Use of existing data sources to refine the funding in ABF for ICU patients

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Healthcare Pricing Office

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Zeumed

Foreword/Acknowledgements

We would like to thank all those working in the hospitals, in particular the ICU Clinical leads, local ICU data coordinators, ICU Clinical Information officers, and NOCA for their assistance in this project. Their knowledge and understanding of the data was so helpful and always forthcoming during what has been a very difficult few years for ICUs in hospitals. We would also like to thank members of the Healthcare Pricing Office who assisted us with different elements of the project and provided their ongoing support.

Funding for Dr. Fiona Kiernan to work on this project was provided jointly by the Acute Hospitals Division and the Healthcare Pricing Office. The initial period of funding covered time worked by Dr. Kiernan in 2019/2020, which was intermittently interrupted by periods whereby COVID-19, impacted her ability to work consistently on this project. The funding was extended for a period February 2021-August 2022.

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Section 1: Introduction

1:1 Rationale for study

Activity Based Funding (ABF) has been in operation in Irish Acute hospitals since 01st January 2016[1]. One of the key benefits of ABF is to provide greater transparency and efficiency in the allocation of hospital resources by funding hospitals based on the quantity and quality of services they deliver to patients. Under the ABF programme, funding is allocated to hospitals based on the mix of patients they treat which is described using Diagnosis Related Groups (DRGs). DRGs provide a means of describing and comparing hospital activity in a complexity adjusted manner, by grouping cases into groups which are clinically similar and which are expected to consume similar amounts of resources.

However, it is recognised internationally that DRG based funding does not always adequately reimburse hospitals for costs incurred in certain instances. For example, costs relating to high cost drugs are often reimbursed as a co-payment to the DRG payment. Tertiary Hospitals typically incur higher costs due to activities such as teaching and training and provision of specialist care which are specific to that type of hospital. Similarly, the costs associated with the treatment of children in a specialist paediatric hospital tend to be higher than those associated with the provision of care in a general hospital setting.

The National Intensive Care Unit (ICU) Audit began collecting data on ICUs in Irish acute hospitals in 2015 and is currently collecting ICU data from 20 Irish acute hospitals. The development of this audit database presents an opportunity for the HPO, in conjunction with the National Clinical Programme in Critical Care, to use this system to develop a more appropriate method of funding ICU through ABF. At a more granular level, local ICU systems which feed into the ICU Audit contain data that would allow per patient costs to be calculated. Access to this data would be necessary to develop the model initially.

There seems to be no clear methodology from the literature on how to account for this particular group of patients who spend time in ICU. However, a review of the literature shows that many countries do account for stays in ICU within their funding models which indicates that this is something which should be considered in Ireland. It is envisaged that this project will allow us to identify the main cost drivers in ICU which can then be used to develop an appropriate funding model that will become part of the overall ABF funding model.

1:1:1 How are ICU patients funded now under ABF?

Patients treated in Intensive Care Units (ICU) tend to be high cost due to the higher resource usage associated with this treatment setting. However, in the current ABF funding model these cases often attract the same DRG price as patients who were not treated in an ICU. This has been largely due to two factors. The first is the lack of a national source of ICU data from which to derive a suitable ICU payment methodology, and the second is the lack of agreement internationally on the most appropriate form of funding for ICU.

[1] For further information on ABF in Ireland please see: https://www.hse.ie/eng/services/publications/activity-based-funding-abf-programme-implementation-plan-2021-2023.pdf

In England, adult, paediatric and neonatal care are unbundled from the core Health Resource Group (which are similar to DRG's in Ireland). Data is submitted for each day of critical care and a grouper produces one adult critical care HRG code per critical care episode. This grouper reflects the number of organs supported and a separate payment is made for these (NHS England, 2021). In Australia there are DRGs associated with relevant ICU admissions (eg. ventilation >=96 hrs & <336 hours, ECMO etc.) as well as a price weight adjustment to the National Efficient Price (NEP) based on the number of hours of ICU admission (SA Health, 2020).

This study uses available data to investigate whether it is feasible, based on data available, to introduce an ABF funding model for ICU patients in Ireland.

1:2 Project Plan

At the outset, a project plan was devised in conjunction with the HPO, the HSE Programme in Critical Care, and Dr. Fiona Kiernan. Dr. Kiernan began working with the HPO officially in October 2019 while working as and ICU Intensivist Consultant in Beaumont Hospital on a part-time secondment basis, and this has continued (with some interruptions due to COVID-19) until August 2022. A discussion was held in January 2020 with stakeholders (see Table 1) to get agreement on the overall approach of the project. This meeting assisted with outlining the aims, expected benefits, and formation of project team.

1:2:1 Project Team and Stakeholders

Key members of the project team and stakeholders are shown in Table 1 below. Although not directly involved in the project, colleagues in the Healthcare Pricing Office and in the participating hospitals were invaluable in helping to complete particular tasks in this project.

TABLE 1: PROJECT TEAM AND STAKEHOLDERS

Name	Position	Role
Project Team		
Fiona Kiernan	CEO and Founder of Zeumed (https://www.zeumed.com/) **Previous role as ICU Intensivist Consultant in Beaumont Hospital and RCSI until end 2021**	Micro Costing and reporting
Fiachra Bane	Head of Data Analytics, HPO	Pricing Specialist
Sinead O'Hara	Statistician, HPO	Data analysis and reporting
Liam O'Connor	Data Analyst, HPO	Data extraction
Mark O'Connor	Head of Costing, HPO	Costing Specialist
Paul Lin	Statistician, HPO	Statistical modelling
Project Sponsors		
Healthcare Pricing Office	Brian Donovan	
HSE Acute Operations	Ciarán Browne	

TABLE 1: PROJECT TEAM AND STAKEHOLDERS (CONT'D)

Name	Position	Role
Project Stakeholders		
Rory Dwyer	Irish National ICU Audit Clinical Lead-NOCA	
Mary Baggott	National ICU Audit Coordinator · NOCA	
Participating Hospitals		
Beaumont Hospital	ICU Lead, ICU Data Co-ordinators, Clinical Information System staff	
St James's Hospital	ICU Lead, ICU Data Co-ordinators, Clinical Information System staff	

1:2:2 Aims and Expected Benefits of project

The project proposal stated the that "The purpose [of the project] is to utilise existing data sources to determine the main cost drivers in ICU and use this information to implement an ABF funding model in ICU which will augment the current ABF funding model."

In doing this the project aims were to:

- Use available ICU activity and cost data to micro-cost ICU attendances for 2017, and thus provide an accurate cost per ICU attendance that will be used for analysis.
- Perform statistical modelling to determine the main cost drivers in terms of patient characteristics and length of stay.
- Apply model developed on ICU data to the patient level costing data collected by the HPO in order to determine whether there is good correlation between the PLC costs and the model.
- Use the most significant and readily available cost drivers as a basis for the funding model.

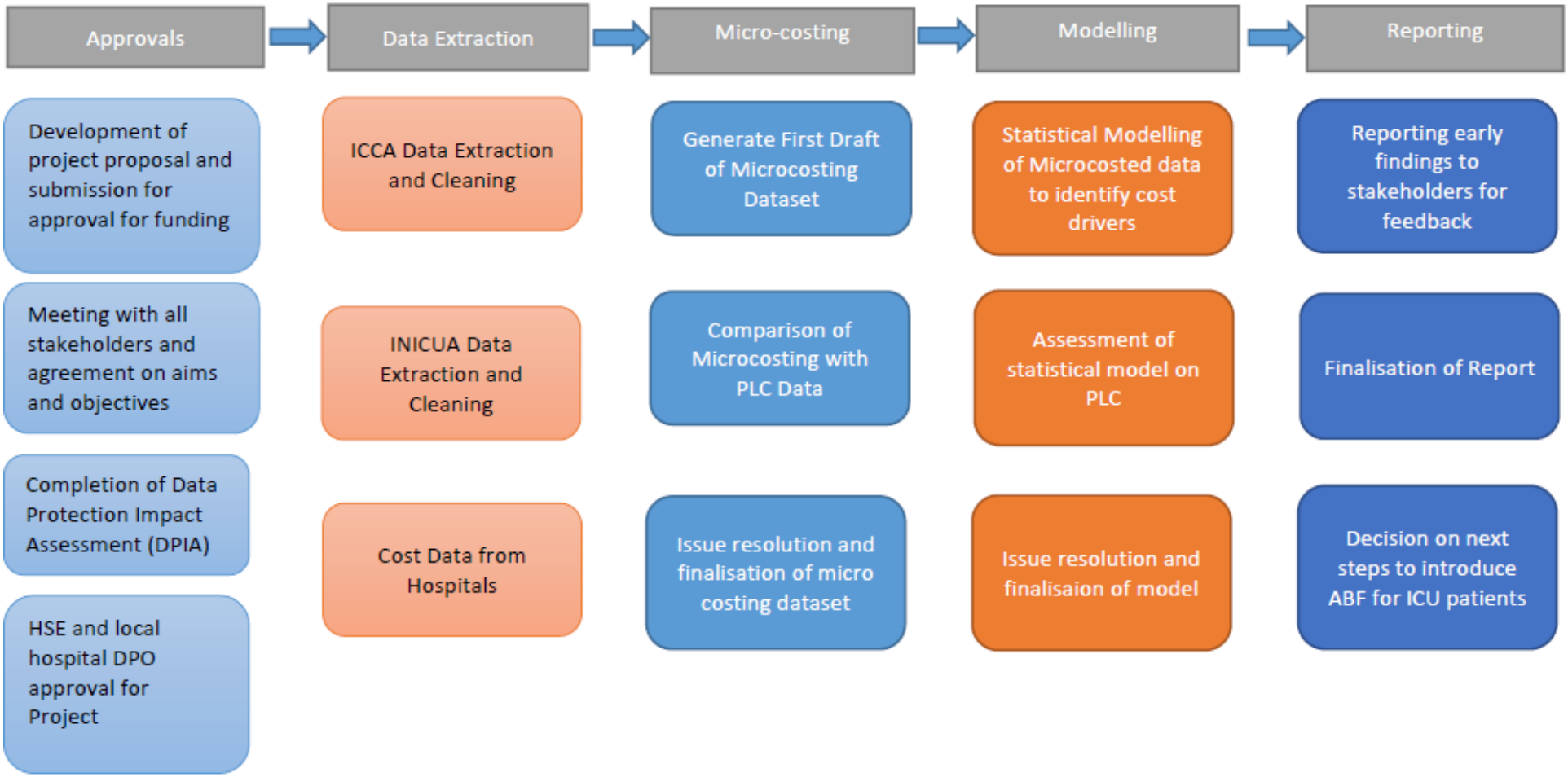
The expected benefits of carrying out this approach were to:

- Produce a minimum dataset specification for ABF funding in ICU.
- Define a set of weights which can be used to determine an appropriate funding model for cases treated in ICU.
- Produce recommendations for the implementation of ICU funding in the ABF funding model.

1:2:3 Project Milestones

There were several key milestones in this project. While these are all outlined in Figure 1, key steps included getting project approval and considering the data protection implications of carrying out this project. As data was acquired for two different hospitals, the data extraction and costing did not occur simultaneously for both.

FIGURE 1 PROJECT MILESTONES AND KEY STEPS



Note: Some of these key steps were delayed by factors outside of our control, and occurred at different stages for both hospitals.

1:2:4 Timeline Challenges

Despite early progress in getting the project proposal and PIA approved within the HSE, there have been a number of challenges which delayed progress on this project.

- Although there was tacit acceptance of the DPIA and Project Proposal from key personnel in the hospitals, it proved to be very difficult to get official confirmation of participation and then to contact to the correct individuals to gain access to the data.
- The ICCA system has a very complicated back-end that was not designed with reporting and analysis in mind. The process of data identification and extraction was time consuming, involving input from the ICU intensivist, database manager, data analysts, product vendor and assistance from hospital staff.
- Covid-19: Similar to all activities in the health service, COVID-19 caused significant delays in this project. At the time, Dr. Kiernan was working as a Consultant Anaesthetist & Intensivist in Beaumont and could only intermittently work on the project. It also led to delays in accessing the data for the project for the second hospital we were working with.
- HSE Cyber-attack: The HSE Cyber-attack occurred in May 2021 which resulted in the HSE shutting down a lot of its IT systems and connections with external agencies. This led to significant delays accessing INICUA (Irish National ICU Audit) data from the second hospital as they no longer could access the system to pull down reports. This was eventually resolved in October 2021.

Section 2: Data Sources

Extraction of data for this project was undertaken with full regard to the recent Data Protection Act 2018 and the General Data Protection Requirements (GDPR). As per Article 25 of the GDPR the project team was cognisant of the requirement to implement data protection principles, such as data minimisation, in an effective manner, and to integrate the necessary safeguards into the processing of data used in this project.

The data extracted for this project used data feeds directly from the hospitals, and also from the HPO. There were challenges and data quality issues for all data sources, which were investigated where possible, and these are briefly discussed in each section below.

2:1 ICU Data

The DPIA was provided to each hospital (Local DPO and ICU Clinical leads), and further local agreements were signed as necessary to extract ICU data. For example, MRN was required from the hospitals and this had to be justified as it is a patient identifier. The HPO collects Patient Level Costing data which uses the MRN as a unique patient ID and therefore could be used to accurately match data between the two datasets. This process is covered in Section 3:1:3.

2:1:1 Philips IntelliSpace Critical Care and Anaesthesia (ICCA) information system

This system is a patient monitoring, documentation and prescribing system used in the two hospital sites in our study. ICCA collects data about a patient's condition, automatically via live data streams from bedside monitors and manually via input by health care providers. These data include ventilation details, medications and notes from medical staff. The data are stored in a reporting database, which is managed using Microsoft SQL Server. This information system does not record any pre or post care received in ICU such as how long the patient was in hospital. The ICCA data was the main source of data for micro-costing as it is recorded at a much more granular level that the INICUA database.

Challenges

The main issue with ICCA is the high level of configurability of the system, meaning that data encoding can vary extensively between sites, and retrieving even a single data element such as capturing when bronchoscopies were performed was challenging. While data from the ICCA system was required for micro-costing, this exercise was time consuming, and is considered to be a once-off exercise. This data is not easily reproduced across hospitals, and even within hospitals, the configuration of the database may have changed over time to suit clinical needs. This step was necessary to get the more granular detail at daily patient level which is not available via the INICUA database.

Data Quality

There are cases where resource use may have been recorded in the free text notes, but this is not easily accessible because it is not included as standard in the flow-sheet in the ICCA system. These cases include the use of intermittent haemodialysis (IHD), nasal bridles, patient hoists, posey mitts, thrombo-embolic deterrent (TED) stockings, sequential compression devices (SCDs).

In one hospital ABG data was recorded for the time period after discharge. On further investigation, ABG data was not valid as these were duplicate records, and this issue arose because of the physiotherapy team recording notes and ABG results post-discharge. This was not possible to detect from a simple analysis of currently available data, and required separate interrogation of the data, and additional reports to remove these duplicates.

2:1:2 The Irish National ICU Audit (INICUA) database

Further data protection approvals were sought from hospitals to retrieve INICUA data. This data comprises of two sets of data. Data that is submitted to the Intensive Care National Audit and Research Centre (ICNARC) and local data items that are recorded to support the audit locally. Of the entire INICUA dataset, 45% comprises the ICNARC dataset and 55% the local dataset (National Office of Clinical Audit, 2020). The INICUA covers the entire patient journey throughout the entire acute hospital stay. It is a quality and patient safety initiative that measures the quality of care in each ICU, benchmarking against international standards. The audit was set up by the National Office of Clinical audit (NOCA) in 2013, with one of its uses listed as "providing data that will help to build on a database for research and development" (NOCA website). This data records elements such as; basic demographic information, pre-admission details, including past medical history and reason for ITU admission and number of days of organ support during their ICU stay. The purpose of the audit is to provide a national resource for research and a local and national benchmarking tool for individual critical care units.

Challenges

There is currently no national system for this standardised dataset. NOCA envisage that this database will be available at a national level but there is no set timeline.

In St. James's, INICUA data was only available for all of 2017 for its cardiothoracic unit (KSICU) and only has data from July 2017 for all other wards, including the general ICU.

Data Quality

There is the possibility of inaccuracies in the NOCA dataset, owing to the fact that NOCA is reliant on human transcribing from the ICIP records. When matching was carried out between the two data sources there were issues of mismatches due to typographical errors in the MRNs in the NOCA data. These were rectified by working with the local ICU data coordinators.

There were also differences in the admission dates and discharge dates between the two data sources. This is possibly due to more accurate information in the notes whereby the local data coordinators are able to more accurately define the admission and discharge dates of patients, while ICIP records the time a bed was allocated to a patient, rather than their ultimate admission time (for example, a patient's post-operative bed allocated and recorded in ICIP while they are still in theatre). As a further example, in some cases (albeit a small number), the total recorded renal support days was greater than combined days of CRRT and IHD.

2:1:3 ICU Cost Data

Both hospitals involved in this study are voluntary hospitals and are reimbursed by the HSE. These voluntary hospitals have separate purchasing and supply agreements distinct from those of the HSE, and their financial management departments are responsible for these negotiations. Cost data was confidentially supplied for this project and applied to the ICU activity data.

These included:

Medication

Price lists were obtained from both hospitals for 2019. 2019 was selected because these price lists were not available for either hospital for 2017[2]. Information for each medication was obtained on a per unit cost basis from each hospital with VAT included as standard.

Example – 1 unit of 75mg aspirin = €0.01.

The products included may be generic or brand name. In general, hospitals purchase generic medications if available. However, in some cases, the price of both the generic and trade name formulations were listed for the same drug. In this case, the lowest cost option was selected.

Consumables

The 2019 price list for consumables supplied to the Intensive Care Units of each hospital was obtained. The catalogue code of Hospital A specified the number of items per box/packet. The catalogue code for Hospital B specified total quantity, but not the number of items per box/packet. Instead the number of items included was obtained from a search of supplier catalogues, and compared with both the price list of Hospital A and a generic reference price list to ensure accuracy. VAT was included as standard.

Example – assuming €250 (including VAT) for the supply of a box of Central Venous Catheters (CVC), with 5 CVC per box, then 1 CVC= €50.

Equipment

The annual contract cost of equipment (including VAT) was obtained from the Physics department in each hospital [3]. The number of machines available for the ICUs in each hospital in 2017 was also obtained from the Physics department and confirmed with senior nursing staff. The only equipment costs included in the model are those that vary dependent on patient need. This means that the annual contract costs of infusion pumps, monitors, and computer system, were excluded as these are found at all bed spaces and do not differ on a per diem basis. Similarly, the costs of the ICU defibrillator were excluded, as use was recorded in the free text medical and nursing notes. However, the annual contract costs of ventilators (invasive and non-invasive) and equipment for renal replacement (CRRT and IHD) were apportioned based on the individual patient's use of the equipment.

Challenges

2019 cost data was used for both hospitals. It is assumed that there were no major changes in price lists between 2017 and 2019, however it is possible that increased generic medication was available in 2019. Some cross checking was possible using PLC reports.

2:2 PLC Data

Ireland's patient level costing programme has been in operation since 2010. Under this programme participating hospitals undertake an annual study to determine the costs associated with the treatment of each individual patient treated in that hospital over a given time period. Ancillary or

[2] This has not been adjusted for inflation because the focus is on developing a weighted model, rather than the identification of an exact cost in euro. However, if an exact euro cost is to be used in the future, then inflation will need to be considered, as will patent expiry and the introduction of novel agents.

[3] This contract cost is separate to depreciation and capital expenditure on equipment. Neither of these measures were included.

"feeder" information systems within the hospital are utilised to determine exactly which services were accessed by each patient. This allows the costs to be allocated down to the patient level. [4]

For this project PLC data from St. James' and Beaumont Hospital were available for 2017. PLC data forms the basis for the price setting process as it is from these data that the initial cost estimates for different patient types are generated. At the patient level, it is an extension of the HIPE data record containing 18 'cost buckets' per episode of care (which are split into direct and indirect costs).

Of these 'Critical Care' is the relevant cost bucket for comparison. This is the fully inclusive critical care ward cost. It includes medical pay cost allocated to these wards as well as indirect costs. While other costs, including bloods, may be incurred in ICUs, these are captured in different cost buckets and therefore ICIP data for these costs were not included in the costing exercise.

Salaries and overheads were also excluded from the initial micro-costing and statistical modelling work, due to the lack of appropriate allocation parameters. The accurate allocation of salary costs to individual patients would require a time and motion study which is beyond the scope of the current work, while overhead allocation is simply best done based on duration in the ICU. Therefore, the direct critical care cost minus salaries and overheads were used for comparison of micro-costing and PLC.

Challenges

It was not possible to investigate differences in the PLC data against ICU data at a granular level in all hospitals as data was not made available.

- One of the hospitals was unable to provide a full breakdown of drugs, and these were recorded as aggregate headings e.g. antibiotics, anaesthetics, anticoagulants etc.
- One hospital was unable to provide Euro amounts for the cost outputs, so the total micro-costing amount could not be compared.

Data Quality

There was also evidence of potential misallocation in PLC data. For example, in one hospital the cost associated with vaccines was €38k for the ICU, however, the micro-costing total was <€1k. It is rare for vaccines to be administered in ICU as patients are considerably immunocompromised (with the exception of tetanus, which is not a high cost medication).

2:2:1 Other

Some elements of the data were more difficult to capture, for example, the cost in one hospital of transferring ventilated patients to radiology/theatre/angiography[5]. The transfer of patients in and out of ICU was captured from ward transfer files in the Healthcare Pricing Office. The additional consumable costs applied were for ventilation tubing and the share of contract costs for transport ventilators. An assumption was made that all transfers required fresh tubing. Transfers to radiology and theatre consume additional resources in terms of staffing and medication. However, these additional staff members are not included in the ICU cost bucket and therefore they do not need to be included in this model. Staff members from the ICU who are involved in transfers are accounted for in the overall ICU salary costs. Emergency medication used during transfer should be recorded retrospectively, and therefore included in the drug file.

[4] The HPO Costing Team developed an internal website which serves as a single source to access information on cost data specifications and how data from the different hospitals should be mapped to it, costing standards and manuals and the review and data quality processes.

[5] In the other hospital, staff interview confirmed that patients are transferred on their standard ventilator, and therefore they do not require additional tubing nor a transport ventilator.

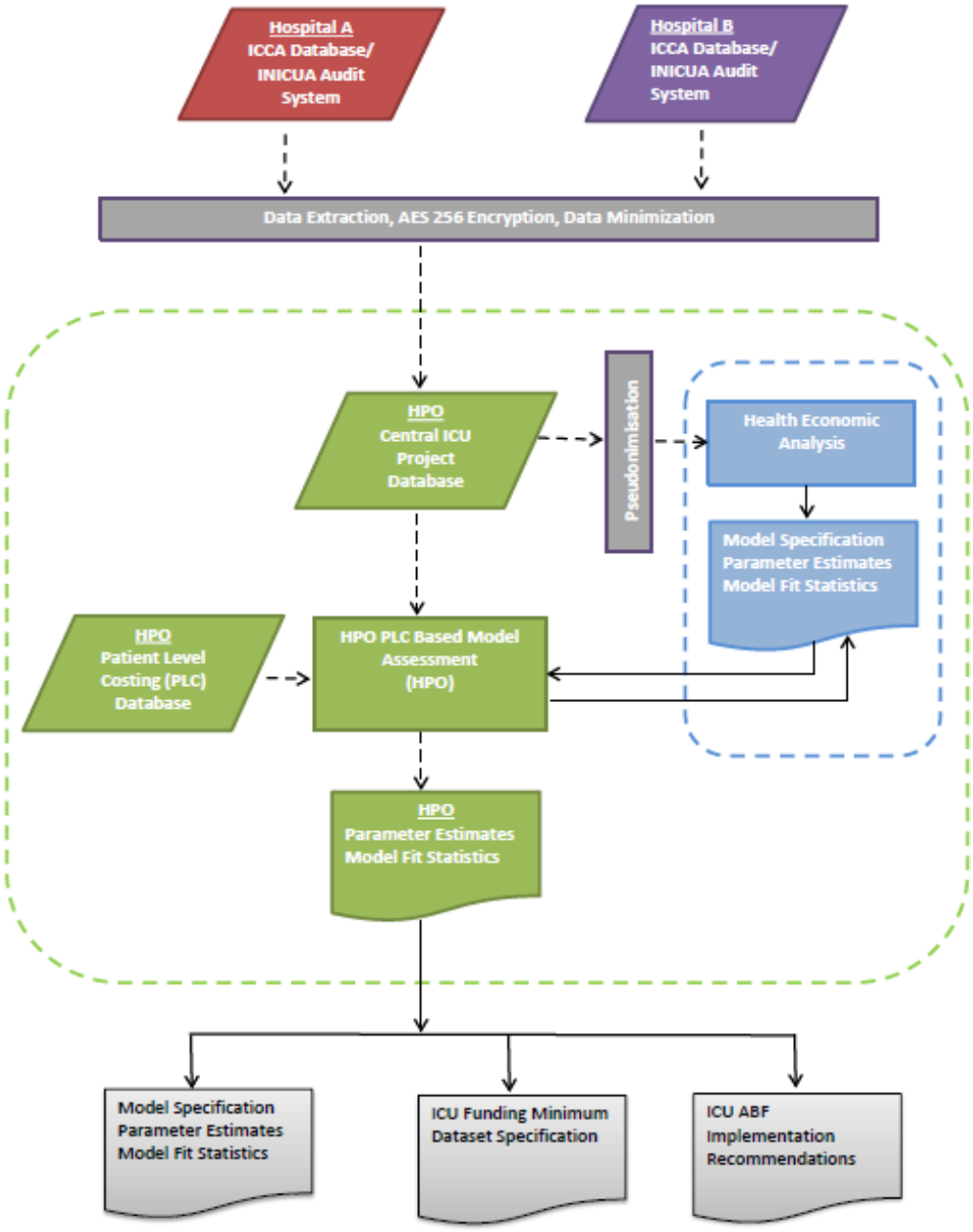
Section 3: Methodology

3:1 Data Extraction and Collation

All patients admitted to ICU between 1st January 2017 and 31st December 2017 were extracted. Each admission was considered to be a separate episode, meaning that patients who were readmitted were given a new identity code, and essentially considered to be a different patient.

The extraction and collation of data for this project was planned at an early stage and a data process flow was included in both the project proposal and the DPIA so the proposed methodology could be examined and approved by the relevant data protection officers. Below, Figure 2 outlines the data process flow and the following sections outline what was involved in this process.

FIGURE 2: DATA PROCESS FLOW



3:1:1 ICCA Data Extraction

Access to the ICCA database was facilitated by a connection via SQL server from the HPO to the hospital[6]. As outlined in the data sources section, extraction of data from this data source was challenging as it is designed mainly as a charting system and is not really designed for secondary use across hospitals given that they are configured based on the needs of the staff in the hospital. This meant that not all elements were stored in the same place. The staff in hospitals were extremely helpful in assisting with that process, and sometimes involved getting advice from the product vendor.

Examples of the data sheets extracted from the system included:

- Medications: Infusions, Bolus Medications, IV Fluids
- Ventilation: Days of Ventilation, Type of Ventilation, Endo Tracheal Tubes
- Dialysis: Days of renal replacement therapy, Renal replacement therapy mode, Dialysis bags

3:1:2 INICUA Data Extraction

Access to the INICUA which is managed by NOCA was facilitated by local ICU data coordinators in the hospitals who prepared the data and sent it securely to the team in the HPO[7].

Using the data manuals, useful fields were identified by the project team and a specified template was sent to hospitals to work from. The data requested included data fields from ICNARC and also additional local data items collected via INICUA.

Examples of the data items requested included:

- Source of admission
- ICNARC Physiology Score
- Status at discharge from unit
- Length of stay in acute hospital following discharge from your unit (days)
- Basic respiratory support - days
- Advanced respiratory support - days
- Basic cardiovascular support - days
- Advanced cardiovascular support - days
- Renal support - days
- Neurological support - days
- Healthcare Resource Group
- Days receiving Level 3/2/1/0 care

While data from ICIP was available for the full year 2017, INICUA data in one hospital was only available from July onwards for particular wards. Details of numbers of patients in both datasets, and the matching of both data sources is available in Appendix 1.

[6] This was carried out using an existing connection that the HPO already has in place for extracting HIPE data.
[7] This data is collected on a daily basis in the hospitals, however, the system is not currently configured to produce daily reports, and therefore INICUA data records supplied for this study represented the entire stay in ICU.

3:1:3 PLC Data

PLC data is held in the HPO and is stored on a local secure server. Additional information and further investigation of PLC data was sourced from the costing accountants who work on PLC data in the HPO. For some of the data, the costing team liaised directly with the Finance departments in the hospitals. Using the MRN, date of birth, and dates of admission and discharge, the ICU and PLC data were matched (details of this process are included in Appendix 2). As one PLC/HIPE record may include multiple ICU encounters for one patient, this process involved grouping ICU encounters for the same patients into one single record.

3:2 Micro-costing

The conduct, appraisal and reporting of micro-costing studies can be complex due to the detailed cost categorization and data collection involved. The majority of literature to date has used provider/staff interview, cost/accounting databases, and time-motion studies to collect data on the quantity of resource utilisation (Xu, et al., 2021). Medical record review is less commonly used, although it remains the gold standard in situations where high quality data can be extracted from the medical records.

We included costs which accrued only to the ICU (see Table 2 for cost components). For example, the costs associated with the insertion of an endotracheal tube were only included if the insertion was recorded as having taken place in the ICU, rather than in the Emergency Department or an operating theatre.

Although medical records are required to map the patient journey correctly, they are not designed for costing studies. Therefore, knowledge of standard practice and additional consumables, as well as knowledge of local ICU practice, was necessary.

The cost components of micro-costing studies include personnel, materials and consumables, overheads, equipment, facility, medication, transportation, laboratory/diagnostics/imaging, productivity loss, food, furniture.

We report our cost components based on the patient journey, rather than by product type.

TABLE 2: COST COMPONENTS IN ICU DATA

Variable list	Examples of cost components
Arterial blood gas	Cartridge and syringe
Bronchoscopy[8]	Disposable bronchoscope, drapes, gowns, gloves, mask, saline, syringes, collection pots, suction catheter
Bariatric bed	Rental of bariatric bed minus service costs of a standard ICU bed
Cervical Collar	Assumed for all patients with traumatic brain or neck injury.
Continuous Renal Replacement Therapy	Effluent bags, fluid, kits, accessory spikes. Particular attention paid to breaks and restarts. Patient share of annual contract cost for CRRT equipment
Drug bolus	Unit cost of lowest cost product. Syringes, giving sets, fluid where applicable.

[8] Disposable scopes were not used as standard in one hospital in 2017. However, since that hospital now uses disposable scopes, and since it was not possible to determine the patient share of the re-usable videoscope/camera stack, a decision was made to use the costs of a disposable scope from the other hospital.

TABLE 2: COST COMPONENTS IN ICU DATA (CONT'D)

Variable list	Examples of cost components
Fluid	Total fluid used for bolus and continuous administration. Base case assumes 500mls bags selected instead of 1l bags.
Enteral feed	Cost of feed based on volume in 24 hrs.
Endotracheal tube insertion	Endotracheal tube, facemask, c-circuit, Guedel airway, suction, bougie, McGrath disposable blade, patient share of battery
Indwelling devices	Arterial line, central lines, vascath, nasogastric/orogastric tubes, PICC, chest drain, iv cannula, rectal tube, intracranial pressure monitor, Swan-Ganz, temperature probe. These include sutures, drapes, gowns, gloves, probe covers, share of annual contract cost of ultrasound, chloroporep, dressings, Magill forceps.
Intermittent haemodialysis	Patient share of annual costs of equipment and consumables. Following interview with nursing staff and HSE and National Renal Office.
Total parenteral nutrition	Cost of TPN based on volume along with administration sets. Cost of breaks and restarts accounted for.
Tubing of devices	Eg - Change of arterial and CVC sets, intravenous administration sets.
Tracheostomy (percutaneous)	Kit, tube and inner cannula, McGrath blade and share of battery, disposable bronchoscope, suture, drapes, gowns, masks and gloves.(2 operators assumed)
Ventilation	This includes non-invasive ventilation, invasive ventilation, oxygen via facemask / nasal cannula, high flow oxygen therapy, high frequency ventilation. The components include share of current contract costs, nebulisers, filters, ventilation tubing, gas sampling, catheter mount, sterile water, humidifiers.
Nitric oxide	PPM rounded to 2.5,5,7.5…22.5 etc. Hourly share of a 10l 1000ppm cylinder. Daily patient share of nitric oxide cart.
Transfers	Only for cases using oxylog ventilator where additional ventilator tubing was required. Information about use of oxylog ventilator from staff/provider interview.

Certain cost components were not included in this initial work. This is because they are either accounted for in a different PLC cost bucket, there is no accurate means of allocating these to individual patients, or because it is not possible to identify these consumables in the current medical record. These are shown in Table 3.

TABLE 3: EXCLUDED COST COMPONENTS

Excluded components	Reason
Salaries	Pay related costs are an important element in both micro-costing and intensive care, however, salaries are excluded in the initial costing and modelling due to the institutional variation in skills mix and the lack of accurate means by which to apportion salary costs to individual patients based on patient characteristics.[9] Salaries are excluded from the micro-costing and statistical analysis but they are included in the final proposed ICU ABF model.
Overheads	Overheads are also a significant cost in the ICU however they cannot be usefully apportioned to individual patients based on patient characteristics. As for salaries, overheads are excluded from the micro-costing work and statistical analysis but are included in the final proposed ICU ABF model.
Laboratory/diagnostics/imaging	These components not included in the ICU cost bucket, but are accounted for in radiology/laboratory cost buckets.
Productivity loss	Not appropriate for current ABF work
Food	While parenteral feed and enteral feed (by ng/og) are recorded, standard meals are not recorded. Excluding this has a negligible impact on costs.
Transportation	This is relevant for patients transferred between units, however this cost is not currently born by individual ICUs and falls under an alternative cost bucket.
Capital costs of equipment and furniture	The time horizon is a short-run analysis, therefore capital costs are excluded. Depreciation was also excluded in this case.
Unmeasurable consumables	The cost of certain consumables was excluded from the study as there was no record of their use for individual patients. This includes basins, curtains, non-sterile gloves, torch, scissors tongue depressor. However, while these costs are unlikely to vary between patients, there are items where the cost varies considerably between patients, yet it is not possible to determine how often these are replaced or reused. For example, a pair of Posey Mitts is in excess of €50 yet these could not be properly accounted for.

[9] According to INMO data there are A) 13 points on the salary scale of staff nurses which allows for an incremental increase in salary, B) a specialist qualification allowance is paid to nurses who have completed the Intensive Care Nursing Course, C) senior staff nurses are paid at a different rate, D) agency staff receive a different hourly rate to permanent staff. Importantly, none of these variations are related to patient factors, as the salary of a nurse allocated to a patient with 4 organ failure may or may not be different to that of a nurse allocated to a patient with 1 organ failure, and any difference is related to chance. Similarly, there are differences in the salaries of consultants, non-consultant hospital doctors (NCHDs), and allied health professionals.

3:3 Use of PLC Data

As discussed in the data sources section, PLC data contains a critical care cost bucket which is a fully inclusive ward cost including medical pay and indirect costs. This cost information was used in this project for several purposes:

- **To align costs between the critical care cost bucket in PLC and ICU micro-cost data.**
  PLC critical care costs for 2017 were obtained from both hospitals, and were compared to the ICU micro-costing data. Cost outputs (e.g. Drugs, Medical and Surgical Supplies, Equipment) which are combined into the critical care cost bucket were obtained from the Finance department in the hospitals to identify at the most granular level available, similarities and differences between the two sets of data. Results of this comparison are discussed in Section 4.5.

- **PLC daily data for statistical modelling**
  The second approach required a more in-depth analysis of PLC data on a daily basis given that the ICU data was available and was being analysed and modelled at a daily level. This data is not readily available and was compiled by the costing team in the HPO. Given that the direct critical care cost bucket contained salaries (see Table 3), the percentage of costs allocated to salaries was computed for each hospital and removed from the daily cost. Use of this data in the modelling is shown in Section 4.6.3.

- Salary and overhead costs
  PLC data on ICU salary and overhead costs from both hospitals were used in order to extend the micro costing model (which calculates the consumable costs) to provide an estimate of total costs in ICU. While there were differences in the costs allocated to salaries and overheads between the two hospitals (see Table 7), this may be due to differences in how the hospitals are allocating their costs. This will be further examined as the model is developed and more hospitals are included.

Section 4: Analysis & Results

In this section, analysis is presented for both hospitals together. Prior to the statistical modelling, the following sections show what the patient cohort looked like, and levels of support were derived from the ICCA data to gauge the support required for these patients. Some high level costs based on the ICCA data are presented which are then compared to PLC data.

4:1 Patients

Table 4 reports the summary statistics for all patients for the combined hospitals (for further details on the total number of patients by ward in each hospital please see Appendix 1). A total of 2,307 patients were included in this work, accounting for 16,218 patient days. The majority of patients were over the age of 45, with a very small proportion aged under 14. Patients were predominantly male, with the proportion (62.9% male) being consistent with recent work from the Swiss Society of Intensive Care Medicine (Todorov, et al., 2021). Length of stay was skewed, with outliers increasing the maximum length of stay to 157 in one hospital. The skew is reflected in the difference between median and mean length of stay.

TABLE 4: PATIENT CHARACTERISTICS

	N	%
Total Patients	2,307	100
Total Patient Days	16,218	
Age Group		
0-14 Years	18	0.8
15-44 Years	391	17.0
45-64 Years	850	36.8
65 Years and Over	1,045	45.3
Unknown	3	0.1
Gender		
Female	855	37.1
Male	1,450	62.9
Unknown	2	0.1
ICU Mortality on Discharge		
Alive	1,967	85.3
Died	340	14.7
Average Length of Stay		
Mean	7.0	
Median	4	
Range	(1-157)	

4:3 Levels of Support

At the outset of this project, the team identified the requirements that the cost model should (1) reflect the level of organ support received by patients and (2) result in estimates that would support a per-diem based ICU ABF payment. In addition to these requirements the project team felt that there would likely be significant interaction between various organ supports. Motivated by these considerations a model was developed with eight levels of organ support for the various possible combinations. These were:

A. No organ support
B. Respiratory support only
C. Renal support only
D. Cardiovascular support only
E. Respiratory and renal support
F. Respiratory and cardiovascular support
G. Renal and cardiovascular support
H. Respiratory, renal and cardio vascular support

The three types of organ support identified above were chosen based on the ability to easily identify the provision of this support on a daily basis in the ICCA data and in the INUCUA data. For instance, liver support can be identified in the INICUA data but it was not readily identifiable from the ICCA data for estimation of costs.

To create these levels of organ support, three variables were created based on the ICCA data to identify for each patient day when they received; respiratory, cardiovascular or renal support on daily basis. These were created as dummy variables to indicate the presence or absence of support, and do not take into account the severity of support required. This is in part because (with the exception of oxygen), the consumables required to ventilate a patient receiving 30% O_2 may be identical to those required to ventilate a patient receiving 90% O_2.

Respiratory support

The ICCA data was examined for all patient days where a patient received invasive mechanical ventilation. This dummy variable was 1 if they received invasive ventilation, and 0 if they did not. This does not take into account the duration of ventilation. This definition does not include non-invasive ventilation despite the fact that the cost of consumables may be similar. This is because non-invasive ventilation can occur outside of the ICU, and therefore is not representative of a defined need for ICU level care. For clarity, it should be noted, that the costs associated with non-invasive ventilation in the ICU are included in the analysis, but non-invasive ventilation is not sufficient to meet the definition of respiratory support as used in this work.

Cardiovascular support

ICCA drug infusion data was examined for all patient days. A dummy variable was created where 1 represents the administration of any form of inotropic or cardiovascular support (eg noradrenaline, adrenaline, vasopressin, dobutamine), and 0 for all patient days where they did not receive this support.

Renal support

ICCA intake/output data sheets were examined to identify patient days receiving continuous renal replacement therapy (CRRT). These days were identified as 1 if they received any CRRT, and 0 if they did not. ICNARC data was then examined to identify patients who received intermittent haemodialysis (IHD). The free text medical/nursing notes in ICCA were then examined separately to identify the associated encounter days for each patient. A dummy variable for IHD was created, with 1

representing a patient day where IHD was received, and 0 representing no IHD. The CRRT and IHD variables were then combined to indicate if a patient received either form of renal support. In the final model a term indicating IHD was also included as it was felt that this would have a significant impact on cost estimates and this indeed turned out to be the case.

These levels of support are outlined in Table 5, and as each patient may have had different levels of support during their ICU stay, the figures represent the number of patient days receiving particular levels of support. Table 5 shows that in 2017, in both hospitals, 23.3% of days were for those receiving respiratory support only (Level=B), 1.7% of days were for those that received both respiratory and renal support (Level E), and 22.3% of days were for those received both respiratory and cardiovascular support (Level F). 6.8% of days were for those that were receiving support for all three (Level H).

TABLE 5: LEVELS OF SUPPORT

Level of Support	Respiratory Support	Renal Support	Cardiovascular Support	Encounter Days	%
A	0	0	0	4,803	30.0
B	1	0	0	3,734	23.3
C	0	1	0	250	1.6
D	0	0	1	1,929	12.0
E	1	1	0	273	1.7
F	1	0	1	3,583	22.3
G	0	1	1	380	2.4
H	1	1	1	1,084	6.8
Total				**16,036**	**100**

4:4 ICU Micro-costs

ICU cost data retrieved from hospitals were applied to daily ICCA data to enable costs per patient day to be calculated.[10]. When all costs were calculated, they were combined into cost buckets; drugs, nutrition, and medical and surgical supplies.

As per Table 6, the total cost from the micro-costing was €4.8 million for both hospitals. Around 50% of these costs related to drugs, with these costs including items used in the administration of medication and fluids. 46% of costs were for medical and surgical supplies which included indwelling devices, tubing, consumables used in renal replacement and ventilation. It also includes the share of the contract costs of equipment when these differ between patients.

[10] As per the methodology outlined in Section 3.2., salaries and overheads are not included in the micro-costing

TABLE 6: ICU MICRO-COSTS BY COST BUCKETS

	Cost (€)	%
Drugs Cost	2,387,179	48.9
Nutrition Cost	239,133	4.9
Medical and Surgical Supplies Cost	2,255,729	46.2
Total Cost	4,882,054	100

Note:	Drugs Cost: Infusions, Bolus Drugs, Fluids
	Nutrition: Enteral Feed, Parenteral Feed
	Medical and Surgical Supplies: Consumables for dialysis and ventilation, Indwelling Devices, Tubes, Oxylog (measured using transfers of ventilated patients to radiology and theatre)

4:5 Comparison to PLC

Table 7 below shows the split of non- pay, pay and overheads that were allocated in the PLC data in the critical care cost bucket, and the overall amount of non-pay costs calculated from the micro-costing. This shows that in Hospital A, 16% of PLC costs are non-pay, 61% are allocated to pay and 22% to overheads. This differs to Hospital B who report 24% to non-pay, 68% to pay and only 9% to overheads[11]. When comparing the two sets of costs, reported shows that in both hospitals PLC non-pay costs exceed the ICU micro-cost by 36%.

TABLE 7: ICU MICRO-COSTING V'S PLC COSTS

	Hospital A		Hospital B	
	ICU Micro-cost[a] (€)	**PLC (€)**	**ICU Micro-cost[a] (€)**	**PLC (€)**
Non-Pay	1,725,113	2,347,429	3,122,092	4,253,760
Pay	–	8,728,055	–	12,119,943
Overheads	–	3,196,262	–	1,531,270
Total		**14,271,746**		**17,904,972**

Note:	a	It was not possible to match all the ICU encounters to PLC records, due possibly to administrative differences, therefore, the total ICU Micro-Cost for both hospitals is less than the total reported in Table 6.

We found important variations in non-pay cost data between the both data sources, and examined these in close detail to determine the reason for these variations. While in some cases this led to changes in the ICU cost data, potential issues in PLC were fed back to the costing team and will be reviewed for current and future returns. The following examples of discrepancies that were found is not exhaustive but shows some of the issues that were highlighted in relation to both sets of data:

- In some cases, it is possible that some items were not recorded in ICCA, or were only recorded in free text notes (for example, antineoplastic medication was included in PLC data in one hospital, but this was not found on the ICIP drug administration record).
- The PLC data from one hospital also allowed us to examine the drug budget by individual name. This was useful as it provided a real world description of resource use. For example,

[11] These differences may arise due to a number of factors, which include differences in the way costs are allocated in a particular hospital. These findings are noted for further review by the HPO.

50mls propofol was available as both Propoven and Diprivan. There is a considerable cost difference (250%) associated with these two versions of the same medication, yet it is not possible to determine which version a patient received (patients are charted propofol rather than a brand name). The lower cost version was included in the base case, but a sensitivity analysis was performed which confirmed that the total cost of propofol in the PLC data was reasonable in this case if the higher cost option was used.

- It is also possible that certain drugs were included only on paper prescriptions despite the use of ICIP.
- In one hospital the Equipment group allocated costs associated with X-ray equipment and X-ray call outs to ICU, however these are usually included in the Radiology cost buckets for PLC.

Comparing these two data sources which are essentially trying to capture the same costs proved to be very useful. It provided an opportunity to examine the PLC data at a more granular level, and give feedback to hospitals on their PLC returns. Some final adjustments were made to the ICU- micro costing file based on this comparison to produce a final micro-costed ICU dataset to use in the statistical cost modelling.

4:6 Statistical Cost Modelling

4:6:1 Model description and rationale

The statistical model used for analysis is a generalised linear model (GLM) with gamma distribution and a log link function. The gamma distribution was chosen due to the nature of the response variable which is the ICU daily cost. This variable takes on continuous, positive values, is highly skewed and variation increases with the mean. The dependent variables are the level of organ support (A-G), the hospital (A,B), neurosurgery specialty (0,1), cardiac specialty (0,1) and IHD (0,1). In each case the dependent variables are treated as categorical variables. The log link function was chosen so that the effects of the dependent variables would be multiplicative rather than additive. The model is applied to individual days at each of the support levels and is therefore based on ICU days. The estimated cost for an entire ICU stay can be derived by summing the cost estimates for each day of ICU stay.

The shorthand form of the statistical model is

$$log(Cost) = Organ\ Support\ Level + hospital + neurosurgery + cardiac\_specialty + IHD$$

The statistical model contains no interaction terms however interactions between support levels are explicitly encoded in the variable Organ Support Level. It should be understood that in the fully specified model each level of the model variables is represented by its own (0,1) dummy variable.

4:6:2 Analysis and Results

As described in Section 4.3, the main variables used in the statistical model are the levels of support and the interaction of these as show in Table 8 below. These show the combinations of support that are used in the final statistical model.

TABLE 8: LEVELS OF SUPPORT

Model Parameter	Level	Respiratory Support	Renal Support	Cardiovascular Support
Intercept	**A**	0	0	0
Support Level	**B**	1	0	0
	C	0	1	0
	D	0	0	1
	E	1	1	0
	F	1	0	1
	G	0	1	1
	H	1	1	1

The final statistical model and parameter estimates are shown in Table 9. The table shows the number of ICU days with each level of organ support, the parameter estimate (on the log scale), the 95% confidence interval for the estimate, the p-value, the multiplicative factor associated with each level of support and the estimated cost per day at each level of support.

TABLE 9: STATISTICAL MODEL PARAMETER ESTIMATES

Model Parameter	Level	Estimate	95% Confidence Interval		P-value	Factor	Euro (€)
Intercept	**A**	9.5	9.4	9.5	<.0001		129
Support Level	**B**	0.7	0.7	0.8	<.0001	2.1	266
	C	1.4	1.3	1.5	<.0001	4.2	540
	D	0.6	0.6	0.6	<.0001	1.8	235
	E	1.7	1.6	1.8	<.0001	5.5	705
	F	1.0	1.0	1.1	<.0001	2.8	364
	G	1.7	1.6	1.7	<.0001	5.2	675
	H	1.9	1.8	1.9	<.0001	6.5	842
Hospital	**Hospital B**	0.1	0.0	0.1	0.0001	1.1	138
Neurosurgery Specialty	**1**	-0.1	-0.1	-0.1	<.0001	0.9	116
Cardiac Specialty	**1**	-0.1	-0.1	-0.1	<.0001	0.9	118
Intermittent Haemodialysis	**1**	-0.9	-1.1	-0.8	<.0001	0.4	50

In this table the Euro value of €129 represents the consumable costs associated with single day stay in ICU. The factor column represents the multiplicative factor which must be applied to this base figure to get the estimated cost for each of the other levels of support. For example, the cost per day of 3 organs support (level H) is €128.96 * 6.53 = €842.

The important points to note in Table 9 in relation to levels of organ support are:

1. The lowest level of organ support (no organs supported) is the cheapest at €129 per day while the highest level of organ support (3 organs supported) is the most expensive at €842 per day.

2. Renal support is the most expensive individual support with a daily cost of €540 compared to €266 for respiratory support and €235 for cardiac support.

3. Despite the need for more consumables for providing respiratory support versus cardiac support, the cost estimates are similar. This is likely due to the fact that the cost burden does not just address consumables directly related to the form of organ support, but also associated costs including medications such as antimicrobials.

4. The costs associated with multiple organ support days are less than the sum of the individual support day components. This is an important finding given that previous work in this area assumed that the costs would be additive over organs supported.

5. Days of mechanical ventilation (respiratory support) is often identified in the literature as being a major cost driver, however this is likely associated with the fact that these patients would be receiving level 3 care and therefore have one-to-one nursing. The current analysis is considering consumable costs only and therefore salaries are not considered at this point of the analysis.

In addition to the level of organ support, the model includes terms for hospital, specialist care (Neurosurgery and specialist cardiac care) and intermittent haemodialysis. The inclusion of these model parameters was motivated by clinical considerations in the first instance and by the results of earlier exploratory models which considered sub-populations of the patient cohort to see the impact on parameter estimates.

The hospital term in the model captures any overall cost differential between the hospitals having accounted for the other model parameters. The final model indicates that having accounted for all other factors hospital B is approximately 10% more expensive than hospital A. This finding must be treated with caution however as it is not clear whether this is a true reflection of relative efficiency or whether it reflects other factors such as incomplete data, underlying costing assumptions or an under-specified statistical model.

In contrast to initial expectations, the provision of specialist care (neurosurgery or cardiac) in the ICU actually reduces the estimated daily cost of care. It was hypothesised that the patients in specialist care were actually a healthier cohort than non-specialist care patients and that this might be driving the observed results.[12]

Also, motivated by clinical knowledge and earlier model results, the use of intermittent haemodialysis (IHD) in one of the hospitals was examined as a cost driver.

[12] In order to test this, the mean and median patient scores (ICNARC Physiology Score, Apache II Physiology Score and Apache II scores) were examined for specialist care versus non-specialist care groups. In general, the scores for specialist care patients are lower, however there are some inconsistent results. A full statistical analysis of this is beyond the scope of the current work however it is noted that ideally we would ideally get a daily patient severity score (Sequential Organ Failure Assessment Score) for future analysis.

Hospital A carries out intermittent haemodialysis on ICU patients whereas all other ICUs exclusively us continuous renal replacement therapy. The use of IHD was included as a term in the model to assess the impact of its us on costs. The results indicate that use of IHD results in a 60% reduction in costs for patients who received dialysis while in ICU.

4:6:3 Sensitivity Analysis on PLC Data

In order to assess the applicability of the final model to PLC data, the model parameters were re-estimated using PLC costs rather than micro-costs. The results of this analysis are reported in Table 10.

TABLE 10: PLC MODEL PARAMETER ESTIMATES

Model Parameter	Level	Estimate	95% Confidence Interval		P-value	Factor	Euro (€)
Intercept	**A**	5.4	5.4	5.4	<.0001		218.9
Support Level	**B**	0.6	0.6	0.6	<.0001	1.8	388.3
	C	0.5	0.5	0.6	<.0001	1.7	374.3
	D	0.6	0.5	0.6	<.0001	1.7	380.5
	E	0.8	0.8	0.9	<.0001	2.3	496.3
	F	0.8	0.8	0.8	<.0001	2.2	480.5
	G	0.9	0.8	0.9	<.0001	2.4	521.9
	H	1.0	1.0	1.1	<.0001	2.8	605.5
Hospital	**Hospital B**	0.2	0.2	0.2	<.0001	1.2	265.7
Neurosurgery Specialty	**1**	0.1	0.1	0.2	<.0001	1.1	248.0
Cardiac Specialty	**1**	-0.2	-0.2	-0.2	<.0001	0.8	180.7
Intermittent Haemodialysis	**1**	-0.1	-0.2	0.1	0.3391	0.9	206.9

This sensitivity analysis resulted in significant changes to the parameter estimates based on the micro-costed data, which has implications for the development of an ICU ABF model. The differences observed indicate that the costs apportioned to ICU patients in PLC are different to those assigned in the micro-costing approach. In general, the estimates obtained from the PLC data show signs of compression i.e. there is less spread amongst the cost estimates for different levels of support than in the micro-costing based model. Compression is also evident in the smaller intercept term in the model based on micro-costing (€129) compared to the model based on PLC data (€219).

Compression is particularly evident in the case of renal support which is recognised as being resource intensive in terms of consumables. The analysis of the micro-costed data picks this up (factor of 4.2) whereas the analysis based on PLC data does not (factor of 1.7). Similarly, the model based on PLC data results in a much smaller adjustment for intermittent haemodialysis (10% reduction) than that based on micro-costed data (60% reduction).

The presence of compression in the PLC based analysis compared to the micro-costing analysis is not surprising given that in the former it is likely that only major items such as drugs are apportioned based individual patient use while in the latter all consumable items are allocated based on actual usage.

4:6:4 Addition of Salaries and Overheads to Model

The model considered so far only describes the consumables cost in the ICU which, as shown in Table 7 accounts for approximately 20% of the total ICU cost. The existing ABF model is based on fully absorbed costs and we therefore need to extend the derived statistical model to include both salary and overhead costs to create an ABF model that adequately addresses the higher costs associated with ICU stays. There are no readily available data on how to apportion salaries to patients in an ICU and obtaining these would require time and motion studies which are beyond the scope of this work. Similarly, there are no data which describe the allocation of overheads to ICU patients beyond a straight pro-rata allocation based on length of stay. In lieu of this, and in order to provide some estimate of total costs for ICU patients, PLC data was used which has a breakdown of salaries and overheads for the ICU units in participating hospitals in 2017 (see Table 7). There are differences in the overall costs assigned to ICU salaries and overheads between the two hospitals. For example, pay costs in Hospital B exceeds Hospital A by almost €3.4 million, and the overhead costs in Hospital B are much lower than Hospital A (see Table 7). This may be due to differences in the allocation of costs within the hospitals and these will be further examined as the model is being developed and data is collected from more hospitals.

The inclusion of these costs will be apportioned by the following methods in the model:

- Medical and non-clinical salaries are allocated on a pro-rata basis solely based on the number of days in the ICU
- Nursing salaries are allocated on a pro-rata basis based on the number of days in ICU weighted in the ratio 2:1 for days on level 3 support versus days on < level 3 support.
- Overheads are allocated on a pro-rata basis solely based on the number of days in the ICU.

Using this approach, Table 11 shows that costs per patient day with the inclusion of PLC salaries and overheads ranges from €1,327 for support level A to €2,773 for support level H.

TABLE 11: STATISTICAL MODEL PARAMETER ESTIMATES WITH SALARIES AND OVERHEADS

Model Parameter	Level	ICU Days	Consumables (€)	Overheads (€)	Salaries (€)	Total (€)
Intercept	**A**	4,803	131	295	902	1,327
Support Level	**B**	3,734	266	295	1,607	2,168
	C	250	521	295	902	1,718
	D	1,929	236	295	902	1,433
	E	273	698	295	1,607	2,600
	F	3,583	359	295	1,607	2,261
	G	380	689	295	1,607	2,591
	H	1,084	871	295	1,607	2,773

Section 5: Discussion

The micro costing and statistical work discussed in the preceding sections suggest that a model of daily costs based on combinations of organs supported is a feasible basis for an ABF funding model. However, there are other practical aspects of a potential ICU ABF model that need to be considered prior to implementation. These are discussed below.

5:1 Form of the ICU ABF Model

The statistical analysis presented above shows that the combination of organ supports per day, the provision of specialist care and the use of intermittent haemodialysis are all significant cost drivers in the model. It also shows that there is significant variation in consumable costs depending on the combinations of organs supported.

As shown in Section 4.6.4, the inclusion of salaries and overheads requires further examination, given that PLC returns from hospitals differ quite significantly from each other. This is an important finding of this study and while it is not envisaged funding based on the current returns, it does provide the opportunity to engage with hospitals on how this data will be used, and the opportunity to review how costs are allocated to the ICU. The inclusion of these costs in the report is important however, to provide some indication of overall costs.

In addition to the inclusion of salaries and overheads, the following changes would be implemented in the proposed ICU ABF model

- The term relating to intermittent haemodialysis (IHD) is omitted from the ABF model because it cannot currently be identified from the available ICNARC data. We understand that this term is currently only applicable to Beaumont Hospital.
- The Hospital effect (Hospital A vs. Hospital B) is not included as this is essentially the efficiency measure in an ABF model. Including it would amount to reimbursing all ICUs at cost.

On this basis the proposed ICU ABF model can be described as shown in Figure 3:

FIGURE 3: ICU ABF MODEL SPECIFICATION

A - No respiratory, renal or cardiovascular support
B - Respiratory Support
C - Renal Support
D - Cardiovascular Support
E - Respiratory + Renal Support
F - Respiratory + Cardiovascular Support
G - Renal + Cardiovascular Support
H - Respiratory + Renal + Cardiovascular Support

$Days_L$ = Days with level L support
β_L = Per-diem value for level L
N_L = Weighted nursing salary per-diem for level L
S = Non-nursing salary per diem
O = Overhead per-diem
γ_{Sp} = Specialist Care Factor

$$ICU\ Value_{Sp} = \sum_{L=A}^{H} Days_L(\beta_L + N_L + S + O)\gamma_{Sp}$$

$$ICU\ Value = \sum_{i=0}^{2} ICU\ Value_{Sp}$$

In the above model it is intended that:

- Salaries will be incorporated based on the daily average of the actual ICU salary costs returned to the HPO in specialty costings rather than estimates from salary scales.
- Overhead costs will be based on the daily average of the actual ICU overhead costs return to the HPO in specialty costings.
- the incorporation of salary costs is activity based i.e. related to the care received by the patient rather than factors of the ICU itself such as the mix of staff levels in the unit.
- The β_L and γ_{Sp} parameters will be scaled each year to reflect the latest actual ICU costs (excluding salaries and overheads) returned to the HPO.
- The γ_{Sp} factor will be 1 where the patient is not under the care of the neurosurgery specialty or undergoing specialist cardiac care and will take the value of the appropriate factor from the statistical model otherwise.

5:2 Implementation of the ICU ABF Model

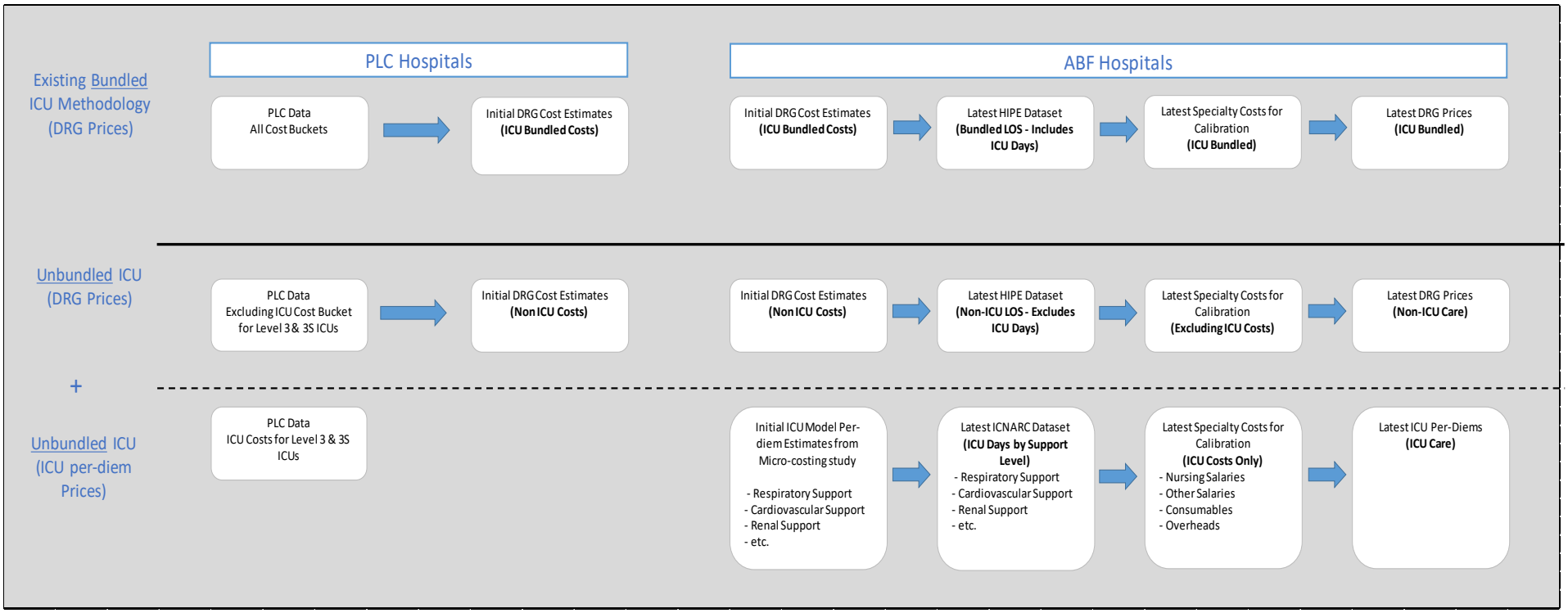
5:2:1 Price Setting Methodology

Given the form of the model as described in figure 3, the implementation of the model also needs to be considered. It is not proposed that an entirely separate ICU ABF model be implemented but rather that the existing ABF model would be augmented based on the current work so that ICU costs are adequately accounted for in the model. Figure 4 shows the implementation steps in the existing ABF model and the proposed implementation of an augmented ABF model which explicitly accounts for differing ICU costs.

The main points to note here are:

1. ICU costs are isolated from non-ICU costs in both patient level and specialty level costing datasets.
2. ICU activity is isolated from non-ICU activity through the exclusion of ICU bed-days from the episode length of stay.
3. As a result of 1 and 2, the resulting DRG prices will only be based on non-ICU cost and activity and will be suitable for funding cases where there is no time spent in ICU.
4. Also as a result of 1 and 2, ICU cost and activity are isolated from the main DRGs. The ICU value in the ABF model is therefore based entirely on ICU costs and activity and is directed solely to hospitals who have level 3/3S ICUs.
5. Although the efficiency of a hospital for ABF purposes will be measured at the level of the entire hospital, it will be possible for the cost to value relationship of individual ICUs to be explicitly investigated and compared.

FIGURE 4: IMPLEMENTATION STEPS FOR CURRENT AND PROPOSED ABF MODEL FOR ICU



5:2:2 Supporting Data Sources

For the purposes of the micro-costing exercise the ICCA data was used directly from the ICU systems however, given the difficulties described earlier it is not practical to use this as a data source for model implementation. Therefore, the model parameters were carefully selected so that the levels of organ support identified in the ICCA are available from the INICUA database.

In order to implement the proposed ICU ABF model the HPO will require access to a subset of fields on the INICUA database to replicate the 8-level model developed in this work. It is noted however that although currently the standard output report from the INICUA system does not provide information on the daily combination of organs supported. In order to ensure this level of data is available the HPO and NOCA teams will need to liaise with the software vendor to arrange for a suitable report to be developed.

Also, to enable extending the model to provide a total cost estimate in ICU, PLC data on salaries and overheads will be required for all hospitals with a Level 3/3s ICU. As discussed earlier in the report, the PLC returns from hospitals will be examined further, given the differences in the costs allocations between the two hospitals. The costing team in the HPO will liaise with hospitals to do this. If possible, the HPO will retrieve greater granularity on nursing salaries to differentiate between staff working across the ICU and staff working directly with patients.

5:2:3 Data Protection

As the proposed model operation requires the establishment of new data flows between hospitals/NOCA and the HPO a DPIA for the process will need to be developed to ensure that patient confidentiality is maintained and data subject rights are protected. The exact source of the new data flow to the HPO will depend on whether the required data can be sourced centrally from a national database or whether it must be sourced from individual hospitals.

5:2:4 ABF Target Setting

Under the current ABF model, target activity levels are set based on a prior year's activity at the DRG level in line with the National Service Plan. Under the augmented model this will not change, however the value of that activity will be derived based on the DRG and ICU components separately and combined into an overall ABF value. This is straightforward when estimating the baseline level of activity but may require additional assumptions to be made when deriving the activity changes associated with the addition of new beds. i.e. what will be the effect of adding additional beds on ICU activity?

5:2:5 ABF Reporting

ABF performance is reported and monitored on a monthly basis. In this process, the latest activity levels as reported to HIPE are combined with the latest expenditure figures from the Acute Operations Finance team to allow comparison of:

1. Actual ABF Expenditure vs Actual ABF Revenue
2. Actual ABF Expenditure vs Planned ABF Revenue
3. Actual ABF Revenue vs Planned ABF Revenue

With significant functionality to allow for drilldown into the drivers of deviation from planned activity and expenditure levels.

This process relies on the availability of actual activity data from HIPE and estimates from prior data to apportion the actual costs into ABF and non-ABF components. To explicitly report on ICU activity in

a similar manner, ICU activity categorised by number of days by organ support as per the ICU ABF model would be required along with a methodology of apportioning actual ABF expenditure to the ICU. The ability to do this will depend on the availability of INICUA data on monthly basis and on assumptions on the apportionment of actual costs to ICU.

5:2:6 Communication and Champions

Any proposed changes to the ABF model resulting from this work will be communicated to ABF stakeholders through the annual ABF Pricing Framework Document. However, it will also be necessary for the changes to be communicated to the ICU clinical community who may not be aware of the current ABF processes or indeed the ABF publications. To this end, it will be necessary for the senior clinical stakeholders in this project to communicate the proposed model changes to their peers and champion its implementation.

5:2:7 ICU ABF Model Benefits

The benefits of introducing an ABF model for ICU are outlined below:

1. ICU costs are no longer bundled into the average DRG price resulting in more accurate patient-centred payments.

2. ICU costs are included entirely in the ICU ABF model and therefore hospitals with ICUs will receive the full value of activity being carried out.

3. The specification of the model will allow for direct comparison of ICUs in terms of complexity adjusted activity and cost.

Section 6: Recommendations

The following are the recommendations to enable Ireland to introduce and ABF funding model for ICU patients.

1. The HPO will engage with NOCA to establish a data transfer of standard reports for daily organ supported using the INICUA dataset.

2. A DPIA should be developed in conjunction with NOCA / participating hospitals with the aim of creating a new data flow of ICU data to the HPO.

3. The HPO should commence work on incorporating the ICU ABF methodology into the existing ABF model.

4. The HPO should further examine PLC returns for ICU cost allocations across all hospitals with a Level 3/3s ICU.

5. Once data feed has been established, the HPO to re-run the funding model including the ICU methodology to better understand the effects of the change.

6. HPO to report and consult with hospitals on the effects of the ICU methodology on the funding model.

7. HPO to shadow fund ABF hospitals for the first year using the ICU model with the intention of going live the following year.

Section 7: Bibliography

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Section 8: Abbreviations

ABF	Activity Based Funding
CRRT	Continuous Renal Replacement Therapy
DPIA	Data Protection Impact Assessment
DRG	Diagnosis Related Group
ECMO	Extracorporeal membrane oxygenation
HD	Haemodialysis
HPO	Healthcare Pricing Office
ICCA	Philips IntelliSpace Critical Care and Anaesthesia
ICU	Intensive Care Unit
IHD	Intermittent Haemodialysis
INICUA	Irish National ICU Audit
NOCA	National Office of Clinical Audit
PLC	Patient Level Costing

Section 9: Appendices

Appendix 1: ICCA and INICUA Records

The following table shows the total number of encounters by clinical unit in the hospitals after data extraction. The following selections were not included:

- In Beaumont, patients who were on the system but had a 'Discharge Disposition' of "Admitted in Error" were excluded (N=56).
- In James's, as we didn't have the field extracted for 'Discharge Disposition', patients who had no costs associated based on ICIP data analysis were excluded (N=108).

TABLE A1: ICCA AND INICUA RECORDS, 2017

Hospital and Unit	ICCA Encounters	INICUA Encounters
Beaumont	**1,009**	**994**
General ICU	654	650
Richmond ICU (Neuro-specialty)-RICU	355	344
St. James	**1,313**	**869**
General ICU+ HDU+ Burns*	865	432
Keith Shaw ICU (Cardiovascular) -KSICU	448	437
Note	*There were a small number of encounters that went straight from one ICU to another, these encounters were merged, and were allocated to the first ICU unit they were admitted to.*	
	**INICUA Data for the General ICU, Burns, and HDU were only available from July 2017 in St. James's. This is when they began INICUA data collection for these wards.*	

When both datasets were merged there were a few reasons why there weren't exact matches between the two datasets.

- For St James's hospital, only patients admitted to the KSICU had INICUA data for the whole year while the other ICU's only had data from July 2017 onwards.
- INICUA data was sent for patients who were admitted in 2017 and were discharged in 2018 while we had restricted ICCA data to those admitted and discharged in 2017.
- There was no matching MRN for a small number of patients, these were investigated and a small number remained unresolved.
- In ICCA we had merged encounters that went straight from one ICU to another, while in ICNARC these were separate encounters and therefore had to be merged together before putting it alongside its ICCA record.

In the costing analysis, we used the combined ICCA and INICUA data for analysis for Beaumont (994 records) and we worked without the INICUA data for the costing exercise for St. James' and therefore used all 1,313 records giving a total file of 2,307 patients with ICU encounters.

Appendix 2: ICU Data and PLC Data Matching

Figure A2 below shows how the ICU data and PLC data were combined to enable comparison of the data at patient level. There was a high level of matching to the PLC records (98.7% in Hospital A and 100% in Hospital B). Non-matches may have occurred due to administrative differences in dates of admission/discharge and age of patient.

FIGURE A2: PLC DATA MATCHING