
IHACPA	Independent Health and Aged Care Pricing Authority
IHI	Individual Healthcare Identifier
MDC	Major diagnostic category
NEC	National efficient cost
NEP	National efficient price
NHCDC	National hospital cost data collection
NMDS	National minimum data set
NWAU	National weighted activity unit
PRC	Precision recall curves
ROC	Receiver operating characteristic
SEIFA	Socio-economic indexes for areas

2. Introduction

2.1. Purpose

This document has been produced as an accompaniment to the National Efficient Price 2024-25 (NEP24). It provides the technical specifications for how the Independent Health and Aged Care Pricing Authority (IHACPA) developed the avoidable hospital readmissions funding approach and risk adjustment methodology. It also provides guidance to hospitals, local hospital networks (LHNs) and state and territory health authorities on how to apply these to hospital activity.

2.2. Background

In early 2016, the Commonwealth Government and state and territory governments signed a Heads of Agreement that committed to improving the health outcomes of all Australians and ensuring the sustainability of the Australian health system. The Heads of Agreement required governments, in conjunction with IHACPA and the Commission, to develop 'a comprehensive and risk-adjusted model to integrate safety and quality into hospital pricing and funding' for 'a set of agreed hospital acquired conditions' to improve health outcomes and decrease avoidable demand for public hospital services.

In May 2020, all Australian governments signed the new Addendum to the National Health Reform Agreement (the Addendum), under which IHACPA is required to develop a pricing model for avoidable hospital readmissions, for implementation from 1 July 2021, following approval from the Council of Australian Governments (COAG) Health Council.

The implementation of pricing and funding for safety and quality has been introduced on a staged basis. Funding adjustments related to sentinel events were introduced in July 2017, followed by funding adjustments for HACs in July 2018. In July 2019, IHACPA commenced a shadow period to analyse funding options for reducing avoidable hospital readmissions.

The Commission was tasked with developing and maintaining a nationally consistent definition of avoidable hospital readmissions. The list of clinical conditions considered as avoidable hospital readmissions was approved by the Australian Health Ministers' Advisory Council (AHMAC) in June 2017.

The shadow period incorporated the following funding options across hospital, LHN and jurisdiction levels:

- Option one: Deduct the price of the readmission episode from the index episode
- Option two: Combine the index and readmission episodes and recalculate the price of the combined episode
- Option three: Adjust funding at the hospital level where actual rates of avoidable readmissions exceed expected rates of avoidable readmissions.

IHACPA has provided detailed reports to its Jurisdictional Advisory Committee (JAC), Technical Advisory Committee (TAC) and Clinical Advisory Committee on the activity and funding impacts of the funding options.

3. Model specifications

3.1. Avoidable hospital readmission conditions

Unplanned hospital readmissions are a measure of potential issues with the quality, continuity and integration of care provided to patients during or subsequent to their original hospital admission (the index admission).

The criteria used by the Commission states that clinical conditions must be:

1. Related to the index admission.
2. Avoidable by improved clinical management in the index admission and/or suitable discharge planning and follow-up.
3. Measurable through coded data generated from the patient medical record.

In June 2017, AHMAC approved the list of avoidable hospital readmissions developed by the Commission. The Commission released Version 2.0 of the list in May 2022. Table 1 presents the AHMAC approved list of avoidable hospital readmissions and readmission diagnoses, together with the condition-specific readmissions intervals.

Table 1: List of avoidable hospital readmissions and readmission intervals

Readmission condition	Readmission diagnosis	Readmission interval
1. Pressure injury	Stage III ulcer	14 days
	Stage IV ulcer	7 days
	Unspecified decubitus and pressure area	14 days
	Unstageable pressure injury	14 days
	Suspected deep tissue injury, depth unknown	14 days
2. Infections	Urinary tract infection	7 days
	Surgical site infection	30 days
	Pneumonia	7 days
	Blood stream infection	2 days
	Central line and peripheral line associated blood stream infection	2 days
	Multi-resistant organism	2 days
	Infection associated with devices, implants and grafts	90 days
	Infection associated with devices, implants and grafts in genital tract or urinary system	30 days
	Infection associated with peritoneal dialysis catheter	2 days
	Gastrointestinal infections	28 days
	Other high impact infections	2 days
3. Surgical complications	Postoperative haemorrhage/haematoma	28 days
	Surgical wound dehiscence	28 days
	Anastomotic leak	28 days
	Cardiac vascular graft failure	28 days
	Pain following surgery	14 days
	Other surgical complications	28 days
4. Respiratory complications	Respiratory failure including acute respiratory distress syndromes	21 days
	Aspiration pneumonia	14 days
	Pulmonary oedema	30 days
5. Venous thromboembolism	Venous thromboembolism	90 days
6. Renal failure	Renal failure	21 days
7. Gastrointestinal bleeding	Gastrointestinal bleeding	2 days
8. Medication complications	Drug related respiratory complications/depression	2 days
	Hypoglycaemia	4 days
	Movement disorders due to psychotropic medications	14 days
	Serious alteration to conscious state due to psychotropic medication	14 days
9. Delirium	Delirium	10 days
10. Cardiac complications	Heart failure	30 days
	Ventricular arrhythmias and cardiac arrest	30 days
	Atrial tachycardia	14 days
	Acute coronary syndrome including unstable angina, STEMI and NSTEMI	30 days
Other	11. Constipation	14 days
	12. Nausea and vomiting	7 days

3.1.1. Readmission intervals

The use of the condition-specific readmission intervals has been developed by the Commission, with input from a panel of clinical and consumer experts.

If a patient with a readmission condition presents at hospital in a timeframe that exceeds the condition-specific readmission interval, these episodes are not considered to be avoidable hospital readmissions.

3.2. Avoidable hospital readmission definition

When AHMAC approved the list of avoidable hospital readmissions conditions developed by the Commission, it also directed the Commission to determine 'a nationally consistent definition for avoidable hospital readmissions'.

The Commission convened a working group in late June 2019 to develop a nationally consistent definition for avoidable hospital readmissions. The Commission adopted the following working definition:

> *An avoidable hospital readmission occurs when a patient who has been discharged from hospital (index admission) is admitted again within a certain time interval, and the readmission:*
>
> 1. *is clinically related to the index admission, and*
> 2. *has the potential to be avoided through improved clinical management and/or appropriate discharge planning in the index admission.*

The above definition has been presented to AHMAC and, pending endorsement, will be used by IHACPA to define avoidable hospital readmissions.

3.2.1. Included and excluded services

A readmission is deemed as an avoidable hospital readmission if:

1. the index and readmission separations meet their respective exclusion's criteria;
2. the readmission has a principal diagnosis on the 'codes' list (and/or an additional diagnosis where specified);
3. the readmission meets any additional criteria (where specified); and
4. the interval between the index admission and readmission (in days) is less than or equal to the interval specified, i.e. date of admission (of the readmission episode) – date of separation (of the index episode) ≤ interval.

Table 2 summarises the services that are included and excluded for avoidable hospital readmissions based on the Commission's advice. In response to stakeholder feedback, IHACPA made the decision to exclude transfers, which are currently flagged as readmissions. The Commission's exclusion criteria in relation to transfers was developed based on hospital-level readmissions.

Table 2: Scope of included and excluded services for avoidable hospital readmissions

	Service scope for avoidable hospital readmissions
Included services	All relevant acute admitted episodes[1] in activity based funded (ABF) hospitals comprising: • Episodes with an urgency status of emergency.
Excluded services	Exclusions comprise: • Any readmissions where the index admission had a separation mode of discharged against medical advice. • Index admissions and readmissions for oncology, haematology, chemotherapy, dialysis, neonatal care and palliative care. • Readmissions for child birth. • Transfer episodes where previously classed as a readmission (i.e. a transfer from the index admission facility to a secondary facility within the same course of care).

Table 3 outlines the complete list of exclusion criteria, based on the Commission's advice for the list of conditions that are considered avoidable hospital readmissions.

Table 3: Complete list of exclusion criteria for avoidable hospital readmissions

Index admission	Readmission
Exclude separations with ANY of the following: • Multi-purpose services and Mothercraft facilities • Admitted for same day and overnight chemotherapy and dialysis (AR-DRG equal to R63Z, L61Z, L68Z, with admission date equal to separation date) • Admitted for oncology or haematology (any diagnosis: C00 to D89) • Admitted for neonatal care (Care type: 7) • Admitted for palliative care (Care type: 3) • Hospital boarder, organ procurement, unqualified newborns (Care types 9, 10, or 7.3) • Not discharged alive (mode of separation starts with 8) • Discharged against medical advice (mode of separation starts with 6)	Exclude separations with ANY of the following: • Multi-purpose services and Mothercraft facilities • Admitted for same day and overnight chemotherapy and dialysis (AR-DRG equal to R63Z, L61Z, L68Z, with admission date equal to separation date) • Admitted for oncology and haematology (any diagnosis: C00 to D89) • Admitted for neonatal care (Care type: 7) • Admitted for child birth (Adjacent AR-DRG equal to O01, O02, or O60) • Admitted as a transfer from a different facility within the same course of care • Non-acute care type (Care type not 1) • Non-emergency admission (Urgency status not equal to 1)

[1] Relevant acute admitted episodes comprise episodes with one or more of the readmission conditions in the list of Avoidable Hospital Readmissions and the readmission interval is less than or equal to the condition-specific timeframes specified in this list.

4. Conditions responsible for readmissions

4.1. Highest presenting clinical conditions

Analysis of the highest presenting clinical conditions responsible for readmissions provides valuable insight to why readmission episodes are occurring.

Table 4 outlines the AHMAC approved list of avoidable hospital readmissions and corresponding number of readmissions for the years 2018-19, 2019-20, 2020-21 and the first nine months of 2021-22.

Table 4: List of avoidable hospital readmissions and number of readmissions over a four year period

Readmission Condition	Number of readmissions (2018-19)	Number of readmissions (2019-20)	Number of readmissions (2020-21)	Number of readmissions (2021-22)[2]	Number of readmissions (total)
1. Pressure injury	99	90	111	61	361
2. Infections	17,079	16,493	15,741	11,681	60,994
3. Surgical complications	9,503	8,913	9,856	5,762	34,034
4. Respiratory complications	2,036	2,113	2,249	1,634	8,032
5. Venous thromboembolism	3,040	2,883	3,174	2,094	11,191
6. Renal failure	1,599	1,651	1,660	1,185	6,095
7. Gastrointestinal bleeding	391	366	380	239	1,376
8. Medication complications	1,039	1,048	990	749	3,826
9. Delirium	1,573	1,694	1,615	1,437	6,319
10. Cardiac complications	15,846	15,793	15,079	10,018	56,736
11. Constipation	2,879	2,860	2,929	1,809	10,477
12. Nausea and vomiting	1,500	1,486	1,663	1,096	5,745

Infections is the leading readmission condition, with 60,994 readmissions over the observation period, followed closely by cardiac complications with 56,736 readmission episodes. These figures can assist clinicians with the development of strategies to reduce or prevent avoidable hospital readmissions relating to specific conditions, and can be used to direct focus on conditions with disproportionately high rates of readmissions.

[2] Note that the 2021 22 readmission counts may, in part, be lower due to the fact that only the first nine months of data were considered. The observation period in 2021-22 is restricted because the longest readmission interval is 90 days.

5. Data specifications

5.1. Activity data

The following data was used for the calculations of the funding adjustments for avoidable hospital readmissions:

- Twelve months activity data for 2018-19
- Twelve months activity data for 2019-20
- Twelve months activity data for 2020-21
- Nine months activity data for 2021-22.

The sample of data used to fit the risk model includes only nine months of activity data for 2021-22 to avoid any potential bias in the training sample, as the longest readmission interval is 90 days. For the purposes of the funding calculations, the hospital list from the most recent NEP Determination was used to define ABF hospitals and their characteristics.

5.2. Data trimming

The following rules are implemented to clean the data, or identify whether an episode is trimmed:

1. Episodes with no associated Medicare PIN were trimmed as it is not possible to identify readmission episodes.
2. Episodes with a missing separation date are trimmed as non-discharged episodes do not have complete ICD-10-AM/ACHI code arrays.
3. Episodes with a Medicare PIN that has inconsistent birth date or sex across episodes were trimmed to ensure that only episodes with consistent patient identifiers are considered when flagging readmissions. This is discussed further in Section 5.2.1.
4. Where the same patient has multiple concurrent admitted episodes, only the episode with the earliest admission date is kept. This is to prevent concurrent episodes resulting in inconsistent flagging of potential readmission episodes.
5. Episodes that do not meet both the index episode denominator criteria and the readmission episode denominator criteria shown in Table 3 were removed as they were deemed irrelevant to the model.

A summary of the episodes trimmed for the 2018-19 to 2021-22 data years is presented in Table 5, along with the total per cent of episodes trimmed from public hospitals using these data trimming rules.

Table 5: Summary of trimmed episodes for the 2018-19, 2019-20, 2020-21 and 2021-22 activity data

Trim type	2018-19	2019-20	2020-21	2021-22
Total Episodes	6,960,457	6,923,469	7,245,126	6,972,918
Trimming due to:				
Missing Medicare PIN	442,341	471,975	488,389	464,720
Missing separation date	-	-	-	-
Not unique Medicare PIN	260,319	256,933	253,771	239,971
Concurrent episodes:				
Reasonable concurrent episodes	244	242	287	492
Same establishment	304	297	133	247
Overlapping episodes	455	433	599	987
Engulfed episode	6,833	6,271	9,118	8,199
Cannot be index or readmission episode	2,368,310	2,464,614	2,596,306	2,517,602
Total episodes remaining (untrimmed)	3,881,651	3,722,704	3,896,523	3,740,700
% of episodes trimmed from public hospitals	10.21%	10.63%	10.38%	10.25%

5.2.1. Medicare Pin Quality

Table 6 shows the quality of the Medicare PIN reporting for 2018-19, 2019-20, 2020-21 and 2021-22 for admitted episodes of care.

Analysis shows the percentage of good quality Medicare PIN data for each year. This is measured by identifying where there is inconsistency in the birth date or sex of the episodes of care to which it has been attached.

For all jurisdictions in all years assessed, the figures seem reasonable and indicate no systemic reporting errors. In cases where the Medicare PIN is considered poor quality, these episodes are removed for the purposes of modelling (i.e. those which have records with multiple different birth dates or sexes associated with it).

Table 6: Quality of Medicare PIN reporting

	Percentage of good quality Medicare PIN			
State/Territory	2018-19	2019-20	2020-21	2021-22
NSW	95.4%	95.5%	96.0%	95.8%
Vic	93.5%	93.4%	93.5%	93.8%
Qld	98.1%	98.1%	98.1%	98.2%
SA	97.5%	97.4%	97.7%	97.7%
WA	97.4%	97.4%	97.5%	97.7%
Tas	99.6%	99.6%	99.5%	99.6%
NT	96.2%	96.0%	96.1%	95.9%
ACT	96.4%	96.9%	95.6%	96.9%
National	**96.0%**	**96.0%**	**96.2%**	**96.3%**

6. Risk adjustment model

6.1. Overview

IHACPA notes the need to balance the perspectives of both hospitals and patients when incorporating safety and quality into pricing. Hospitals that treat high-risk patients should not be disadvantaged compared to hospitals that treat fewer such patients. Likewise, high-risk patients should have confidence that hospitals take all necessary actions to manage their risks and mitigate the occurrence of adverse events.

The equitable risk adjustment criterion used by IHACPA states that:

> *Pricing and funding approaches should balance the likelihood that some patients will be at higher risk of experiencing an adverse event while recognising that all hospitals have scope to improve safety and quality.*

The risk adjustment model is constructed on the premise that a patient's likelihood of experiencing a potentially avoidable hospital readmission is the same regardless of the funding option considered. Therefore, a risk adjustment model is derived for each readmission condition, which assigns the risk of being readmitted for each episode of care, based on the risk factors identifiable in the National Minimum Data Set (NMDS).

In this model, episodes are assigned to a 'Low', 'Medium' or 'High' complexity group representing the risk of a readmission occurring based on identified risk factors. This new risk modelling approach for assessing the impact of risk factors has a basis in assessing risks in top predictors for each risk adjustment variable, essentially changing how the scores are assigned for 'Low', 'Medium' and 'High' risk category patients.

6.1.1. Previous risk adjustment model

The previous modelling approach for avoidable readmissions was based on the HACs logistic regression model. This modelling approach had limitations due to the large number of false positive outputs (where readmissions were identified as positives) from a much larger data set of non-readmission episodes. The logistic regression approach showed poor performance on accurately predicting episodes that were not readmissions and provided a less than optimal fit to the given data.

During the development of the avoidable hospital readmissions model, receiver operating characteristic curves (ROC curves) were used to measure performance, however these presented an incomplete picture of model performance trained on imbalanced data. IHACPA has since updated the metrics used to describe the performance of the readmissions risk adjustment model.

6.2. Finalised risk adjustment model

6.2.1. Final risk adjustment model

The avoidable readmission risk adjustment model represents a shift away from the more familiar logistic regression model used for the HACs risk model, to a predictive modelling approach based on gradient boosting decision trees. The shift to a new model has seen a substantial improvement in model performance due to its ability to model more complex interactions between risk factors, while reducing the possibility of 'overfitting' to characteristics specific to the available data.

The previous logistic regression risk model estimated the effect of each risk factor independently. For example, for a given readmission category, being admitted to an intensive care unit (ICU) might indicate an increased risk of readmission of 3 per cent. Each risk factor has an associated marginal risk like this which, when added together, gives a total risk score.

The revised modelling approach is based on gradient boosting decision trees. Under this model, the marginal risk of each risk factor is not a constant, but depends on the combination of risk factors present in a particular episode. For example, for a given readmission category, being admitted to ICU will have a different marginal impact depending if the patient is admitted to a surgical or medical AR-DRG, and similarly for all other risk factors.

Modelling interactions between risk factors using methods such as the previous logistic regression will often result in 'over-fitting' the model to the data on which it is trained, picking up natural variance present in the data and measuring it as a real effect. In AHRs, over-fitting has been reduced using the gradient boosted decision tree machine learning technique, which involves fitting hundreds of thousands of similar models to subsets of the same data. This allows for natural variance to be accounted for, therefore reducing over-fitting while retaining the benefits of decision tree classification algorithms.

The gradient boosted decision tree risk adjustment model has the additional benefit of also determining the best aggregation for risk factors that have multiple levels as an implicit part of the method. For example, in the HACs risk adjustment model, some of the five-year age brackets are combined for some HACs depending on manual analysis and interpretation of sample size and statistical significance testing. The gradient boosting decision tree model is able to filter out factors automatically, or determine how to achieve the most optimal grouping for the most accurate possible outcome.

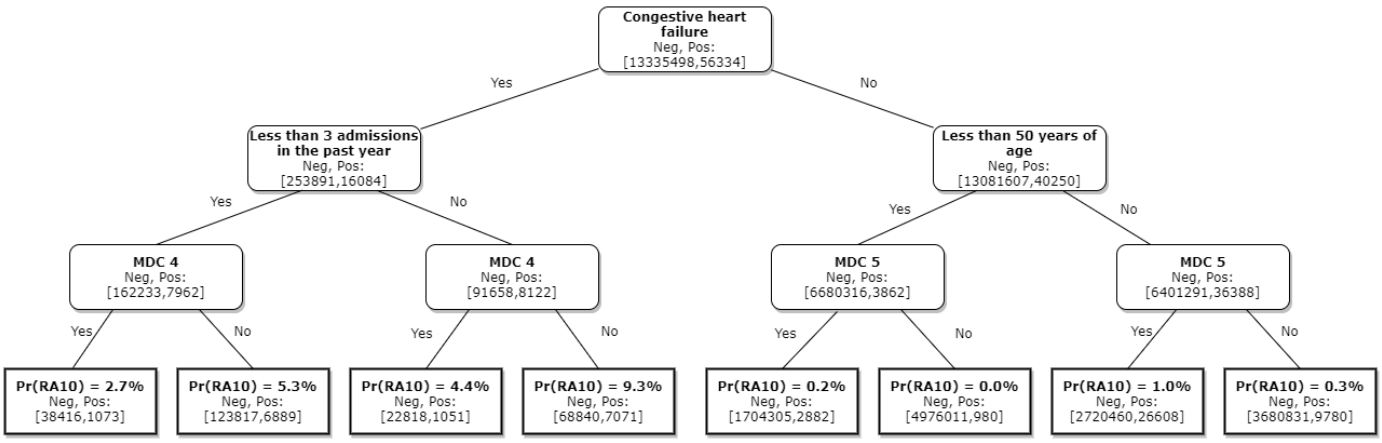
6.2.2. Gradient boosting decision trees

6.2.2.1. Decision trees

IHACPA investigated the performance of regression-based decision tree models as an alternative to the logistic regression model used for HACs. The model builds a decision tree to classify the target variable. It does this by selecting features that give the highest information gain and splitting the data set on that feature. Figure 1 shows an example of a regression-based decision tree model for the Cardiac complications readmission category.

This method does not represent hard-to-predict observations as well as the gradient boosted methods discussed below, so was not selected as the final modelling technique for AHRs.

Figure 1: Example regression based decision tree classifier for Readmission 10 – Cardiac complications



In Figure 1, the numbers in square brackets show how many non-readmissions (Neg) and readmissions (Pos) are considered at each stage. These episodes are then split on the risk factor (stated in bold) and shown on the next level of the decision tree.

For example, the node at the top of the tree shows that 13,335,498 non-readmissions and 56,334 cardiac complication readmissions are considered in this model. These are then split, based on whether the episode has the congestive heart failure risk factor, into 253,891 non-readmissions and 16,084 cardiac complication readmissions with congestive heart failure, and 13,081,607 non-readmissions and 40,250 cardiac complication readmissions without congestive heart failure.

Splitting on the congestive heart failure risk factor produces two nodes where less than 2 per cent of non-readmissions are on the left-hand side, though it contains over 28 per cent of cardiac complication readmissions. We therefore say that splitting on this feature produces a high information gain. This process is repeated at the next level down on the major diagnostic category (MDC) risk factor, specifically if the episode is in MDC 4. At each level of the decision tree, the model identifies the risk factor that produces the highest information gain and splits the data set on this.

Leaf nodes are produced at the bottom of the chart. If the model was allowed to continue splitting the data set until each leaf node was either purely non-readmissions or purely readmissions, it would produce a much deeper model than is shown in Figure 1, with many more layers of nodes. To avoid overfitting, however, the model is limited to a “depth” of five layers of nodes (three in the example tree shown). The leaf nodes at the bottom of Figure 1, therefore output a probability of whether an episode with the corresponding risk factors will lead to an avoidable readmission for cardiac complications.

Tracing a single example through the model in Figure 1, if an episode: has the congestive heart failure risk factor; more than three admissions in the previous year; and is not in MDC 4, the model says that this episode has a 9.3 per cent chance of leading to an avoidable readmission for a cardiac complication.

6.2.2.2. Gradient boosting decision tree model

Using a decision tree by itself, as shown in Figure 1, may not consider all of the risk factors, due to the limited tree depth. On the other hand, fitting a much larger decision tree is undesirable because it can overfit the data, meaning that the resulting model could perfectly describe the data it is trained on, but not generalise well to the broader population. A technique that captures the benefits of decision trees while producing a more general model is called ensemble learning.

The gradient boosted model implemented is one such technique and has been used in other studies to predict readmissions, with sound results. This approach fits multiple decision trees in a sequential manner (a type of ensemble learning called boosting). The first decision tree is fit as shown in the previous example, and then the subsequent trees are fit to the residuals, or errors, from the preceding model. This way, as more and more decision trees are fit to the errors made by the preceding tree, the model gradually gets better and better.

As the model adds new trees, it tests its performance on a validation data set which was not used to train the model (comprising 10 per cent of the data). When the model performance stops improving with respect to this validation set, the model stops adding new decision trees and the training process is complete. This is done to prevent overfitting by adding too many decision trees to the model.

6.2.3. Performance metrics

IHACPA has generally used receiver operating characteristic (ROC) curves to measure the performance of the HAC and early iterations of the readmissions risk adjustment model.

However, these metrics do not present the whole picture about the performance of models, due to imbalance in the data. That is, the ROC curve metrics alone may not clearly reflect significant changes in model performance where the number of episodes with no subsequent avoidable hospital readmissions is far greater than the number of episodes with an avoidable hospital readmission. To account for this, IHACPA has used precision recall curves (PRC), which are more informative that ROC curves on highly unbalanced data, alongside ROC curves in evaluating readmissions risk modelling.

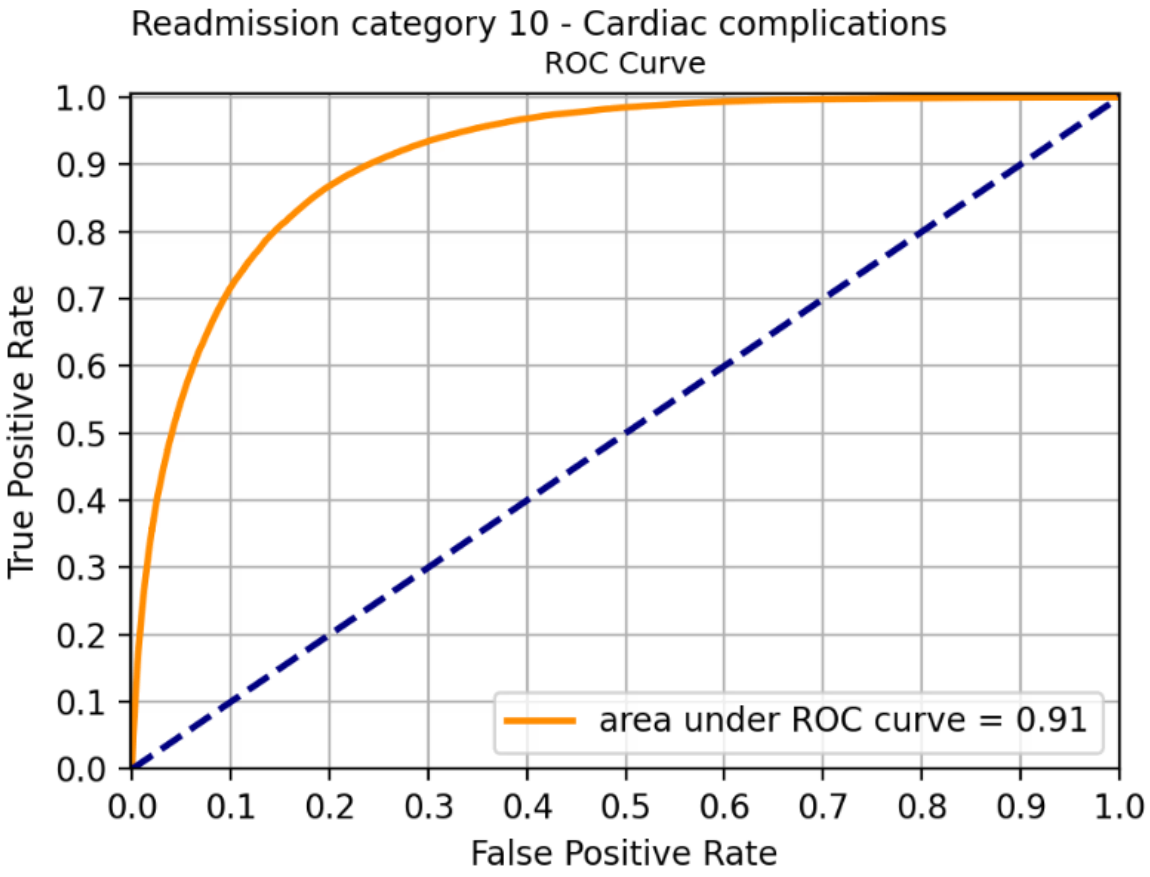
6.2.3.1. Receiver operating characteristic curve

The ROC curve is a parametric plot of the true positive rate versus the false positive rate of the model where the theoretical threshold is varied between 0 and 1 – so that the probability outcome of the model can be assigned as leading to a readmission or not, dependent on the threshold. The idea being that for anything short of a perfect model, a higher true positive rate will also yield a higher false positive rate.

The issue with using the ROC curve to assess model performance on imbalanced data is that the rates being compared have different denominators. The true positive rate is *True positives/All positives*, while the false positive rate is *False positives/All negatives*. In each of the risk adjustment models, the number of negatives (episodes with no subsequent avoidable hospital readmission) is close to 13,000,000. While the number of positives varies from around 350 for readmission category 1 (pressure injury), and 56,000 for category 10 (cardiac complications) in the four years of activity data used for training.

The risk adjustment model for readmission category 10 (cardiac complications) has an area under ROC of 0.91. To illustrate the issue described above, a single point on the curve may be considered. Picking a threshold to correctly identify 20 per cent of the 56,000 avoidable hospital readmissions (i.e. 0.2 on the vertical axis in Figure 2) gives a false positive rate (i.e. the horizontal axis in Figure 2) of around 0.1 per cent, or 1,300,000 false positives. Note that these figures are used for comparison of risk models only. In practise, risk models assign a probability (which is always low for a readmission), and do not use thresholds to assign definite positive/negative outcomes.

Figure 2: ROC curve for readmission 10



6.2.3.2. Precision recall curve

The precision recall curve (PRC) is a complement to the ROC curve. It may give additional insight compared to the ROC curve when evaluating model performance on imbalanced data.

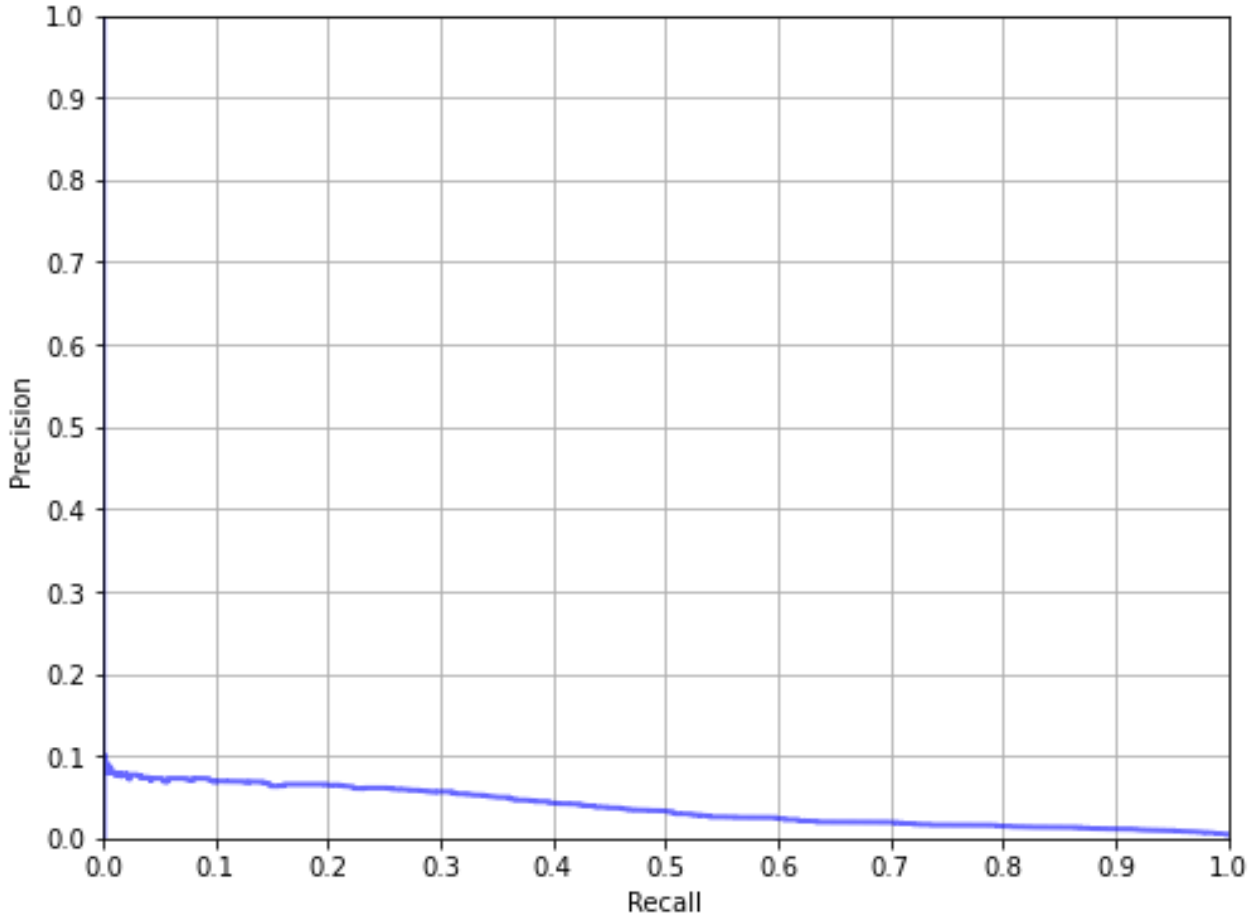
Precision is the number of true positives out of all the predicted positives, meaning the number of episodes which actually led to an avoidable hospital readmission out of those predicted to have led to one.

Recall is another name of the true positive rate and represents how successful the model is in identifying avoidable hospital readmissions. That is, out of all the avoidable hospital readmissions in the data set, how many the model has identified.

This curve is also parametric, based on a threshold to declare each point as a readmission or not as a readmission. Similar to the ROC curve, PRC is a plot of precision versus recall as the threshold varies between 0 and 1.

Figure 3 demonstrates the PRC for readmission 10 when using the originally considered logistic regression model. Picking a threshold which identifies 20 per cent of unplanned readmissions (recall) in the data set, it will have a precision of around 8 per cent, meaning that it will return about 28,000 episodes correctly classified as leading to an avoidable hospital readmission, and around 130,000 false positives.

Figure 3: Precision Recall curve for readmission 10 with logistic regression model

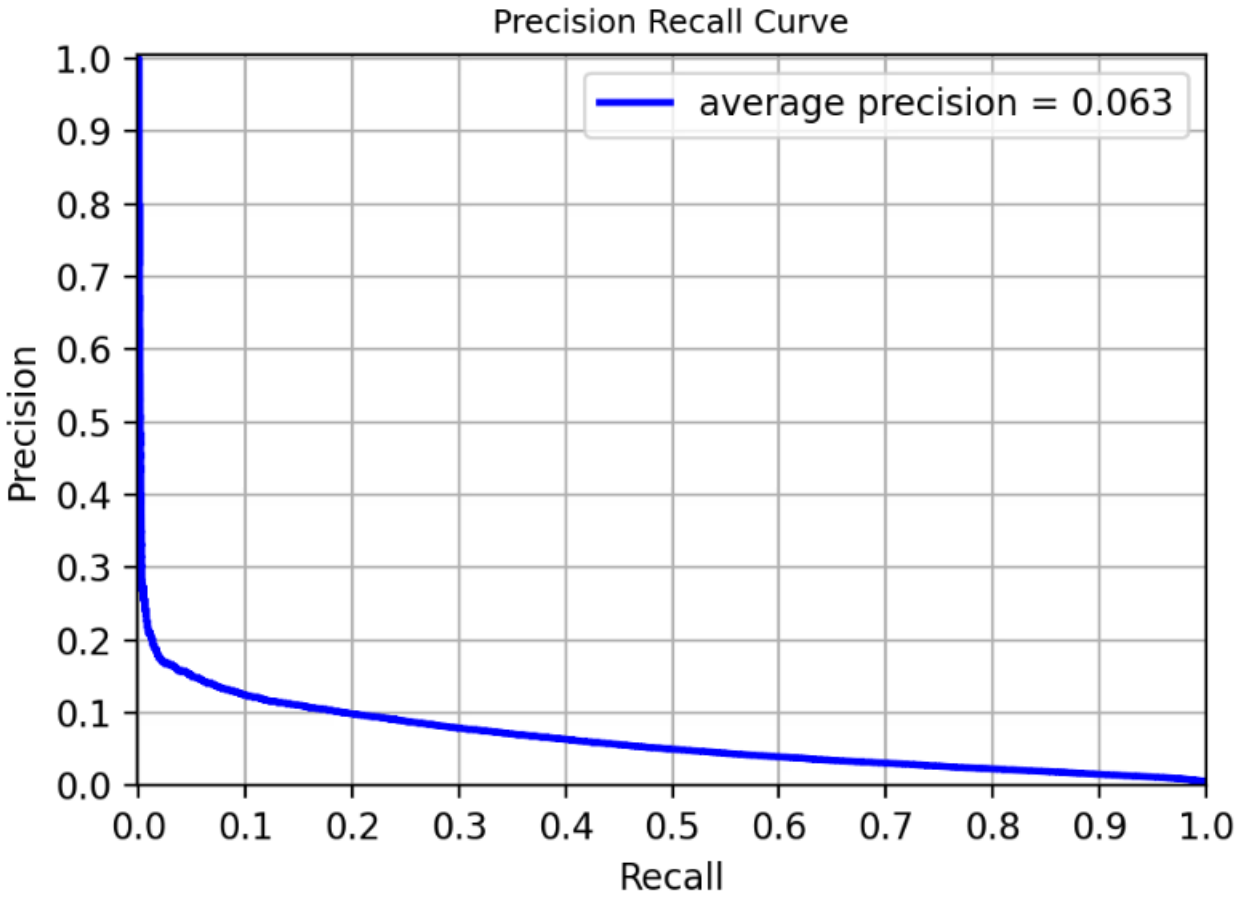


6.2.3.3. Training and testing data sets

The HAC risk models use the same set of data for training and testing model performance. This is not a significant issue for linear models like logistic regression, as overfitting is less likely. The decision tree-based model implemented for readmissions is non-linear and in the extreme case can fit a model perfectly to the training data. So here we report performance metrics calculated on a hold-out "test" data set that was not used to fit the model. This is a standard method used in the literature for testing the performance of a machine learning model on new data.

When comparing Figure 4 below with Figure 3, a considerable improvement in the model precision at each level of recall is apparent. At 20 per cent recall, the model has precision of around 10 per cent, a significant improvement compared with the 8 per cent of the logistic regression model. This effect is even more significant at lower recall values.

Figure 4: Precision Recall curve for readmission 10 with gradient boosting decision tree



Note that this is the best performing model. In terms of area under ROC and PRC, the gradient boosting decision tree models with the additional risk factors (discussed further in Section 7) perform better across all readmission categories than the logistic regression models. ROC curves and PRC for the implemented readmission model are given in **Appendix A.**

7. Risk factors

For the determination of patient-level funding options, episodes are assigned to a 'Low', 'Medium' or 'High' complexity group representing the risk of a readmission occurring based on any identified risk factors. IHACPA notes that risk factors for avoidable hospital readmissions were examined independently of risk factors included in the funding model for HACs, as there are additional elements of long-term patient characteristics that must be taken into account.

7.1. Previous risk factors

Throughout the shadow period, IHACPA has assessed a number of risk factors. During this assessment, Charlson comorbidity diagnostic categories and chronic condition flags, of which the latter are determined based on the presence of chronic disease category ICD-10-AM codes, were examined for inclusion in the risk factor set for AHRs. The original risk factors proposed throughout the shadow period and the shadow period definitions of Charlson comorbidity and chronic disease categories are presented in **Appendix B**.

7.1.1. Feedback on risk factors development

Stakeholders expressed concern about using risk factors that were overly statistically driven and requested clinical evaluation of the final list. IHACPA has endeavoured to achieve a balance of statistical significance and clinical relevance through a literature review of other readmissions studies[3,4] and the use of feature importance breakdowns for key risk factors associated with each of the readmission conditions. Feature importance breakdowns is an attribute of the revised risk adjustment model, where the statistical importance and model contribution of each risk factor can be assessed and utilised in the readmission category models as required.

IHACPA has refined the list of risk factors based on stakeholder feedback, consultation with the University of Melbourne and assessment of clinical relevance using the top feature importance breakdowns to remove risk factors that did not significantly contribute to model performance and prediction of readmissions.

IHACPA also consolidated the risk factors contained within the Charlson comorbidity flags and chronic condition flags to eliminate overlapping risk factors and statistically or clinically insignificant factors.

In the NEP 2024-25 period, IHACPA revised the ICD-10-AM codes used in identifying the presence of risk factors, to make sure the most relevant advice was taken into account for ICD-10-AM 11th and 12th editions. This review was carried out in consultation with clinical, technical, and jurisdictional committees and resulted in significant changes to the codes used in identifying risk factors. The up-to-date set of ICD-10-AM codes used in identifying standalone and Charlson risk categories in avoidable hospital readmissions are presented in Table 7. Note that, due to consideration discussed in Section 7.2.2., not all of these potential risk factors are implemented in the modelling process.

[3] Min, X., Yu, B. & Wang, F. Predictive Modeling of the Hospital Readmission Risk from Patients' Claims Data Using Machine Learning: A Case Study on COPD. Sci Rep 9, 2362 (2019). https://doi.org/10.1038/s41598-019-39071-y

[4] Donzé J, Aujesky D, Williams D, Schnipper JL. Potentially Avoidable 30-Day Hospital Readmissions in Medical Patients: Derivation and Validation of a Prediction Model. JAMA Intern Med. 2013;173(8):632–638. doi:10.1001/jamainternmed.2013.3023

Table 7. Updated diagnosis codes for flagging risk categories for AHR modelling

Risk factor group	Diagnostic category	Diagnosis Codes
Standalone categories	Mental health	F-prefix R3581 U79-prefix
	Drug use	F10-prefix to F19-prefix Z64.2-prefix Z72.2-prefix
	Homelessness	Z59.0
	Post transplant status	Z94-prefix
	Pacemaker status	Z95.0
	Ventilator	Z99.1
	Asthma	J45-prefix J46-prefix U83.3
	Obesity	E66.90 E66.91 E66.92 E66.93 E66.1 E66.2
	Malnutrition	E40 E41 E42 E43 E44.0 E44.1 E45 E46
	Parkinson disease	G21-prefix G22-prefix
Charlson categories	Acute myocardial infarction	I21-prefix I22-prefix
	Congestive heart failure	I50-prefix I11.0-prefix I13.0-prefix I13.2-prefix U82.2
	Peripheral vascular disease	I70-prefix I71-prefix I73-prefix
	Cerebral vascular accident	I60-prefix to I66-prefix I67.0-prefix to I67.9-prefix I68.0-prefix to I68.2-prefix I68.8-prefix I69-prefix
	Dementia	F00-prefix F01-prefix F03-prefix U79.1-prefix
	Pulmonary disease	J40-prefix to J47-prefix J60-prefix to J67-prefix U83.1 U83.2 U83.3 U83.4
	Connective tissue disorder	M30-prefix to M36-prefix M05-prefix M06-prefix U86.1 U86.3
	Peptic ulcer	K25-prefix to K28-prefix
	Liver disease	K70.0-prefix to K70.3-prefix K70.9-prefix K71.0-prefix K71.2-prefix to K71.9-prefix K72.0-prefix K73-prefix to K75-prefix K76.0-prefix to K76.4-prefix K76.8-prefix K76.9-prefix B18-prefix
	Diabetes	E10.8 E10.9 E11.8 E11.9 E13.8 E13.9 E14.8 E14.9-prefix
	Diabetes complications	E10.0-prefix to E10.7-prefix E11.0-prefix to E11.7-prefix E13.0-prefix to E13.7-prefix E14.0-prefix to E14.7-prefix
	Paraplegia	G81-prefix G82.0-prefix to G82.2-prefix
	Renal disease	N03-prefix N05.2-prefix to N05.6-prefix N07.2-prefix to N07.4-prefix N01-prefix N18.0-prefix N18.3-prefix to N18.9-prefix N19-prefix N25-prefix I12.0-prefix I13.1-prefix Z49.0-prefix to Z49.2-prefix U87.1
	Cancer	C0-prefix to C3-prefix C40-prefix C41-prefix C43-prefix C45-prefix to C49-prefix C5-prefix C6-prefix C70-prefix to C76-prefix C80-prefix to C86-prefix C88.0-prefix C88.2-prefix to C88.4-prefix C88.7-prefix C88.9-prefix C90.0-prefix to C90.3-prefix C91.1-prefix C91.3-prefix to C91.9-prefix C92-prefix C93.0-prefix C93.1-prefix C93.3-prefix C93.7-prefix C93.9-prefix C94.0-prefix C94.2-prefix to C94.4-prefix C94.6-prefix C94.7-prefix C95.0-prefix C95.1-prefix C95.7-prefix C95.9-prefix
	Metastatic cancer	C77-prefix to C79-prefix
	Severe liver disease	K70.4-prefix K71.1-prefix K72.1-prefix K72.9-prefix K76.5-prefix to K76.7-prefix Z94.4-prefix U84.3
	HIV	B20-prefix to B24-prefix R75-prefix Z21-prefix

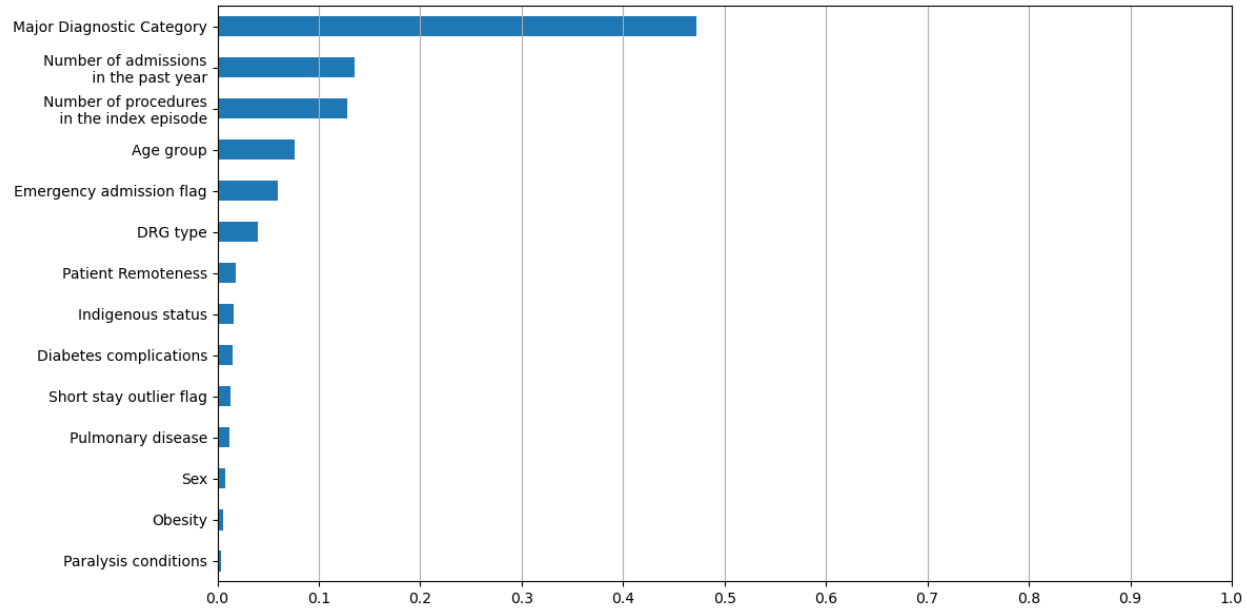
7.2. Finalised risk factors

7.2.1. Key risk factors

With decision tree-based risk models it is possible to calculate the importance of each risk factor, giving it a percentage score for its contribution to the model. This provides insight into the statistical significance and impact of the proposed risk factors. IHACPA has created top feature importance breakdowns for each readmission category to finalise the risk factors.

Figure 5 below shows the top feature importance breakdown for infections (category 2), which is the highest presenting readmission condition over the four year period assessed. The top feature importance breakdowns of all readmission categories are provided at **Appendix C**.

Figure 5: Top features relating to infections



The feature importance tables have validated the significance of several new risk factors proposed in the during the development of the AHR model.

During the shadow reporting period, stakeholders queried using length of stay in the risk adjustment model, as it is a factor under the control of the hospital and influenced by processes of care. There was concern that it could potentially capture patients who were discharged too early or be indicative of a less complex patient. It should be noted that readmissions where the index admission had a separation mode of discharged against medical advice are excluded.

7.2.2. Determination of finalised risk factors

IHACPA developed a discrete set of risk factors for each readmission category for NEP21, instead of using a one-size-fits-all approach. The finalised risk factors were determined using feature importance breakdowns for each readmission category and underwent clinical consultation before being included in the final model. The top performing risk factors with the largest contribution to predicting the readmission category were used in the risk adjustment models, based on a minimum relative feature importance threshold of 0.01. This approach was selected as it does not trim potentially important risk factors in some readmission categories, as would be the case if limited to an arbitrary number of risk factors (for example, top 10 risk

factors). The same applies for risk factors that are not statistically significant for other readmission categories and can be subsequently eliminated from the lists.

This approach can be used to update risk factors in readmission categories if, in addition to fulfilling relative feature importance criteria, a risk factor is considered significant under these criteria for two of the past three years and if the potential changes to the risk factor list is reviewed by IHACPA's Clinical Advisory Committee before being implemented.

Overall, this approach reflects the best risk factors (of those considered) for the best performing risk adjustment model for each readmission category. However, this method does have some shortcomings as the models for certain readmission categories may perform less optimally than other categories due to low episode sample sizes. This is particularly true for the pressure injury and gastrointestinal bleeding categories, where the extremely low sample sizes means that both risk factor selection and the risk model in general are less robust compared to the other readmission categories.

Another consideration is the use of chronic condition flags as risk factors, due to concerns that if the presence of a chronic condition impacts the course of care, it would be coded differently. The primary purpose of using Charlson comorbidity flags and chronic condition flags is to capture whether a patient has these types of conditions, and their related risk of readmission. For example, if a patient was readmitted for renal failure, their risk profile would be affected by having one or more of the chronic condition flags and they are therefore more likely to be readmitted due to their chronic condition.

Table 8 lists the final risk factors used in each readmission model.

Table 8: Risk factors for each readmission category

	01. Pressure injury	02. Infections	03. Surgical complications	04. Respiratory complications	05. Venous thromboembolism	06. Renal failure	07. Gastrointestinal bleeding	08. Medication complications	09. Delirium	10. Cardiac complications	11. Constipation	12. Nausea and vomiting
Past year admissions	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Age group	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Major Diagnostic Category	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Procedure count	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
AR-DRG type		✓	✓			✓	✓	✓	✓	✓	✓	✓
Drug use									✓			
Transfer admission								✓				
Emergency admission	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
ICU					✓				✓			
Sex[5]		✓		✓	✓	✓	✓		✓		✓	✓
Indigenous	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

[5] In previous NEP technical specifications, this category was referred to as 'gender'. It has been updated in this technical specification to distinguish it from the reporting of 'gender' in APC datasets from 2022-23 onwards. For the purposes of the AHR risk adjustment model, the 'male' sex category includes all patients who are not reported as 'female'.

	01. Pressure injury	02. Infections	03. Surgical complications	04. Respiratory complications	05. Venous thromboembolism	06. Renal failure	07. Gastrointestinal bleeding	08. Medication complications	09. Delirium	10. Cardiac complications	11. Constipation	12. Nausea and vomiting
Low length of stay		✓			✓							
Malnutrition												✓
Pacemaker	✓											
Patient remoteness	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Post transplant						✓						
Charlson comorbidity flags												
Acute myocardial function										✓		
Congestive heart failure						✓				✓		
Diabetes					✓			✓				
Diabetes complications		✓				✓		✓		✓		
Dementia				✓					✓			
Pulmonary disease		✓			✓							
Renal disease						✓		✓		✓		
Chronic condition flags												
Arthritis and osteoarthritis												✓
Cerebral palsy				✓							✓	✓
Chronic heart failure										✓		
Chronic kidney disease						✓						
Chronic respiratory failure				✓								
Chronic obstructive pulmonary disease	✓			✓								
Crohns disease											✓	✓
Depression					✓				✓			
Disorder of intellectual											✓	
Downs syndrome			✓									
Hypertension					✓	✓	✓					
Ischaemic heart disease					✓					✓		
Obesity		✓			✓							
Osteoporosis							✓					
Severe liver disease						✓						
Spina bifida	✓											
Paraplegia	✓	✓		✓								
Total number of risk factors:	11	14	9	13	16	16	11	12	13	14	12	13

7.3. Results

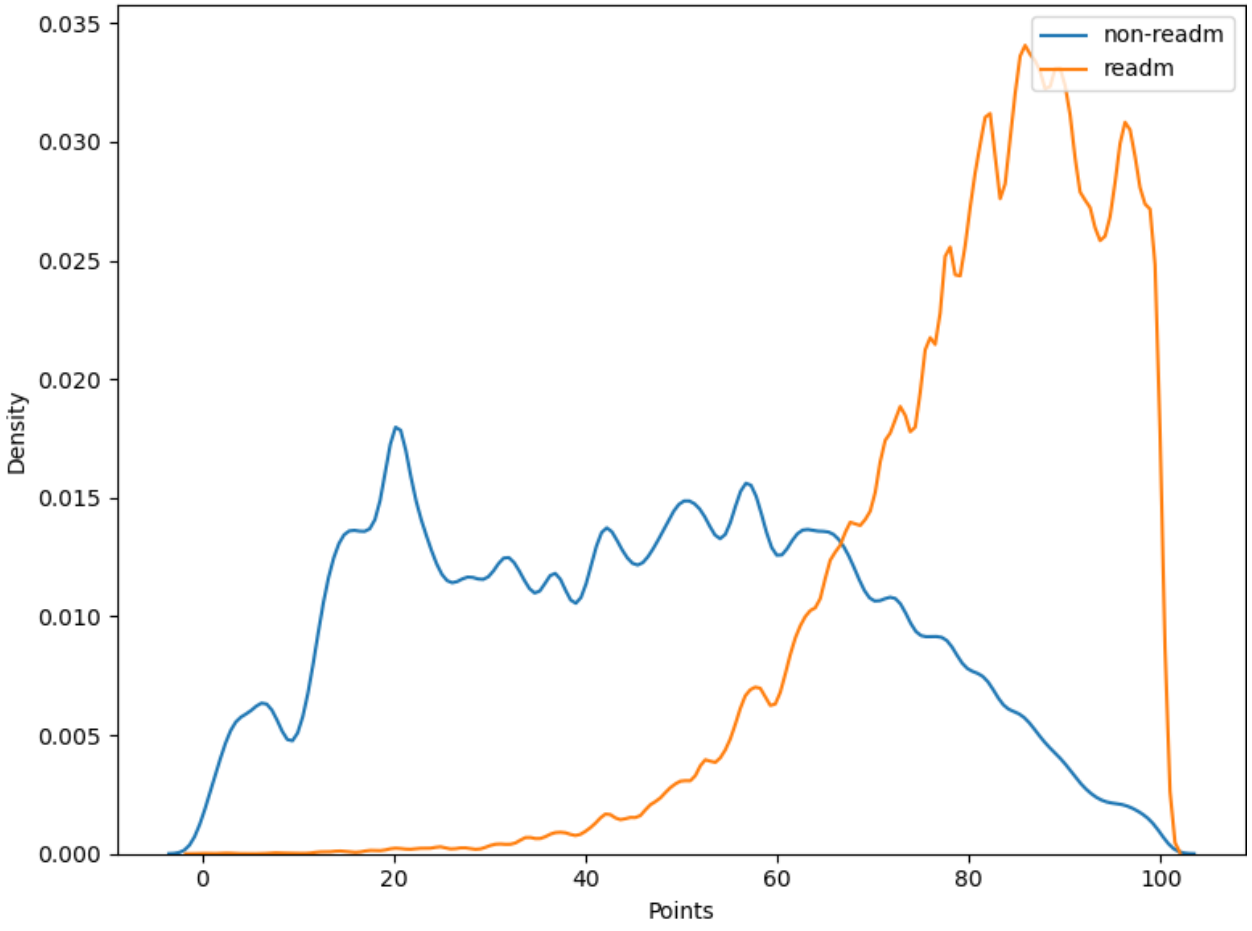
7.3.1. Complexity points

For comparability to the HAC model, IHACPA converted the resulting probability scores into complexity points, which are then used to assign an episode into a 'Low', 'Moderate' or 'High' complexity.

To calculate the points, IHACPA calculated out min-max scaling parameters on model outputs to between the 1st and 99th percentiles. These are then used to rescale the model outputs to between 1 and 100, constraining results below 1 and above 100 (from the <1st and >99th percentile outliers) to 1 and 100, respectively.

Figure 6 shows the distribution of complexity scores for episodes with readmissions due to cardiac complications (category 10).

Figure 6: Readmission complexity due to cardiac complications



This shows the episodes resulting in readmission tend to have greater complexity than those which do not. Similar complexity distributions are provided for all readmissions in **Appendix D**.

7.3.2. Dampening factors

The avoidable readmission funding adjustment is applied at an episode level by reducing the efficient price of an episode based on an incremental cost associated with the potentially avoidable hospital readmission. This is similar to the incremental cost of a HAC used for the HACs funding adjustment.

To calculate the risk categories the distribution of points scores for readmission index episodes is split into three equal sized groups. The first tercile (rounded to the nearest integer value) is then the threshold between the low and medium risk categories, and the second tercile is the threshold between the medium and high risk categories.

The 'incremental cost' (i.e. NWAU of the readmission episode) is then reduced by a dampening factor that depends on the index episode risk of readmission, and is subtracted from the total NWAU of the index episode. The dampening factor for each risk category is calculated as the mean points score for the low risk category divided by the mean points score for that risk category, so that:

- The risk score for the low risk category is (*mean_low / mean_low)*, or one,
- The risk score for the medium risk category is *(mean_low / mean_medium)* and
- The risk score for the high risk category is *(mean_low / mean_high)*.

Table 9 shows the adjustment applied to avoidable hospital readmissions identified within the same jurisdiction. The adjustment factors vary depending on the readmission category and the complexity group of the episode. For low complexity episodes, the full NWAU of the readmission episode is deducted from the index admission. For high complexity episodes, only a portion of it is removed (e.g. 34.7 per cent for Medication complications).

Table 7: Adjustment factors for AHR01 to AHR12

	01. Pressure injury	02. Infections	03. Surgical complications	04. Respiratory complications	05. Venous thromboembolism	06. Renal failure	07. Gastrointestinal bleeding	08. Medication complications	09. Delirium	10. Cardiac complications	11. Constipation	12. Nausea and vomiting
Complexity group point thresholds												
Low	0	0	0	0	0	0	0	0	0	0	0	0
Moderate	64	65	92	67	80	75	50	72	79	78	58	55
High	82	80	96	81	87	89	78	89	89	89	76	75
Complexity group dampening factors												
Low	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Moderate	0.4580	0.5560	0.2980	0.4790	0.6990	0.5310	0.4100	0.4120	0.4760	0.5060	0.4390	0.5710
High	0.3630	0.4550	0.2860	0.3850	0.6240	0.4530	0.2780	0.3470	0.4210	0.4420	0.3300	0.4140

It is possible for an episode to contain more than one AHR. In this case, dampening factors are calculated for each AHR that applies to the episode, and the maximum adjustment is used for the funding adjustment.

8. Scope options

8.1. Overview

IHACPA has analysed all scope options (readmissions that occur within the same hospital, Local Hospital Network (LHN) and jurisdiction) in the shadow reporting period for stakeholder consideration.

8.1.1. Impact within the same hospital, LHN or jurisdiction

IHACPA has undertaken analysis of 2018-19, 2019-20, 2020-21 and 2021-22 data of all avoidable hospital readmissions by the location of the readmission. The analysis indicates that:

- 47.7 per cent of readmissions occurred when patients presented to the same hospital.
- 16.9 per cent of readmissions occurred in a different hospital in the same LHN.
- 35.4 per cent of readmissions occurred in a different LHN in the same state or territory.

8.1.2. Impact within or across financial years

IHACPA has undertaken analysis of 2018-19, 2019-20, 2020-21 and 2021-22 data of all avoidable hospital readmissions within or across financial years. The analysis indicates that:

- 97.3 per cent of readmissions occurred within the same financial year.
- 2.7 per cent of readmissions occurred across financial years.

8.2. Scope option for implementation

Throughout the shadow period, stakeholders were supportive of IHACPA's preference for using the widest scope possible to maximise coverage of readmission episodes. Modelling the readmissions adjustment at a jurisdictional level was found to unequivocally be the best option as it provided the most robust data validation.

Applying funding adjustments at a jurisdictional level was also found to have a less disproportionate impact on smaller states and territories with fewer LHNs, as a large percentage of readmissions occur within the same jurisdiction. The wider scope meant a fuller coverage of readmissions.

IHACPA will implement the funding adjustment using the Medicare PIN in the short term, with a view to shift to using an IHI available to the jurisdictions in the medium term. In progressing the implementation of the funding adjustment, IHACPA will consolidate the process with transparency in the pricing, data and reconciliation practices.

9. Funding adjustment

9.1. Overview

From 1 July 2019, IHACPA commenced a 24-month shadow period encompassing three funding options for avoidable hospital readmissions:

- Option one: Deduct the cost of the readmission episode from the index episode;
- Option two: Combine the index and readmission episodes and recalculate the funding of the combined episode;
- Option three: Adjust funding at the hospital level where actual rates of avoidable readmissions exceed expected rates of avoidable readmissions.

Throughout the shadow period IHACPA worked closely with jurisdictional stakeholders in analysing and evaluating the three scope options for potential implementation.

The majority of stakeholders expressed a preference for funding option one throughout the shadow period. Funding option one is the simplest to apply as it follows the same methodology as the HACs adjustment, where the funding adjustment is applied at the place of the index admission. Of the funding options investigated, option one impacted the jurisdictions more proportionately when compared to funding options two and three, which showed adjustment bias against smaller regional and remote hospitals when the scope is expanded beyond the hospital level.

Stakeholders initially had reservations about the potentially punitive effect of funding option one for episodes involving a transfer within hospital networks. IHACPA has made the decision to trim transfer episodes from the readmissions data to consolidate this risk and provide a more accurate picture of the readmissions landscape.

Stakeholders also expressed concerns about funding option one being a disincentive for hospitals to discharge patients to avoid penalisation for a potential readmission. However, this could be viewed as a positive change in clinical behaviour to reduce avoidable readmissions and improve patient safety if discharges were previously occurring too early.

9.2. Funding option for implementation

IHACPA has implemented the funding adjustment for avoidable hospital readmissions using funding option one: deduct the cost of the readmission episode from the index episode.

Under this episode-level approach, an avoidable hospital readmission would nominally receive no funding, with a funding adjustment applied to impact on where the index admission occurred (even when the readmission occurred in a different hospital/LHN to the index admission).

To accomplish this, an NWAU adjustment is applied to the index episode, based on the total NWAU of the associated readmission. For episodes considered low risk under the risk adjustment methodology, the full NWAU of the readmission episode is deducted from the index episode (up to the value of the index episode). This is similar to the full incremental cost deduction in the context of HACs.

This option is risk adjusted by the adjustment factors given in Table 8, for example, if the risk of a readmission is high, only a small percentage of the readmitted episode NWAU is deducted from the index episode.

9.2.1. Application of funding adjustment

IHACPA developed the following example to assist stakeholders in applying and calculating the funding adjustment:

The index episode occurred at Hospital A:

- AR-DRG D12B (Other Ear, Nose, Mouth and Throat Interventions, Minor Complexity)
- NWAU 0.8505

The readmission episode occurred at Hospital B:

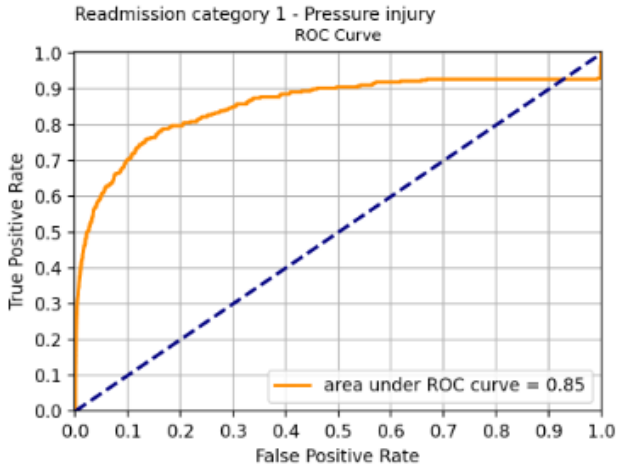
Readmission condition category 3 (Surgical complications)

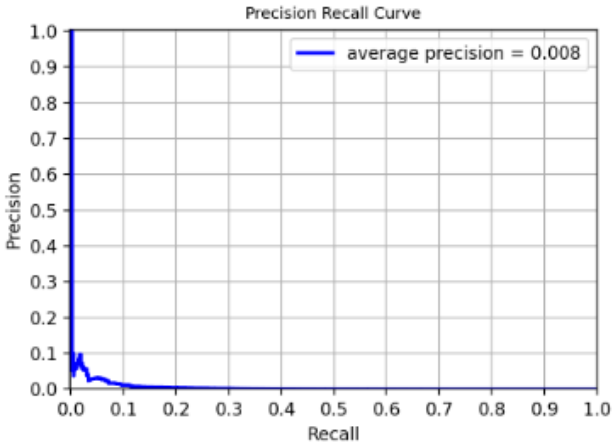
- AR-DRG G66A (Abdominal Pain and Mesenteric Adenitis, Major Complexity)
- NWAU 0.6768
- Complexity score for readmission category 3 is 93, moderate complexity.

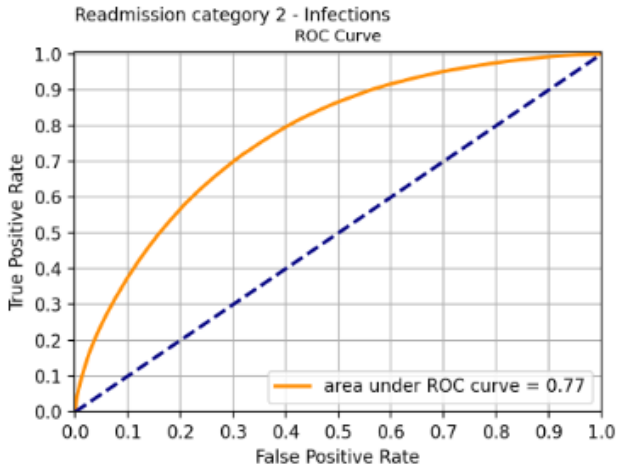
The calculation

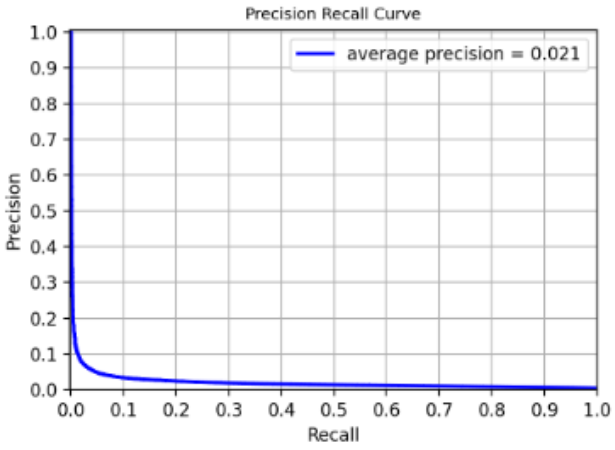
- The incremental cost of the readmission is the NWAU of the readmission episode, i.e. 0.6768.
- The dampening factor for readmission category 3 moderate complexity is 0.2980 therefore the NWAU reduction is 0.6768 * 0.2980 = 0.2017
- The readmission episode is funded with the full NWAU, i.e. 0.6768.
- The funding deduction applies to the index episode, so the index episode is assigned NWAU of 0.8505 - 0.2017 = 0.6488.

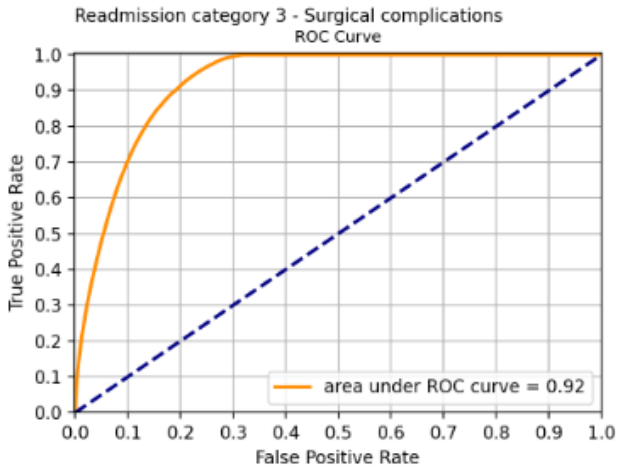
Appendix A: Model fit curves

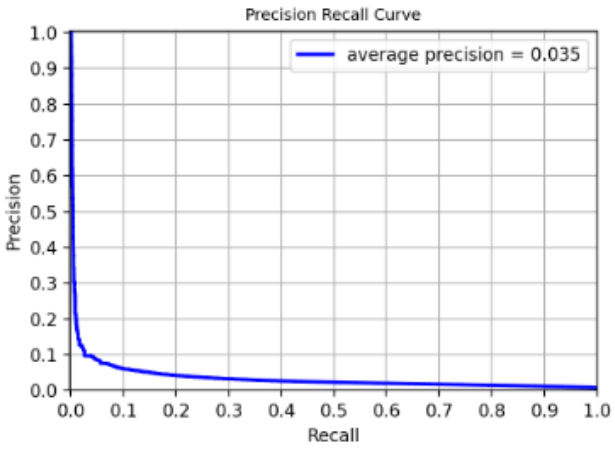


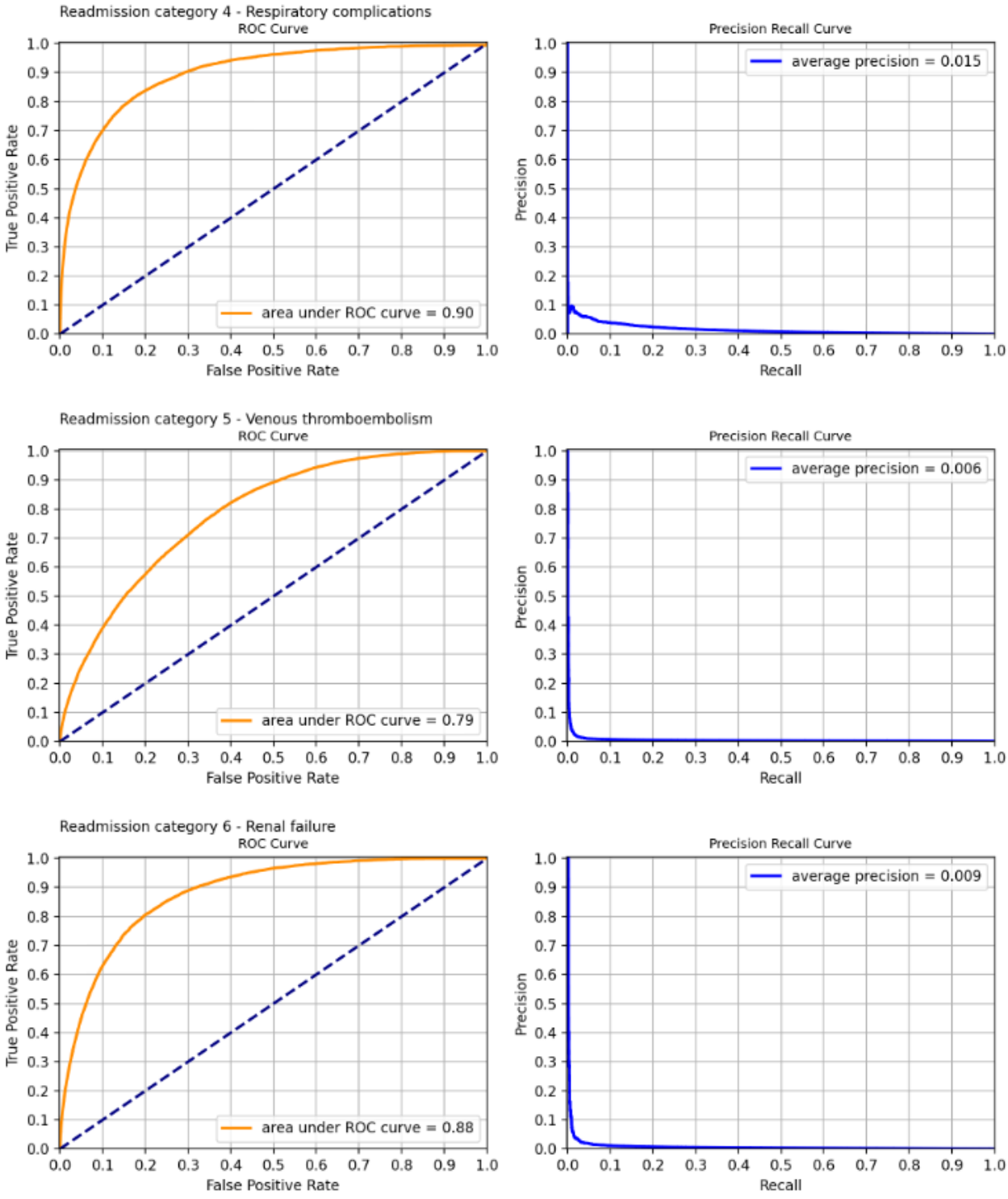


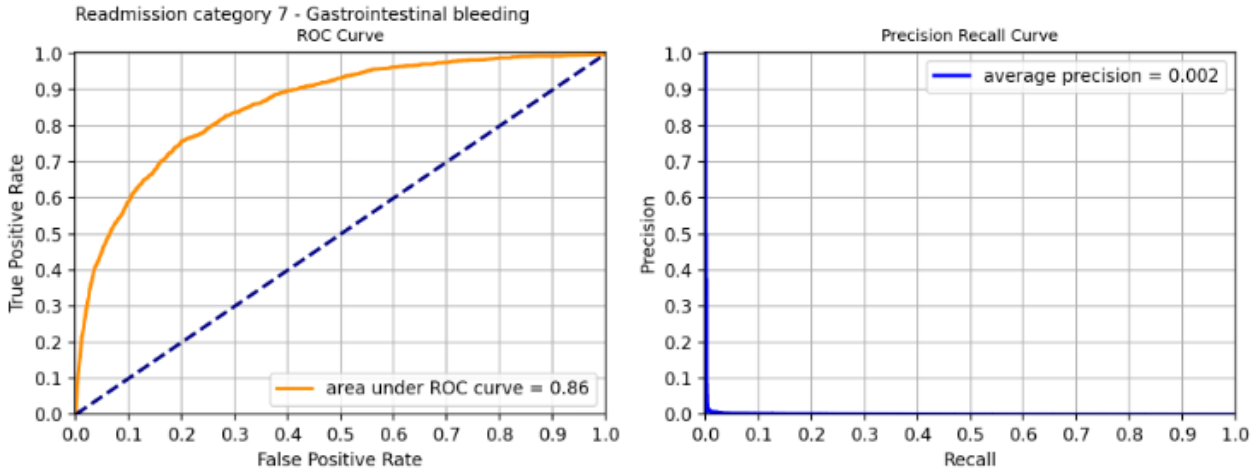


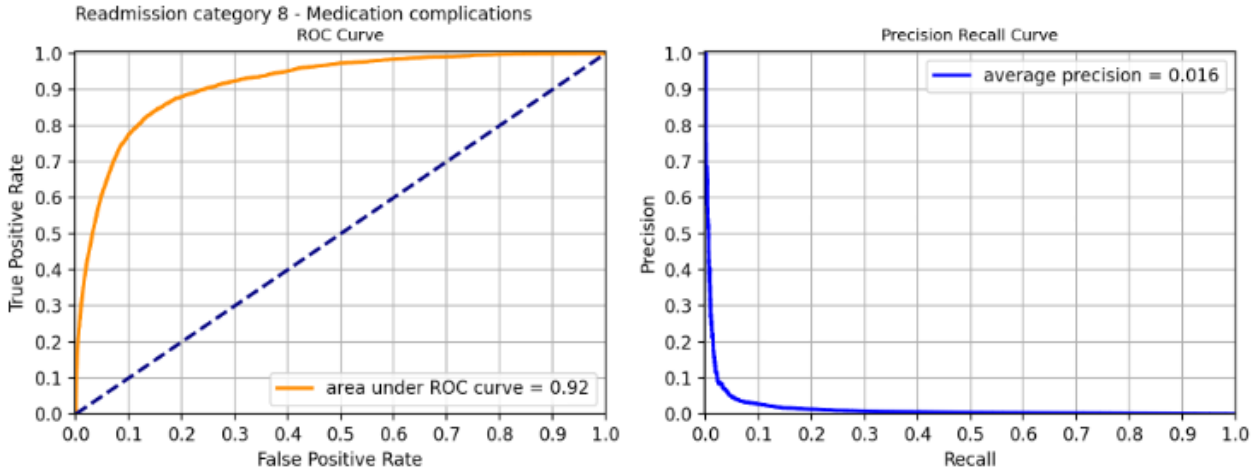


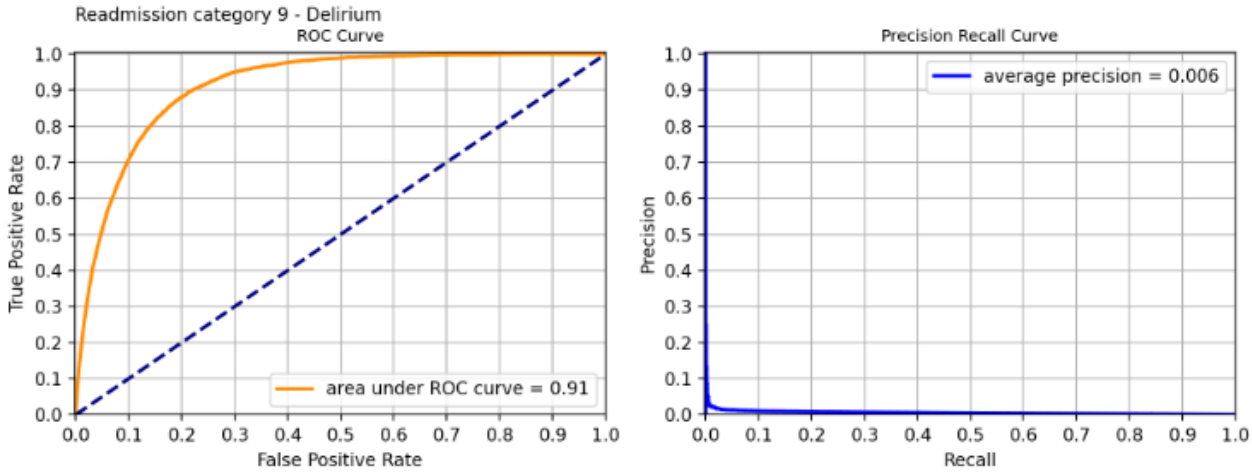


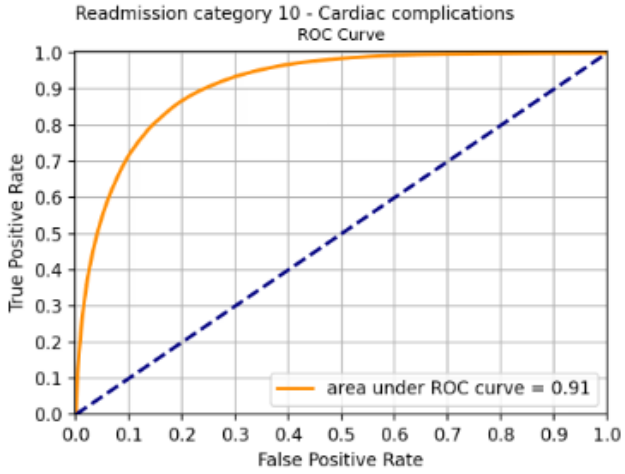


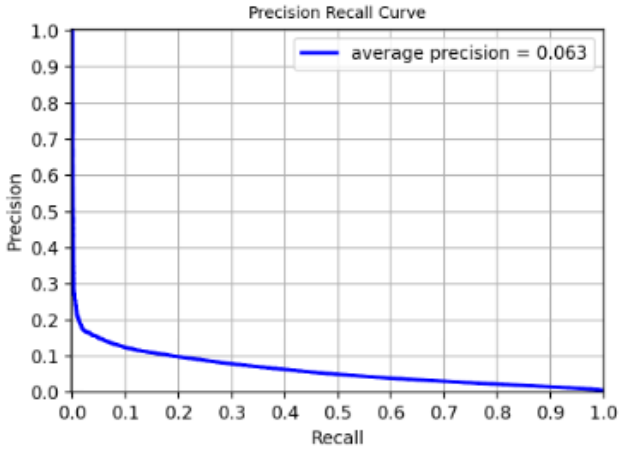

Readmission category 4 - Respiratory complications
ROC Curve
True Positive Rate
False Positive Rate
area under ROC curve = 0.90
Precision Recall Curve
Precision
Recall
average precision = 0.015
Readmission category 5 - Venous thromboembolism
ROC Curve
True Positive Rate
False Positive Rate
area under ROC curve = 0.79
Precision Recall Curve
Precision
Recall
average precision = 0.006
Readmission category 6 - Renal failure
ROC Curve
True Positive Rate
False Positive Rate
area under ROC curve = 0.88
Precision Recall Curve
Precision
Recall
average precision = 0.009

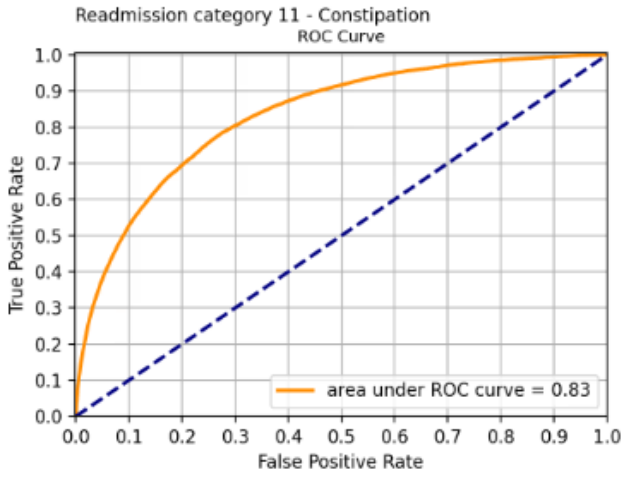

Readmission category 7 - Gastrointestinal bleeding
ROC Curve
True Positive Rate
False Positive Rate
area under ROC curve = 0.86
Precision Recall Curve
Precision
Recall
average precision = 0.002

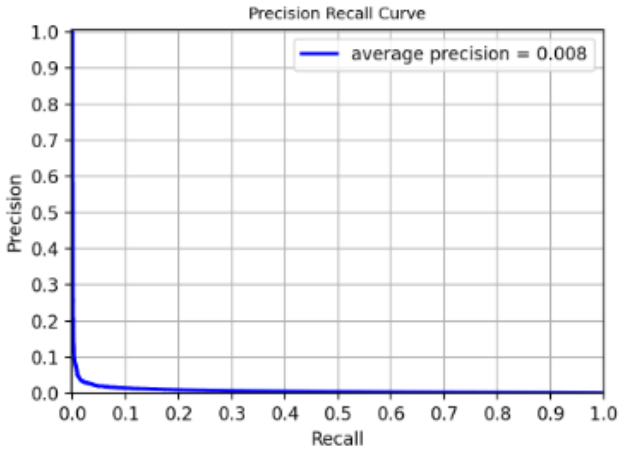

Readmission category 8 - Medication complications
ROC Curve
True Positive Rate
False Positive Rate
area under ROC curve = 0.92
Precision Recall Curve
Precision
Recall
average precision = 0.016

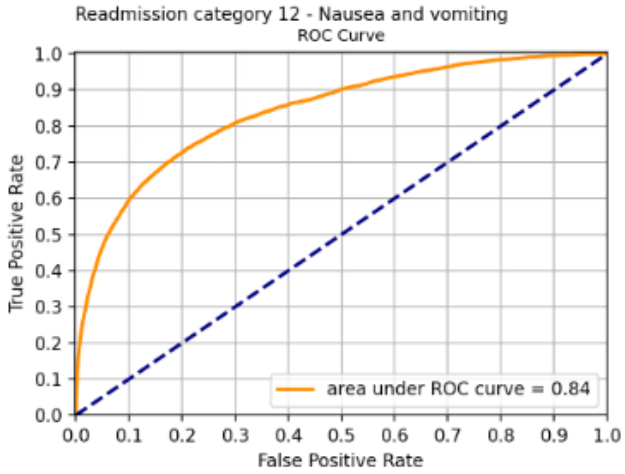

Readmission category 9 - Delirium
ROC Curve
True Positive Rate
False Positive Rate
area under ROC curve = 0.91
Precision Recall Curve
Precision
Recall
average precision = 0.006

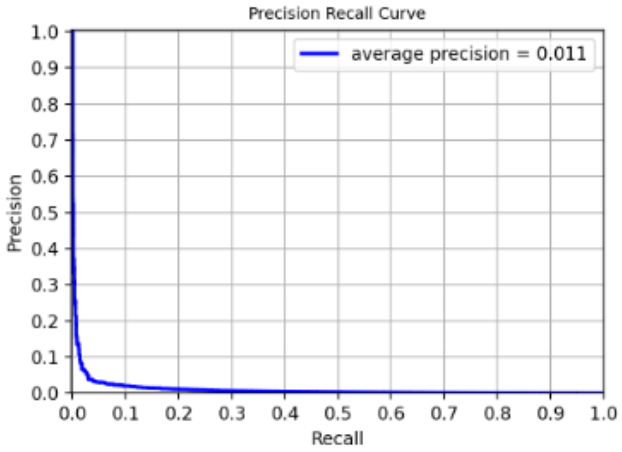

Readmission category 10 - Cardiac complications
ROC Curve
True Positive Rate
False Positive Rate
area under ROC curve = 0.91


Precision Recall Curve
Precision
Recall
average precision = 0.063


Readmission category 11 - Constipation
ROC Curve
True Positive Rate
False Positive Rate
area under ROC curve = 0.83


Precision Recall Curve
Precision
Recall
average precision = 0.008


Readmission category 12 - Nausea and vomiting
ROC Curve
True Positive Rate
False Positive Rate
area under ROC curve = 0.84


Precision Recall Curve
Precision
Recall
average precision = 0.011

Appendix B: Shadow period risk factors, Charlson diagnosis codes and chronic condition diagnosis codes

Table B1: Risk factors assessed throughout the shadow period

First Report	Second Report	Third Report
• Patient age • Sex • Indigenous status • Treatment remoteness • Diagnosis related group type (medical, surgical, other) • MDC • Charlson score • Socio-Economic Indexes for Areas (SEIFA) • ICU status • Admission status • Transfer status	• Patient age • Charlson score • MDC • Emergency status • ICU hours • AR-DRG type • Sex • Transfer status • Patient remoteness • Indigenous status • Mental health condition present • Presence of a pacemaker • Dependence on ventilation • Post transplant • Asthma • Obesity/malnutrition • Presence of a HAC	• Patient age • MDC • Emergency status • ICU hours • AR-DRG type • Sex • Transfer status • Patient remoteness • Indigenous status • Mental health condition present • Presence of a pacemaker • Dependence on ventilation • Post transplant • Asthma • Obesity • Malnutrition • Presence of a HAC • Length of stay in the index admission • Number of procedures undergone in the index admission • Number of hospital admissions in the year prior to the index admission • Charlson comorbidity diagnostic categories • Chronic condition flags

Table B2: Previous Charlson diagnostic category definitions

Diagnostic category	Diagnosis codes
Acute myocardial infarction	I21-prefix I22-prefix I25.2-prefix
Congestive heart failure	I50-prefix
Peripheral vascular disease	I71-prefix I79.0-prefix I73.9-prefix R02-prefix Z95.8-prefix Z95.9-prefix
Cerebral vascular accident	I60-prefix I61-prefix I62-prefix I63-prefix I65-prefix I66-prefix G45.0-prefix G45.1-prefix G45.2-prefix G45.8-prefix G45.9-prefix G46-prefix I64-prefix G45.4-prefix I67.0-prefix I67.1-prefix I67.2-prefix I67.4-prefix I67.5-prefix I67.6-prefix I67.7-prefix I67.8-prefix I67.9-prefix I68.1-prefix I68.2-prefix I68.8 I-prefix 69-prefix
Dementia	F00-prefix F01-prefix F02-prefix F05.1-prefix
Pulmonary disease	J40-prefix J41-prefix J42-prefix J44-prefix J43-prefix J45-prefix J46-prefix J47-prefix J67-prefix J60-prefix J61-prefix J62-prefix J63-prefix J66-prefix J64-prefix J65-prefix
Connective tissue disorder	M32-prefix M34-prefix M33.2-prefix M05.3-prefix M05.8-prefix M05.9-prefix M06.0-prefix M06.3-prefix M06.9-prefix M05.0-prefix M05.2-prefix M05.1-prefix M35.3-prefix
Peptic ulcer	K25-prefix K26-prefix K27-prefix K28-prefix
Liver disease	K70.2-prefix K70.3-prefix K73-prefix K71.7-prefix K74.0-prefix K74.2-prefix K74.6-prefix K74.3-prefix K74.4-prefix K74.5-prefix
Diabetes	E10.9-prefix E11.9-prefix E13.9-prefix E14.9-prefix E10.1-prefix E11.1-prefix E13.1-prefix E14.1-prefix E10.5-prefix E11.5-prefix E13.5-prefix E14.5-prefix
Diabetes complications	E10.2-prefix E11.2-prefix E13.2-prefix E14.2-prefix E10.3-prefix E11.3-prefix E13.3-prefix E14.3-prefix E10.4-prefix E11.4-prefix E13.4-prefix E14.4-prefix
Paraplegia	G81-prefix G04.1-prefix G82.0-prefix G82.1-prefix G82.2-prefix
Renal disease	N03-prefix N05.2-prefix N05.3-prefix N05.4-prefix N05.5-prefix N05.6-prefix N07.2-prefix N07.3-prefix N07.4-prefix N01-prefix N18-prefix N19-prefix N25-prefix
Cancer	C0-prefix C1-prefix C2-prefix C3-prefix C40-prefix C41-prefix C43-prefix C45-prefix C46-prefix C47-prefix C48-prefix C49-prefix C5-prefix C6-prefix C70-prefix C71-prefix C72-prefix C73-prefix C74-prefix C75-prefix C76-prefix C80-prefix C81-prefix C82-prefix C83-prefix C84-prefix C85-prefix C88.3-prefix C88.7-prefix C88.9-prefix C90.0-prefix C90.1-prefix C91-prefix C92-prefix C93-prefix C94.0-prefix C94.1-prefix C94.2-prefix C94.3-prefix C94.5-prefix C94.7-prefix C95-prefix C96-prefix
Metastatic cancer	C77-prefix C78-prefix C79-prefix
Severe liver disease	K72.9-prefix K76.6-prefix K76.7-prefix K72.1-prefix
HIV	B20-prefix B21-prefix B22-prefix B23-prefix B24-prefix

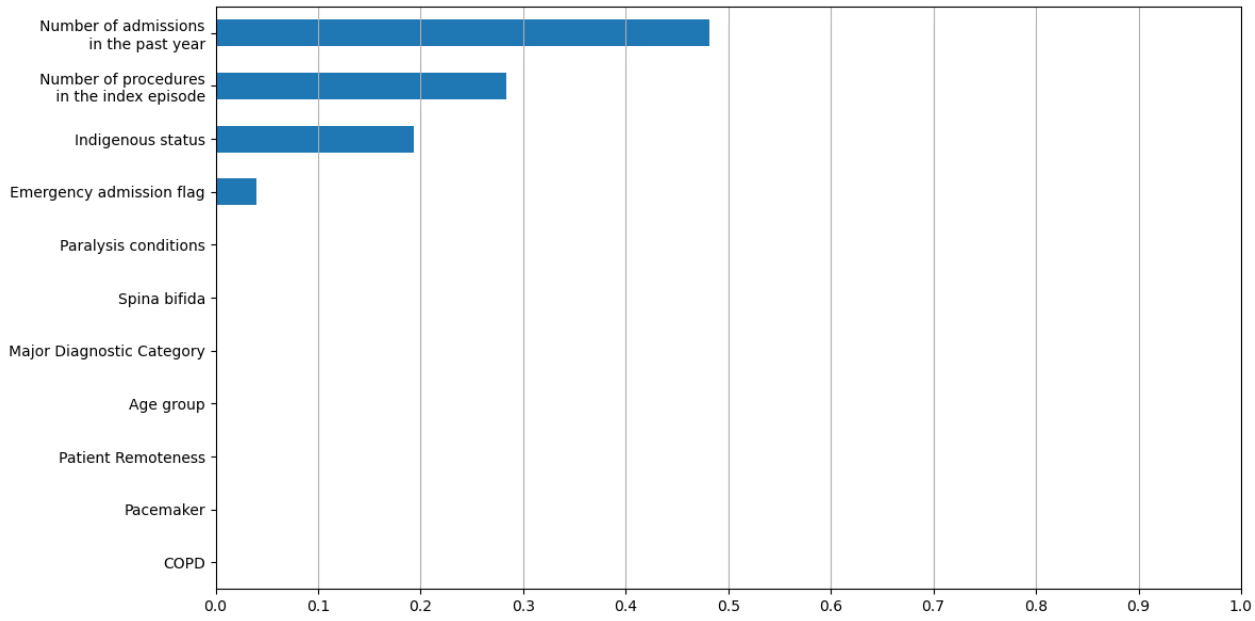
Table B3: Chronic disease code categories

Category	U code	Chronic condition codes
Obesity	U78.1	E66.9 (ICD-10-AM 10th edition only) E66.90 E66.91 E66.92 E66.93 (ICD-10-AM 11th and 12th edition only)
Cystic fibrosis	U78.2	E84
Dementia	U79.1	F03 F00.0 F00.1 F00.2 F00.9 F01.0 F01.1 F01.2 F01.3 F01.8 F01.9 F02.0 F02.1 F02.2 F02.3 F02.4 F02.8 (ICD-10-AM 10th and 11th edition only) F00.00 F00.01 F00.10 F00.11 F00.20 F00.21 F00.90 F00.91 F01.00 F01.01 F01.10 F01.11 F01.20 F01.21 F01.30 F01.31 F01.80 F01.81 F01.90 F01.91 F02.00 F02.01 F02.10 F02.11 F02.20 F02.21 F02.30 F02.31 F02.40 F02.41 F02.80 F02.81 F03.00 F03.01 (ICD-10-AM 12th edition only)
Schizophrenia	U79.2	F20.0 F20.1 F20.2 F20.3 F20.4 F20.5 F20.6 F20.8 F20.9
Depression	U79.3	F33.4 F33.8 F33.9 F32.00 F32.01 F32.10 F32.11 F32.20 F32.21 F32.30 F32.31 F32.80 F32.81 F32.90 F32.91
Disorder of intellectual development	U79.4	F70.0 F70.1 F70.8 F70.9 F71.0 F71.1 F71.8 F71.9 F72.0 F72.1 F72.8 F72.9 F73.0 F73.1 F73.8 F73.9 F78.0 F78.1 F78.8 F78.9 F79.0 F79.1 F79.8 F79.9
Parkinson's disease	U80.1	G20
Multiple sclerosis	U80.2	G35
Epilepsy	U80.3	G40.00 G40.01 G40.10 G40.11 G40.20 G40.21 G40.30 G40.31 G40.40 G40.41 G40.50 G40.51 G40.60 G40.61 G40.70 G40.71 G40.80 G40.81 G40.90 G40.91
Cerebral palsy	U80.4	G80.00 G80.9 G80.00 G80.01 G80.02 G80.03 G80.09
Tetraplegia, paraplegia, diplegia, monoplegia and hemiplegia, due to any cause	U80.5	G81.0 G81.1 G81.9 G83.0 G83.1 G83.2 G83.3 G82.00 G82.02 G82.04 G82.06 G82.10 G82.12 G82.14 G82.16 G82.20 G82.22 G82.24 G82.26 G82.30 G82.32 G82.34 G82.36 G82.40 G82.42 G82.44 G82.46 G82.50 G82.52 G82.54 G82.56
Ischaemic heart disease	U82.1	I25.9 I25.10 I25.11 I25.12 I25.13
Chronic heart failure	U82.2	I50.0 I50.9
Hypertension	U82.3	I10
Emphysema without mention of COPD	U83.1	J43.9
Chronic obstructive pulmonary disease	U83.2	J44.9
Asthma, without mention of COPD	U83.3	J45.0 J45.1 J45.8 J45.9
Bronchiectasis without mention of CF	U83.4	J47
Chronic respiratory failure	U83.5	J96.10 J96.11 J96.19
Crohn's disease	U84.1	J96.10 J96.11 J96.19
Ulcerative colitis	U84.2	K51.0 K51.2 K51.3 K51.8 K51.9
Chronic liver failure	U84.3	K72.1
Rheumatoid arthritis	U86.1	M06.90 M06.91 M06.92 M06.93 M06.94 M06.95 M06.96 M06.97 M06.98 M06.99

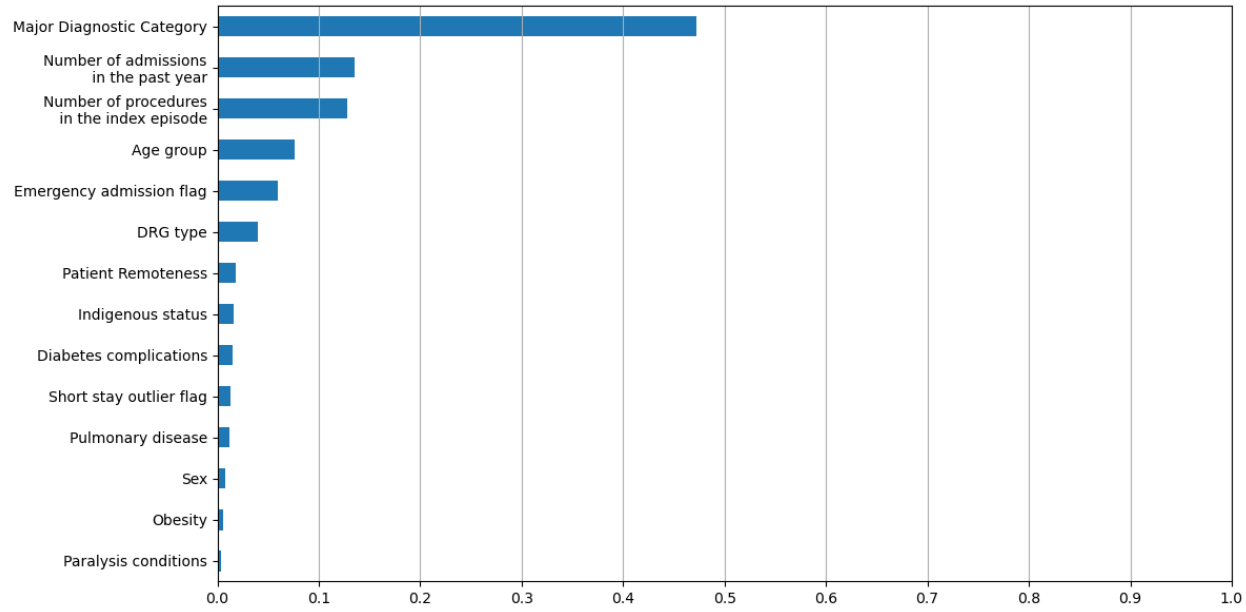
Category	U code	Chronic condition codes
Arthritis and osteoarthritis	U86.2	M15.0 M16.0 M16.1 M17.0 M17.1 M18.0 M18.1 M13.90 M13.91 M13.92 M13.93 M13.94 M13.95 M13.96 M13.97 M13.98 M13.99 M19.01 M19.02 M19.03 M19.04 M19.07 M19.08 M19.09 M47.90 M47.91 M47.92 M47.93 M47.94 M47.95 M47.96 M47.97 M47.98 M47.99
Systemic lupus erythematosus	U86.3	M32.0 M32.1 M32.8 M32.9
Osteoporosis	U86.4	M81.90 M81.91 M81.92 M81.93 M81.94 M81.95 M81.96 M81.97 M81.98 M81.99
Chronic kidney disease stage 3 to 5	U87.1	N18.3 N18.4 N18.5
Spina bifida	U88.1	Q05.00 Q05.01 Q05.02 Q05.10 Q05.11 Q05.12 Q05.20 Q05.21 Q05.22 Q05.30 Q05.31 Q05.32 Q05.40 Q05.41 Q05.42 Q05.50 Q05.51 Q05.52 Q05.60 Q05.61 Q05.62 Q05.70 Q05.71 Q05.72 Q05.80 Q05.81 Q05.82 Q05.90 Q05.91 Q05.92
Down's syndrome	U88.2	Q90.0 Q90.1 Q90.2 Q90.9

Appendix C: Key risk factor breakdowns

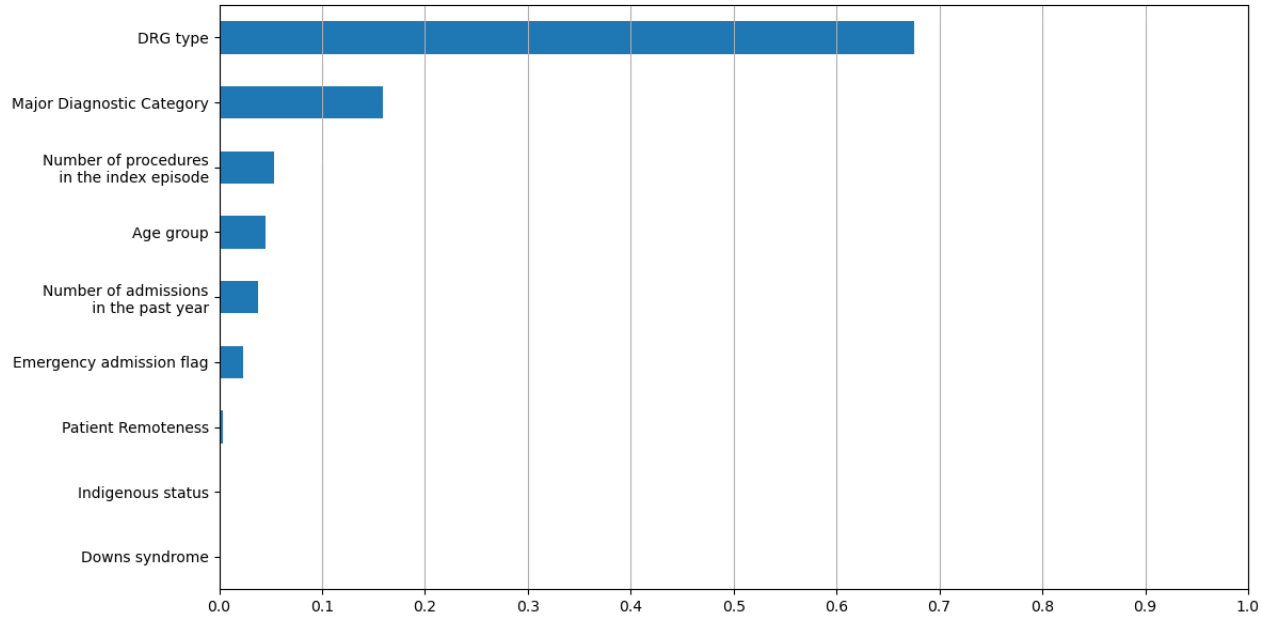
Readmission category 1 – Pressure injury



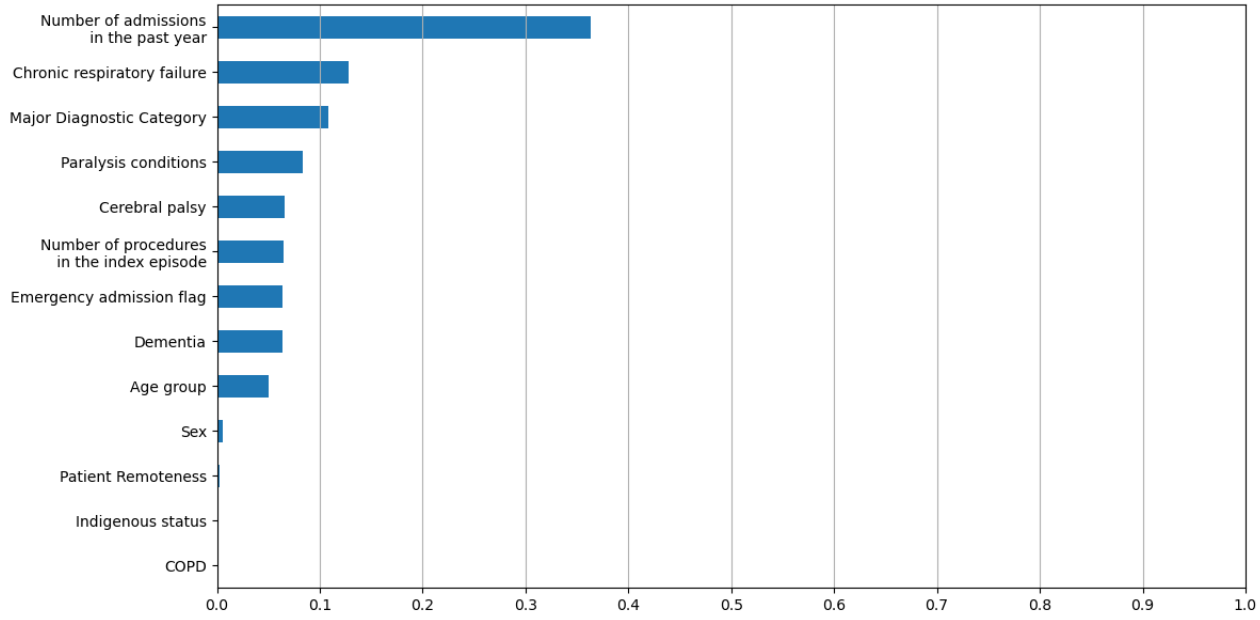
Readmission category 2 – Infections



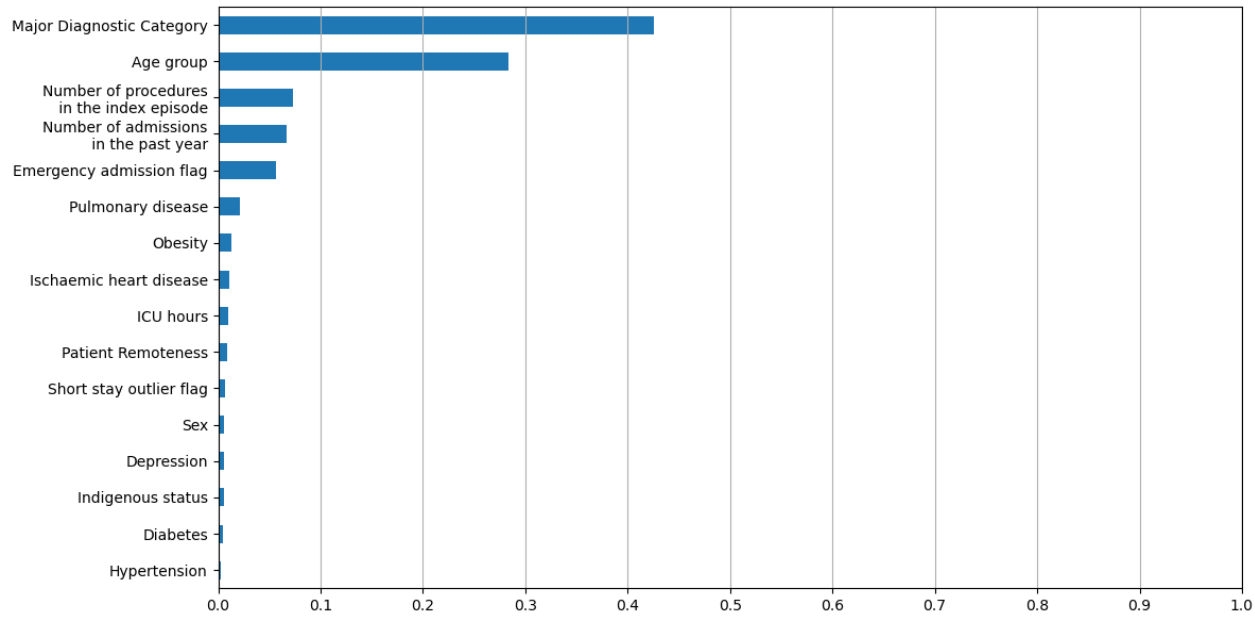
Readmission category 3 – Surgical complications



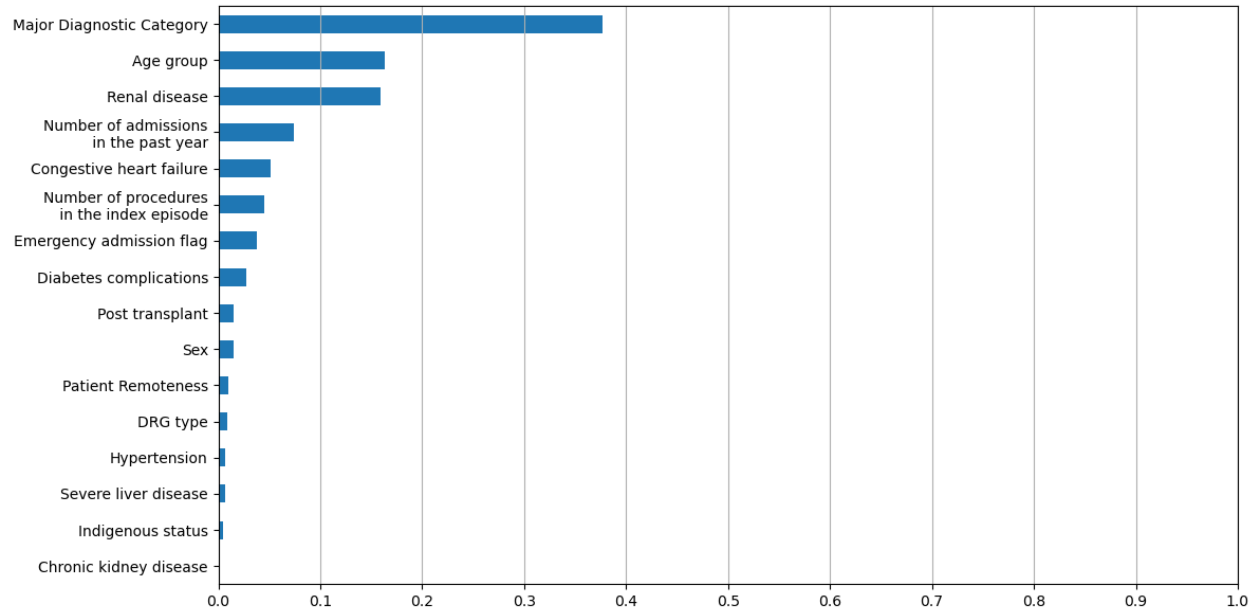
Readmission category 4 – Respiratory complications



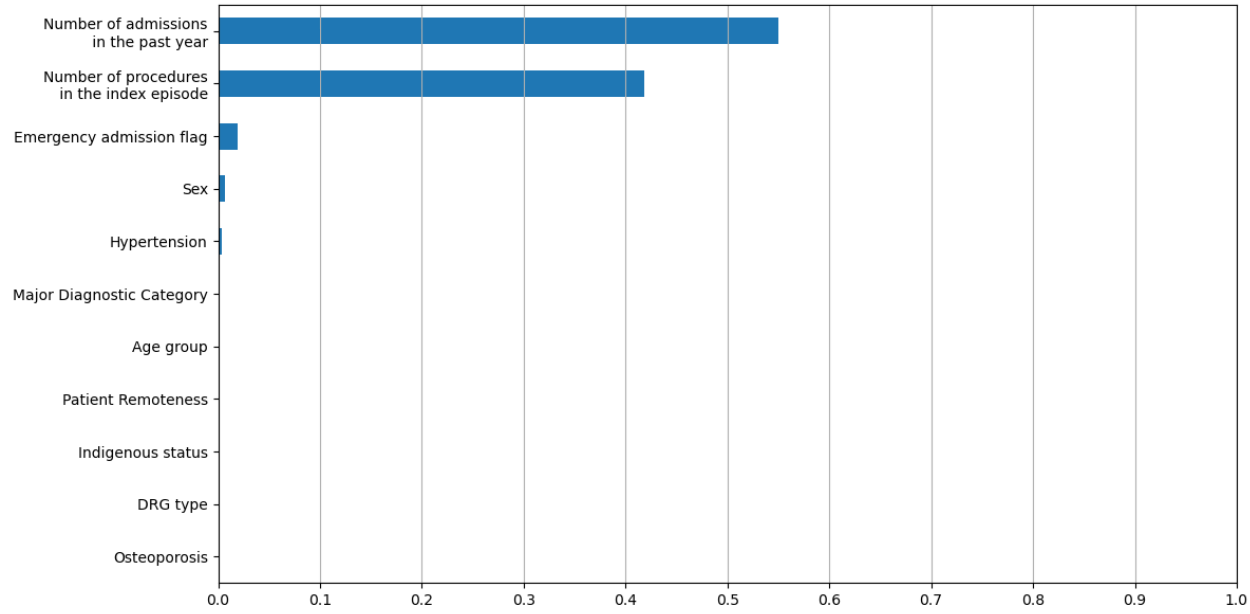
Readmission category 5 – Venous thromboembolism



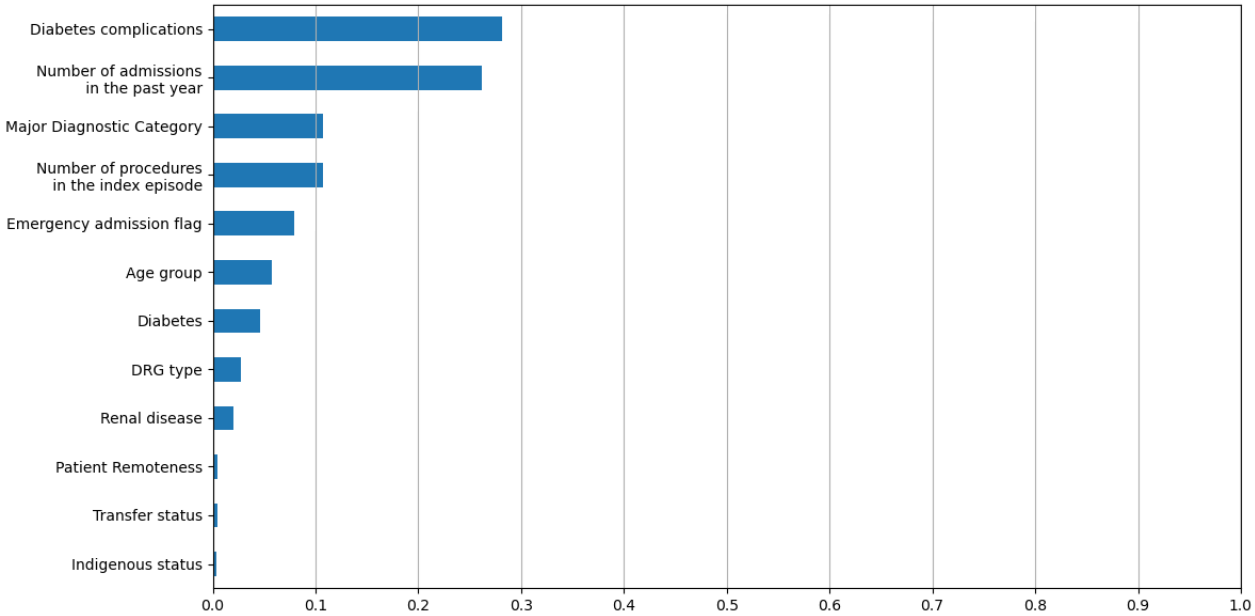
Readmission category 6 – Renal failure



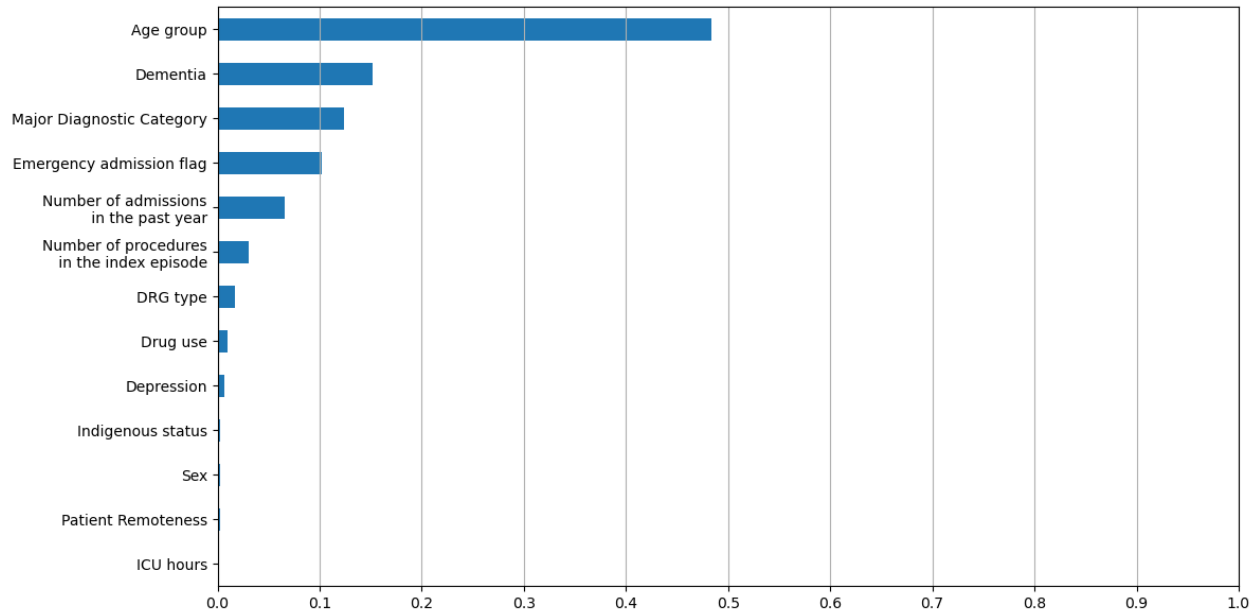
Readmission category 7 – Gastrointestinal bleeding



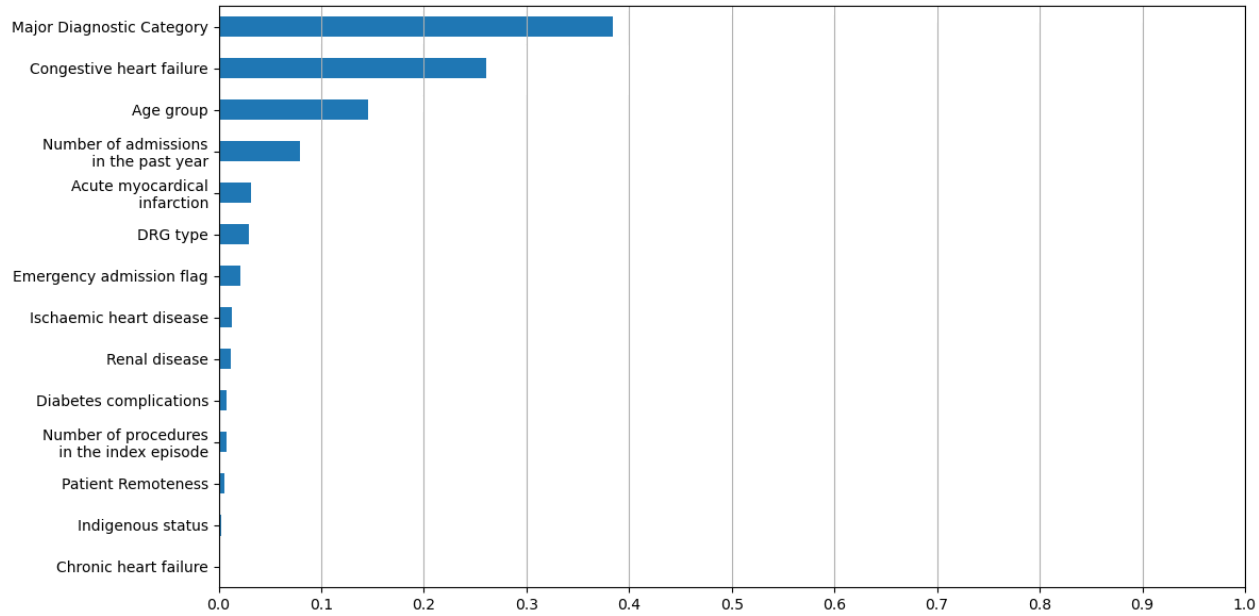
Readmission category 8 – Medication complications



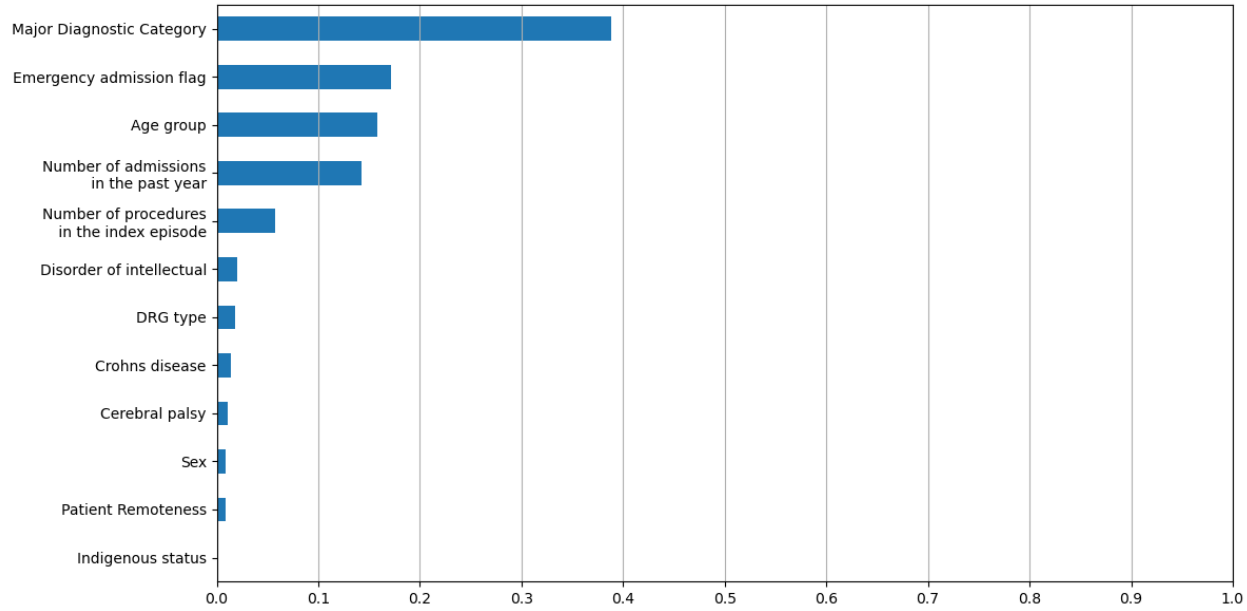
Readmission category 9 – Delirium



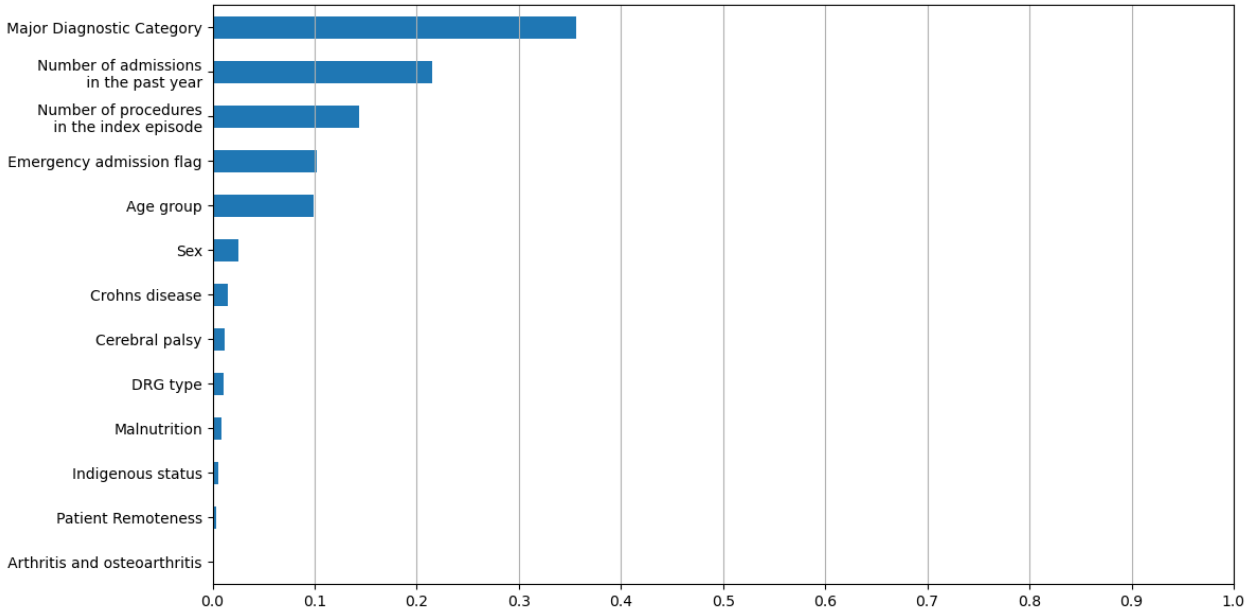
Readmission category 10 – Cardiac complications



Readmission category 11 – Constipation

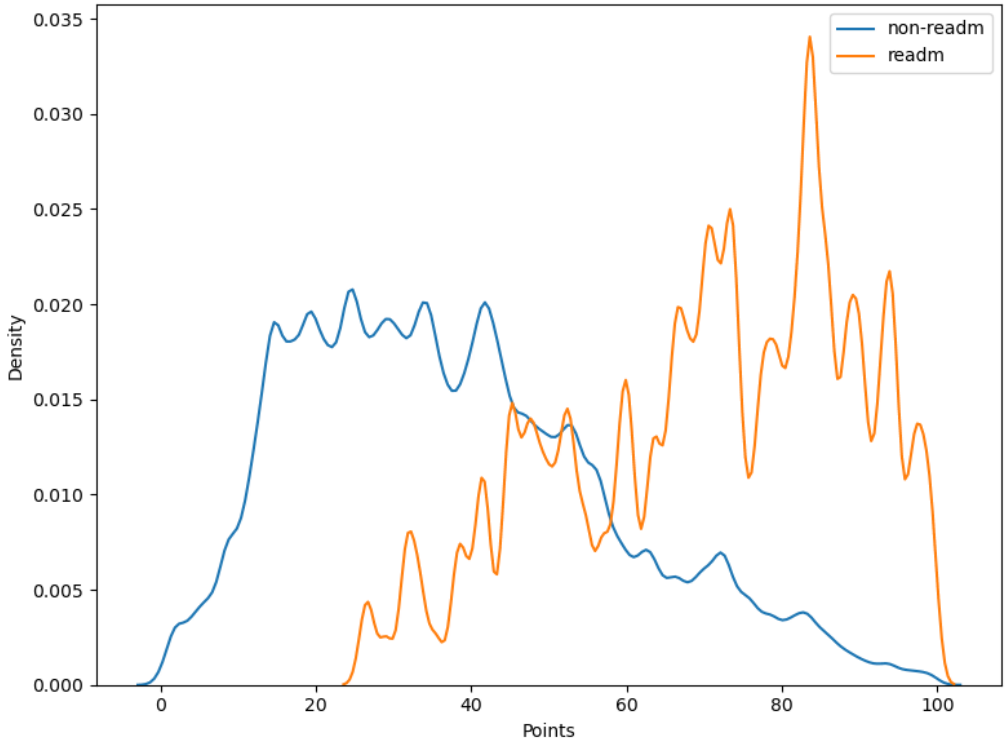


Readmission category 12 – Nausea and vomiting

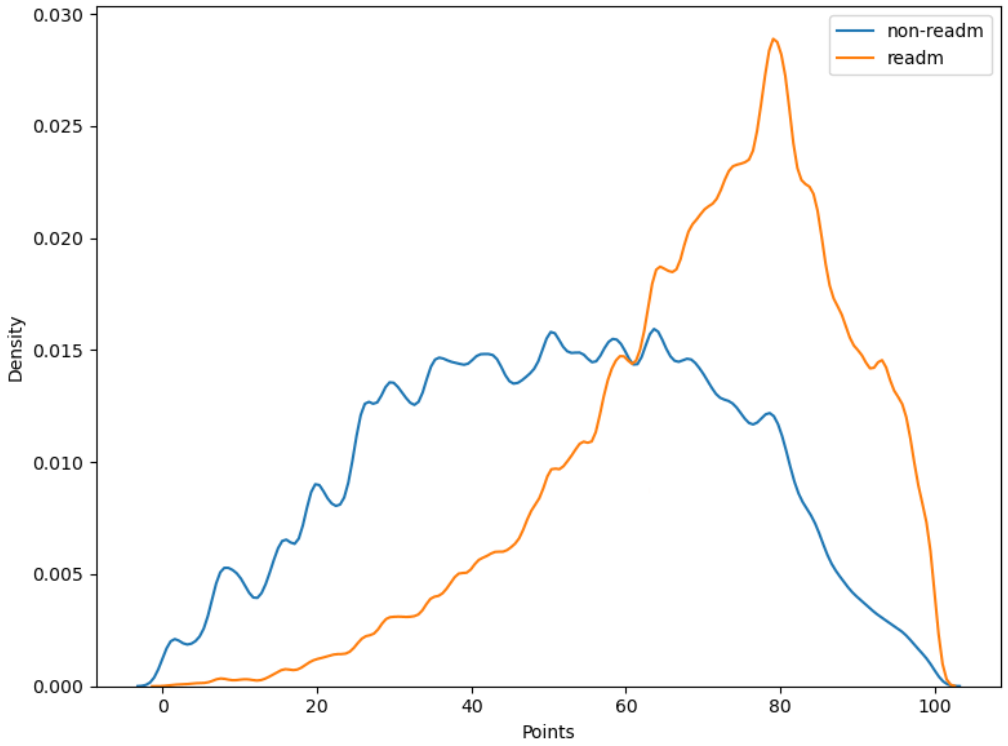


Appendix D: Model complexity distributions

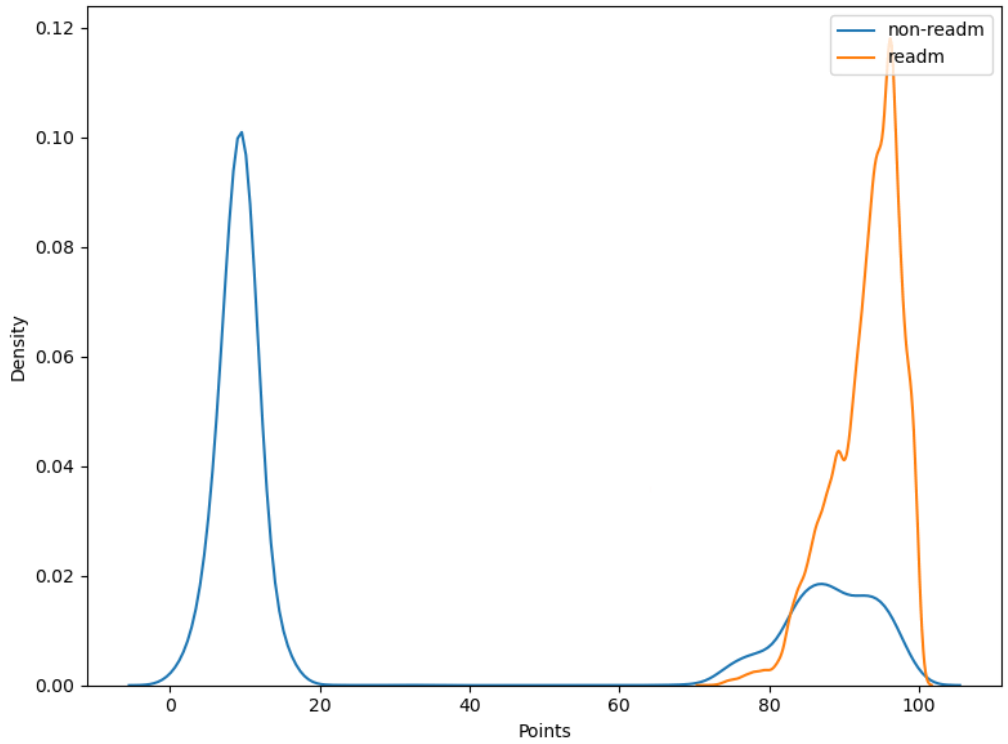
Readmission category 1 – Pressure injury



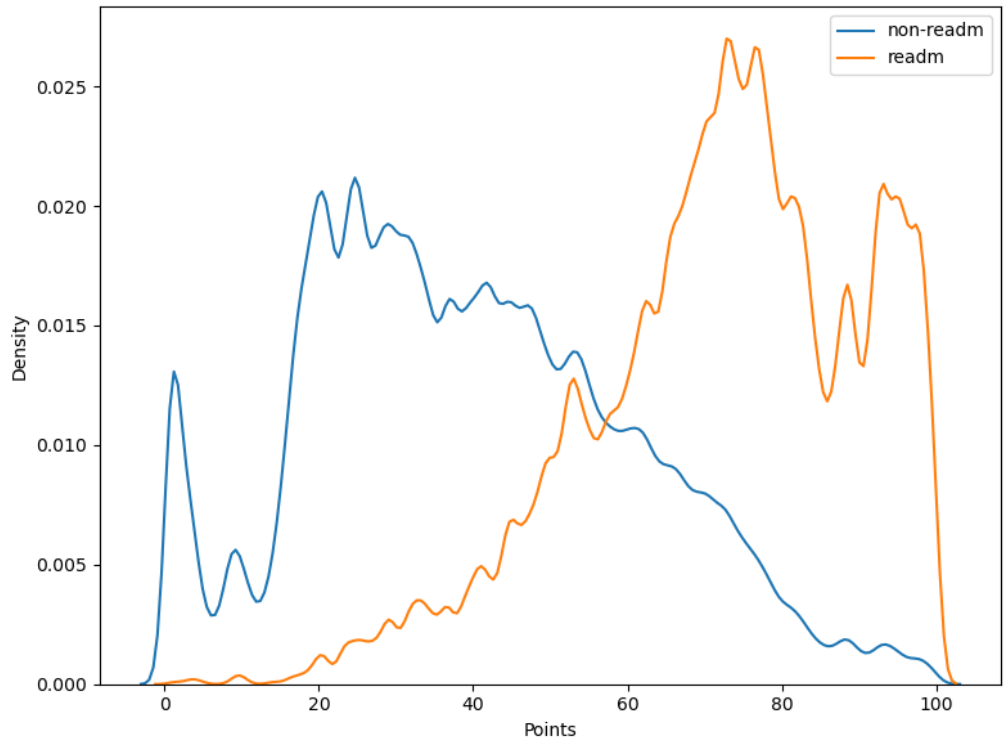
Readmission category 2 – Infections



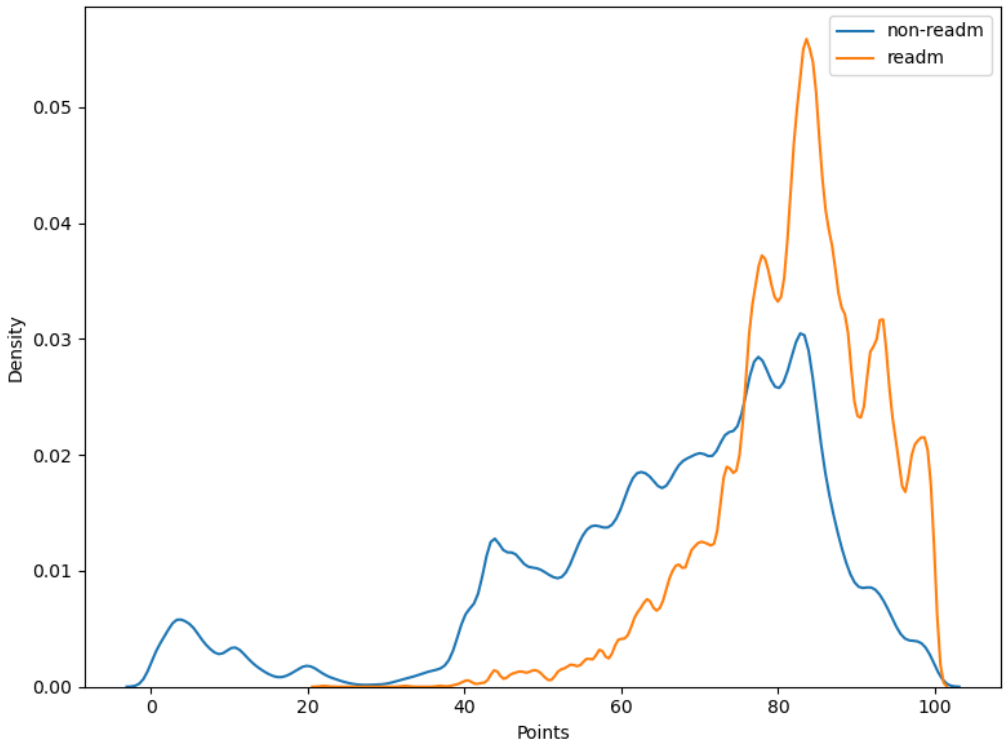
Readmission category 3 – Surgical complications



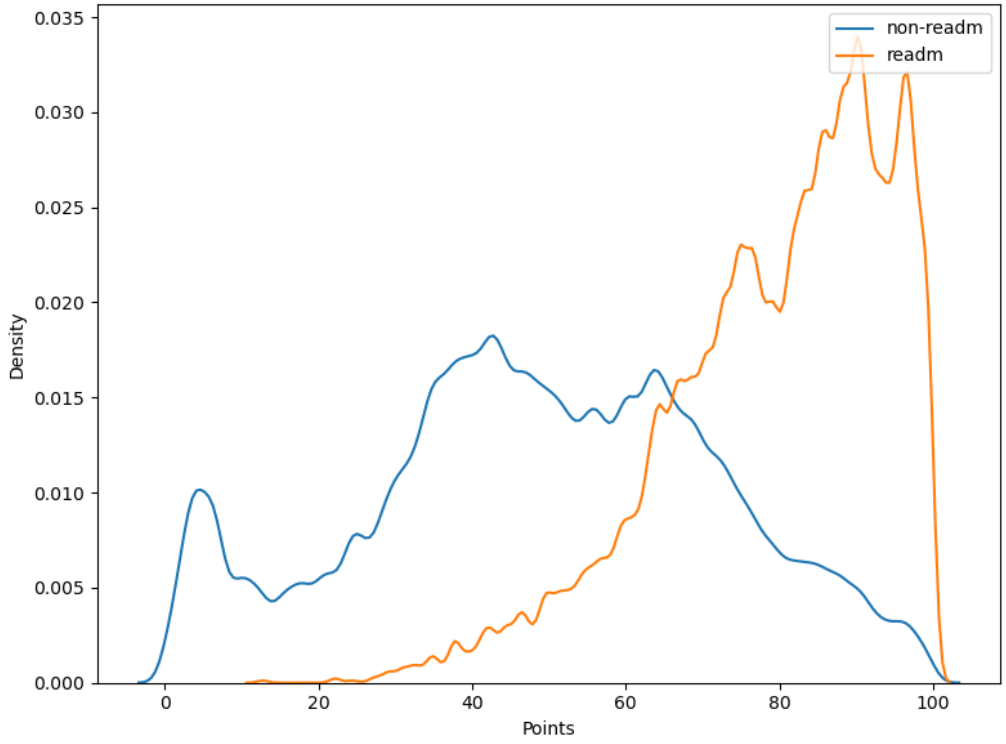
Readmission category 4 – Respiratory complications



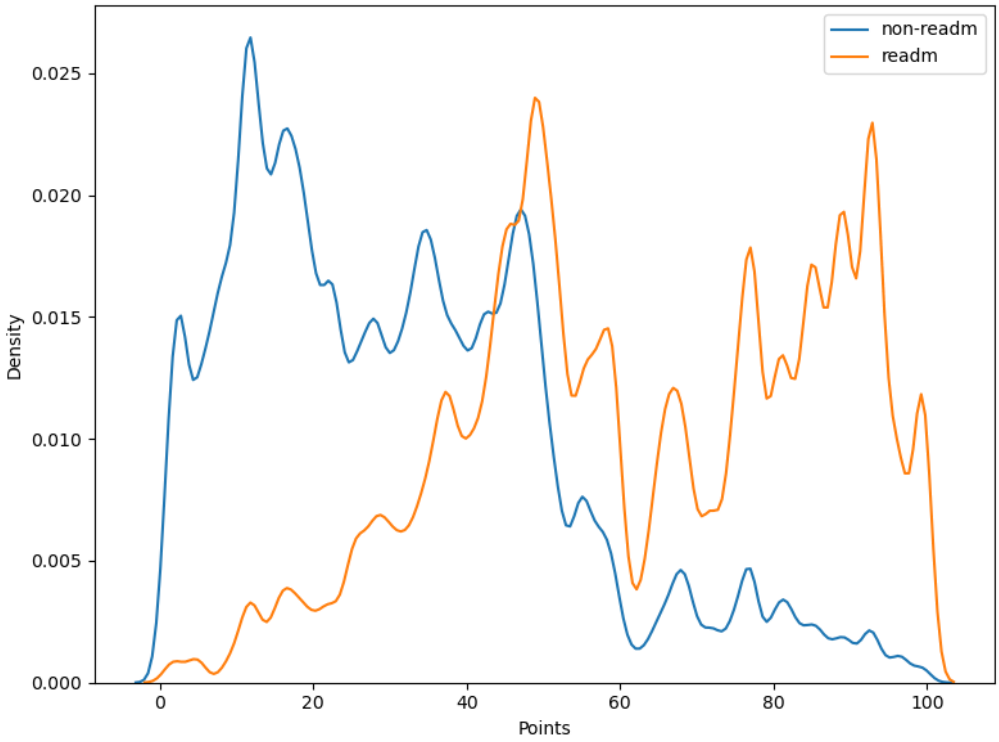
Readmission category 5 – Venous thromboembolism



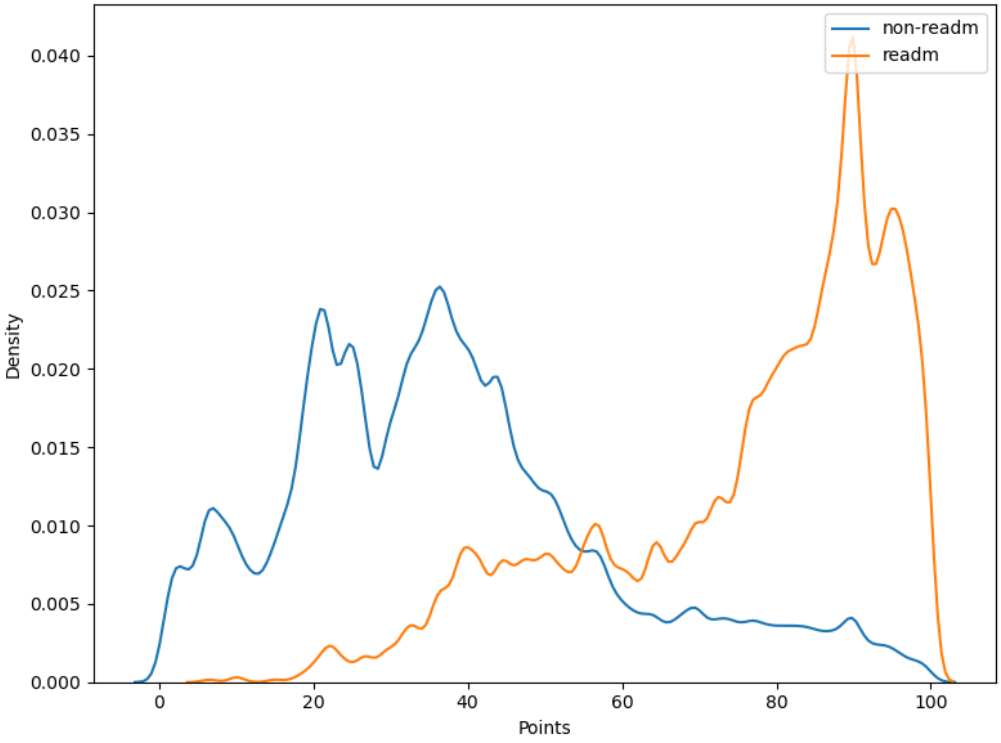
Readmission category 6 – Renal failure



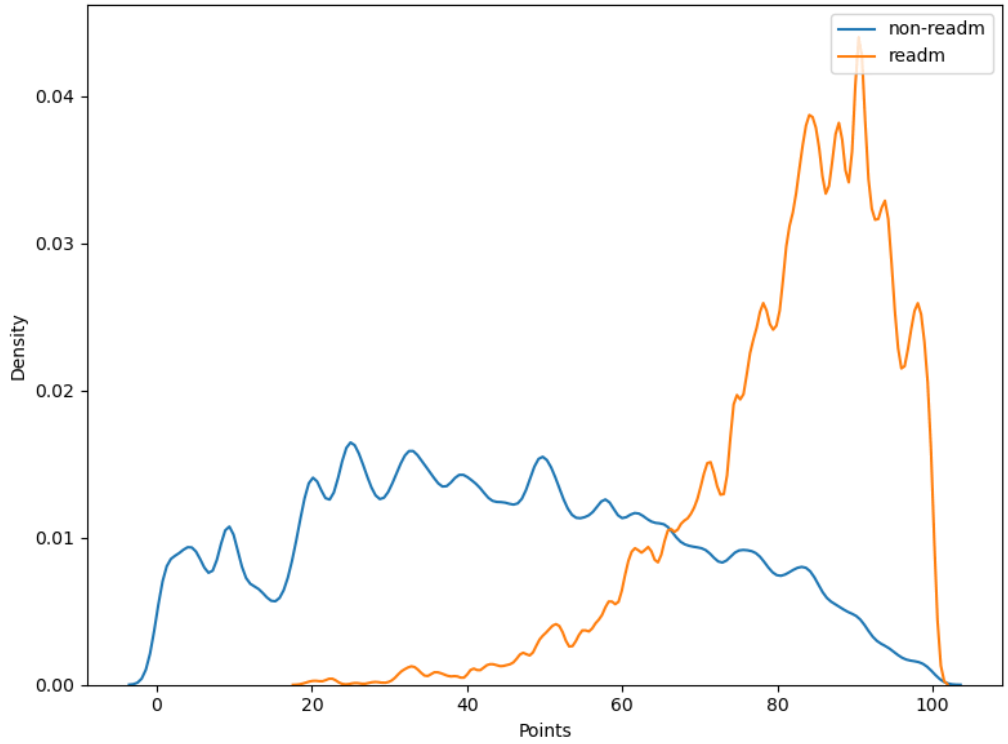
Readmission category 7 – Gastrointestinal bleeding



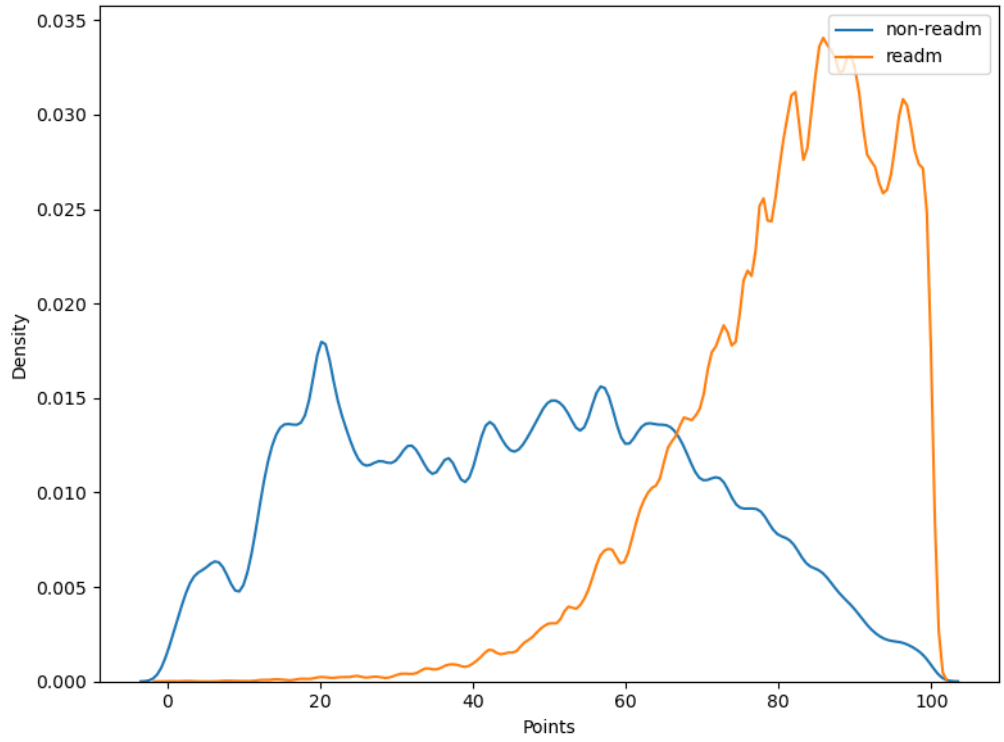
Readmission category 8 – Medication complications



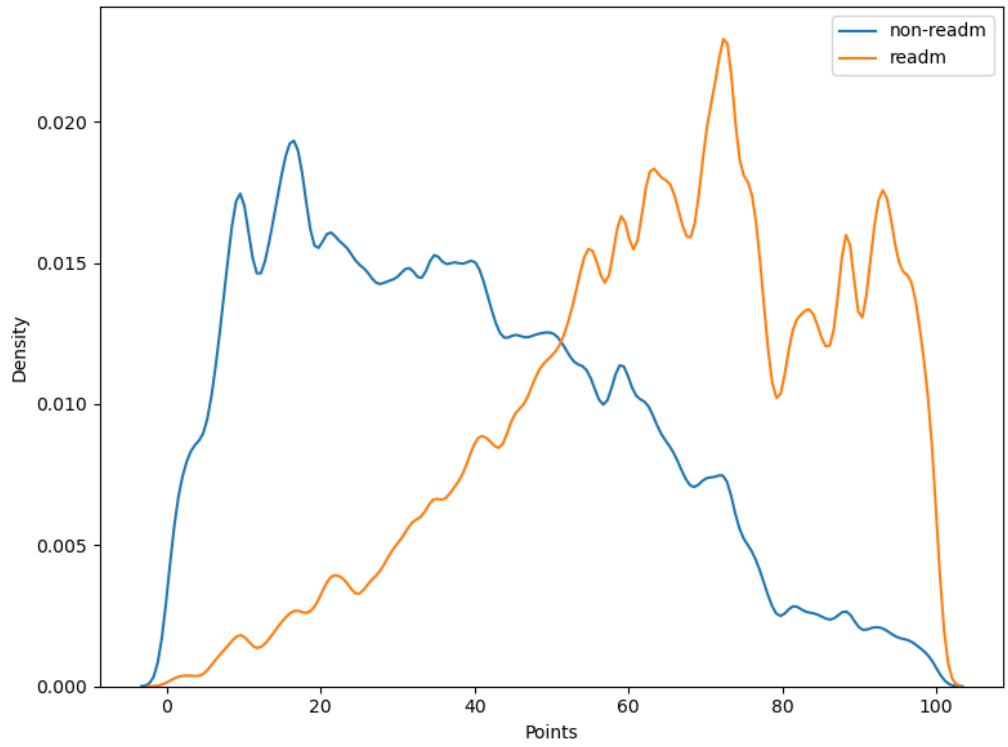
Readmission category 9 – Delirium



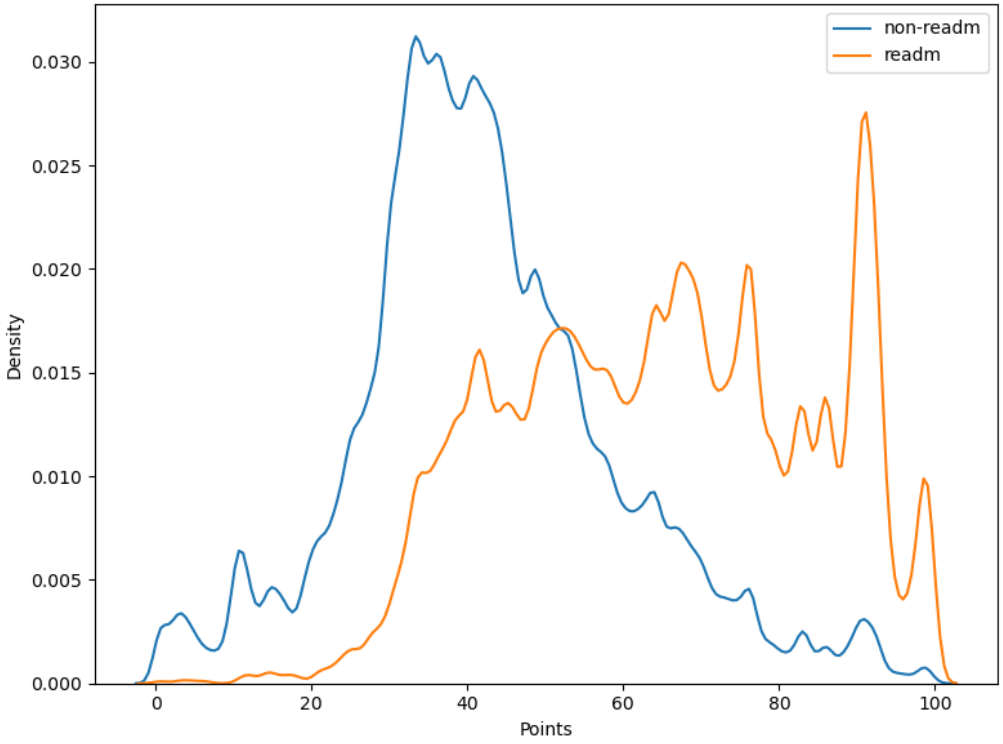
Readmission category 10 – Cardiac complications



Readmission category 11 – Constipation



Readmission category 12 – Nausea and vomiting



Independent Health and Aged Care Pricing Authority

Level 12, 1 Oxford Street
Sydney NSW 2000

Phone 02 8215 1100
Email enquiries.ihacpa@ihacpa.gov.au
Twitter @IHACPAnews

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