SUSQI PROJECT REPORT

Project Titles:

Switching intravenous (IV) medications to enteral forms in Critical Care (IV to Enteral Switch)
Continuous Tazocin infusions compared to intermittent dosing (Tazocin Infusions)

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Background

IV to Enteral Switch

Critically unwell patients in the Intensive Treatment Unit (ITU) require medications which are often administered intravenously (IV) or enterally (this can be by mouth or via one of our types of feeding tube). Patients requiring IV medications will have a form of intravenous cannulation (peripheral or central) for this. An enteral route is established early in a patient's admission to deliver medication and feed.

IV administration of medications (including its diluents, carrier solutions and catheter flushes) account for up to 42% of the overall fluid volume in a patient's first 3 days of ITU admission. This is referred to as a "fluid creep". This, alongside fluid overload percentage (cumulative fluid balance divided by ideal body weight as a percentage), was found to independently predict ITU mortality (Briassoulis et al, 2025).

There have been multiple studies surrounding fluid balance and increased ITU mortality. A systematic review and metanalysis found that mortality risk increased by 1.19 times per litre of increased fluid balance (Messmer et al, 2020). In patients following septic shock reversal (defined as a serum lactate of ≤2, and requiring no vasopressor support), ITU mortality increased by 3.18 times once a cumulative fluid balance reached 10ml/kg, following shock reversal until ITU discharge or death, and increased the ITU, hospital, 30-day and 90-day mortality (Van Mourik et al, 2020).

Gamble et al (2022) showed that paracetamol and phosphate were amongst the top four contributors to mean administration volumes within the first three days of an ITU stay for 210 patients. From this we can assume that by reducing the volumes of these administered in our ITU, we could potentially reduce mortality that is associated with fluid overload.

In our 45 – bed critical care unit, spanning General Critical Care (GCC) and Cardiothoracic Critical Care (CTCC), in University Hospital Coventry and Warwickshire (UHCW), we aimed to reduce the number of administrations of IV medications where an enteral route is established and appropriate.

We chose the following three medications to focus on in this project: phosphate, paracetamol and omeprazole.

Enteral phosphate replacement has been found to be adequate for mild and moderate hypophosphatemia in critically unwell patients. IV phosphate (as polyfuser phosphate or sodium glycerophosphate) costs £18.61 per 500ml dose or £8.79 per vial, compared to one enteral phosphate (as Phosphate Sandoz) which costs £0.25 per tablet (BNF, 2026). Enteral phosphate has a 70% bioavailability, requiring 4 tablets (£1.00) for dose equivalence (EMC phosphate, 2023).

Enteral paracetamol has a peak effect time of one hour with a relatively high bioavailability of up to 90%, compared to IV paracetamol with an onset time of 15 minutes, making it effective for managing acute pain in the out-of-hospital setting (Charlton et al, 2020). However, one bottle of IV 1g/100ml paracetamol costs £5.30, whilst 1g of oral paracetamol costs £0.10 (BNF, 2026), (EMC paracetamol, 2025).

Critically unwell patients admitted to ITU are at risk of developing stress-related mucosal damage (SRMD) of the stomach which requires stress ulcer prophylaxis (SUP). Proton Pump Inhibitors (PPI) are used to reduce this risk (Brett S, 2005). Oral lansoprazole has an 80-85% bioavailability, making it adequate for gastroprotection at a cost of £0.12 per 30mg orol-dispersible tablet, compared to £5.20 for 40mg IV omeprazole which is the equivalent dose that we give for this purpose (BNF, 2026). The British Society of Gastroenterologists (BSOG) recommend that IV PPI should only be prescribed to those who have a high-risk ulcer post endoscopy, those not established on a full enteral feeding regime, or who cannot have enteral administration (Siau et al, 2020).

In addition to an increased cost in IV preparations compared to oral, IV medications also carry an increase in carbon emissions which contributes between 88-178kg CO_2e/patient/day in a critical care unit (Gaetani et al, 2024). For example, IV paracetamol contributes between 310-628g CO_2e per 1g vial, whilst oral paracetamol contributes only 38g CO_2e per tablet (Hunfield et al, 2024). In addition, it is estimated the waste production per patient in critical care is 1.1-13.7kg/patient/day. The two predominant sources of waste originate from electricity and gas, and consumables. This is inclusive of the single use plastic used during the IV administration of medications which contributes to a large proportion of total plastic waste in hospitals (Lee et al, 2002).

In 2020 the National Health Service (NHS) became the first healthcare system in the world to commit to becoming net zero by 2040 due to healthcare contributing up to 5% of total emissions in England. In 2025, medicines contributed to 17% of emissions within the NHS Carbon Footprint Plus, and clinical consumables and equipment 10% and 8% respectively (NHS Green Plan, 2025)

As a result of the NHS's commitment, all Trusts and ICBs in England now have a Green Plan with a mission to reduce emissions at a local level. At UHCW, medicines and chemicals accounted for 12.1% of total emission within the trust in 2024/2025, lower than national average (UHCW sustainability, 2025).

Within the Trust, relevant aims of the project that action our Green Plan include:

- Switch medication from intravenous to enteral where clinically appropriate.
- Reducing consumables, in particular single-use plastic.
- Reduce waste arising by 15%.
- Focus on cutting emissions and improving care quality in at least one clinical area… Critical and perioperative care.

This project was undertaken by a critical care consultant, two senior house officer residents, and two foundation year two doctors within the critical care department at UHCW. We undertook this project as part of our hospitals Green Team competition to reduce waste and carbon emissions in the department, whilst also improving patient care by providing fluid stewardship to reduce the risk of fluid overload in critically unwell patients. This is through our Trust's vision of "Our fundamental purpose is to deliver the best possible care for our communities through local integrated care, valuing and empowering our people, being a centre of excellence, promoting sustainability and advancing research, innovation and teaching."

Tazocin Infusions

Piperacillin with Tazobactam (Tazocin) is a broad-spectrum intravenous antibiotic used commonly in the ITU. Critically ill patients who have infections need optimal antibiotic delivery to fight the high morbidity and mortality of sepsis and septic shock. It is estimated that there is a 20.3% mortality associated with sepsis and 40% of survivors are impacted by cognitive, psychological or physical consequences after surviving it (The UK Sepsis Trust, 2026).

At present in UHCW Tazocin is given by intermittent doses normally three or four times a day. Recent evidence presented by Abdul-Aziz *et al*. (2024) in a systematic review and meta-analysis comparing prolonged versus intermittent infusions of β-Lactam antibiotics (including Tazocin), found that prolonged infusions were associated with a reduced risk of mortality at 90 days for critically ill adult participants with sepsis or septic shock (relative risk reduction of 14%). It showed a Number Needed to Treat (NNT) to prevent 1 death of 26 patients. A NNT statistic shows the strength of an intervention to achieve a specified outcome; in this instance how many patients you would need to treat with a β-Lactam continuous infusion rather than an intermittent dosing regimen to save one life that otherwise would have been lost to sepsis if they were treated with intermittent dosing of β-Lactam antibiotics. The clinical benefits were clear, and we hypothesised that there would also be a sustainability benefit to Tazocin infusions compared to the current practice of intermittent dosing.

In our current practice intermittent doses of Tazocin are given two, three (most commonly) or four times a day and each time a dose is given an inventory of 8 single use items (see Table 4 in the measurements section) are used to prepare and give the dose. In the proposed new practice of giving 24 hourly Continuous Tazocin Infusions (CTIs) these items would only be used once every 24 hours hence the postulated environmental and economic sustainability benefit that we planned to measure.

Medication ordering data showed that between March 2025 – February 2026 across our ITUs (GCC and CTCC) we used 6,600 doses of Tazocin. We planned to use this information and audit data collected in March-May 2026, to understand how many courses of Tazocin are given per year via current intermittent dosing practice and thus calculate the predicted sustainability benefit of the new CTI protocol.

Specific aims

IV to enteral switch project

- Empower and educate the nursing and medical staff to highlight and review drug routes and administrations.
- Reduce the amount of IV medication (of phosphate, paracetamol and omeprazole) where clinically appropriate on the unit by 30% by switching to an enteral route

Tazocin Infusions

- To measure how many patients would be suitable for CTI
- To measure the environmental sustainability benefit of the newly created CTI protocol
- To measure the economic sustainability benefit of the newly created CTI protocol
- To examine the practice of Tazocin drug administration to patients to investigate for any other unpredicted sustainability benefits or pitfalls.

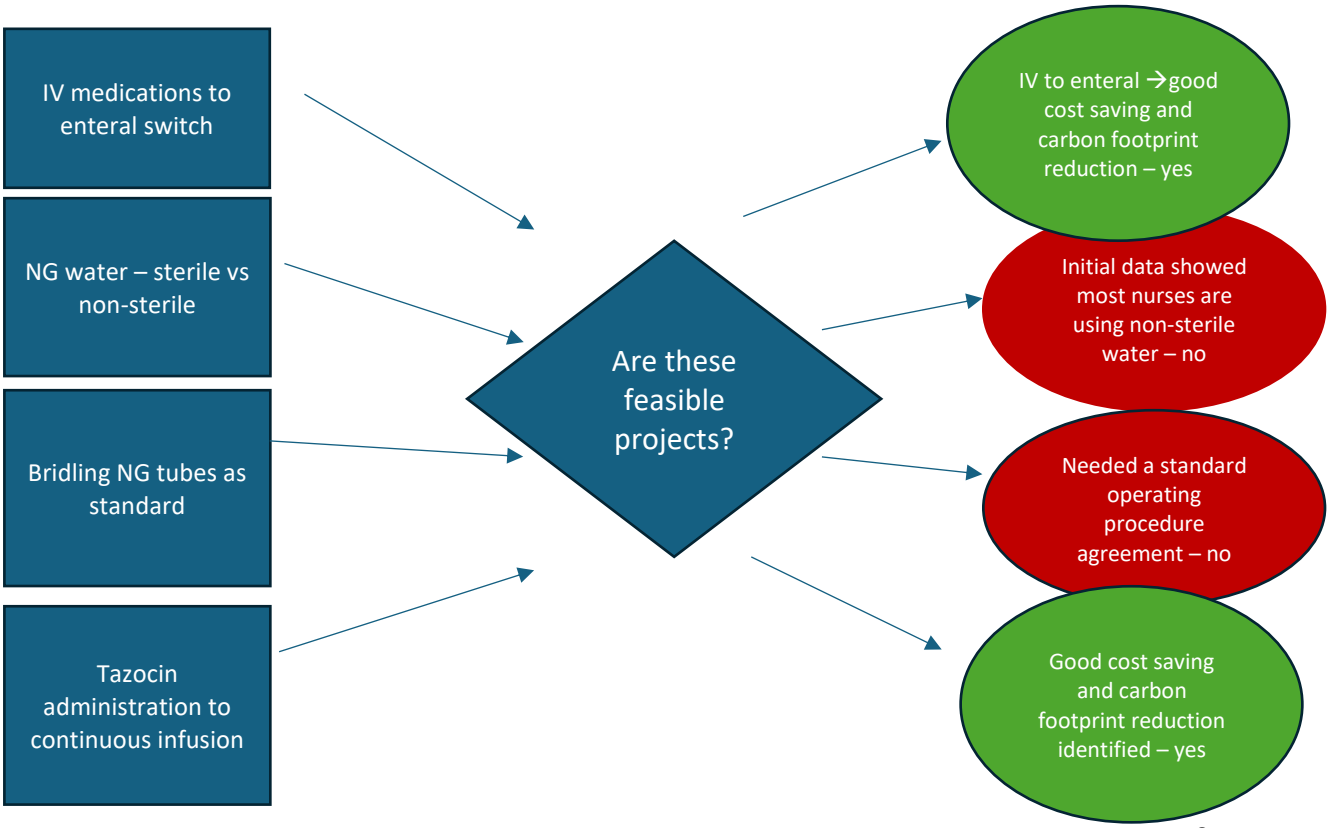
Methods

Both projects

Studying the system:

When looking for potential SusQI projects we observed specific sustainability challenges that we had encountered when working in our department. We asked other members of the multi-disciplinary team (MDT) what departmental practices they thought were wasteful and could be improved with more sustainable practice, (asking specifically if there were opportunities to reduce, re-use or recycle).

This information gathering phase led to four initial project ideas for discussion within our team.



We identified the IV to enteral switch and Tazocin infusion projects as the ones with the most potential to produce an environmental and economic sustainability improvement within the allotted time frame.

We considered a project examining the clinical practice of giving nasogastric water to ensure that drinking water is used rather than sterile water as per the protocol. Initial data suggested this was a minor training issue and not a frequent problem thus was easily rectified without a full project.

We also identified an issue with Nasogastric Tube (NGT) usage in ITU. Tests to confirm the NGT position are often inconclusive delaying a patient's feed and medication until x-rays can be done and reported. A project addressing this would have required a new standard operating procedure and initial equipment expenditure. As such it was not feasible due to time and funding constraints.

Regarding switching IV medications to enteral we were aware of some limitations to be cautious of. Some patients with specific pathologies affecting their digestive system are unable to have any enteral feeding or medication and need IV medication instead. Some other patient groups specifically need the IV medication as part of its treatment mechanism compared to enteral. We were aware that intervention advising consideration of an IV to enteral switch of medication is not a 'one size fits all' process and clinical judgement would be required as it is not always appropriate.

Anecdotal information from working on our ITUs showed us that there were many unnecessary prescriptions of IV medications when patients had an enteral route for their medications. We also noted the workload associated with amending these prescriptions and that there was not always a multi-disciplinary drive to remind the medical staff to review and amend these prescriptions.

Changes made/being made:

IV to enteral switch project

We identified that we needed a focus on the review and amending of drug charts. We did this by:

- Educating the medical staff responsible for prescriptions.
- Empowering and educating the critical care nursing staff to highlight inappropriate prescriptions for their patients.

We wanted this to have a multidisciplinary approach where either a nurse or doctor could highlight the medication review. Ultimately, the choice would lie with the responsible medical staff to make prescription changes.

We decided to focus on using the wording 'enteral' to encompass both oral and effervescent tablets (given via feeding tube) as both would have similar use of consumables. The following criteria were established for identifying medication route:

- IV phosphate should only be prescribed in severe hypophosphataemia as described in the UHCW refeeding guidelines or if there is no enteral route available.
- IV paracetamol should only be prescribed if there is no enteral route available/ inappropriate for enteral feeding or if the patient is vomiting.
- IV PPI should be prescribed for patients who have high risk ulcers post endoscopy (as per the British Society of Gastroenterology) and for those not established on a full enteral feeding regime. Otherwise, enteral PPI should be prescribed if needed, this is known amongst the ITU medical staff.

We designed a dedicated educational poster (Appendix 1), provided impromptu bedside teaching and disseminated information during handovers. This was important as it meant that we reminded medical staff just before they reviewed the drug chart of their respective patients of the day. Additionally, the poster was placed on each Omnicell (a medication dispensing cabinet) in the ITUs, to be visible to nurses when collecting medications. This is also where we conducted bedside information sessions with the nursing team.

Tazocin Infusions

There are rigorous review processes for approving new methods of medication administration in hospital. One of our ITU consultants and pharmacists had already progressed this by developing a clinical guideline for CTI administration. Demonstrating the number of patients who would benefit was key to gaining guideline approval, alongside highlighting sustainability advantages, as cost and carbon savings support both hospital finances and net zero goals.

Currently the intermittent Tazocin dosing (4.5g) is given twice daily in patients with significant kidney impairment (renal dose), three times daily in most instances and four times daily for severe

infections and to treat some specific pathogens. To deliver CTIs all patients would be given an initial one-off 4.5g loading dose (administered in the same way 1 Tazocin dose is currently given) followed, immediately by the continuous infusion. The infusion dose is based on the patient's kidney function, but the parameters are the same as for the current intermittent dosing regime. Figure 1 displays the equivalent CTI regime for the current 3 dose frequencies of Tazocin administration.

Figure 1: Representation of the regimens used for Tazocin administration in current practice (intermittent dosing) and proposed CTI practice (including day 1 loading dose).

Dose Regime	Intermittent Dosing (current practice)	Continuous Tazocin Infusion Day 1	Continuous Tazocin Infusion Days 2-7
Normal Dose	3 x 4.5g Doses / day	1 x 4.5g Loading dose immediately followed by 13.5g infusion over 24h	13.5g Infusion over 24h
High Dose	4 x 4.5g Doses / day	1 x 4.5g Loading dose immediately followed by 18g infusion over 24h	18g Infusion over 24h
Renal Dose	2 x 4.5g Doses / day	1 x 4.5g Loading Dose Immediately followed by 9g infusion over 24h	9g Infusion over 24h

As part of the project we observed three different critical care nurses giving a Tazocin dose via current (intermittent dosing) practice to make a list of the items used to deliver it. Across all three instances the inventory list was the same thus reliably informing on equipment used.

Changes that were made that did not work

Both projects

There were no interventions as part of our SusQI that were unsuccessful.

Main stakeholders

Both projects

The main stakeholders in this project were all grades of ITU Doctors, Advanced Critical Care Practitioners and the critical care nursing staff. We also engaged with the critical care pharmacy team and the sustainability team at UHCW.

Resources

Both projects

We had no financial resources available to fund these projects. Staff time for project work was in part encompassed by our 'Educational and Development Time' but this was not realistically enough time and so project work had to be done in our free time and when clinical workload allowed. As such this limited the amount of data the team could collate.

Measurement

IV to Enteral switch project

According to data obtained from the information systems manager for critical care at UHCW, the average length of stay for a patient on our general critical care is 7.25 days and on cardiothoracic critical care 4.53 days. In 2025, across both units, we had a total of 2224 patients. The majority of patients would have had paracetamol and PPI prescribed, whilst less required phosphate.

We initially collected data on the number of IV medication doses administered to each patient on each unit over the course of a week, with the intention of extrapolating this over 52 weeks to estimate annual activity. However, we found that this dataset was not representative of the problem identified and did not accurately reflect typical practice.

Instead, our critical care pharmacy team were able to supply the drug usage summary reports which showed the number of IV components that were taken from the Omnicell each month from April 2025 to March 2026. This was more accurate data for a whole year rather than extrapolating data from a week. We can also extract this data monthly and see changes as we continue to deliver our intervention. We used this data to model a reduction in IV drug usage. We were unable to accurately measure how much total fluid was reduced as individual patients had different fluid requirements depending on their illness, admission weight and fluid output.

Tazocin Infusions

To determine the cost and carbon saving of CTIs we designed an audit to measure the number of patients on twice, three and four-times daily dosing to compare what the change would be if they were switched to CTI.

Not all patients are suitable for CTIs at every stage of their care. It is likely CTIs would (at least at the start of their ITU stay) be initiated for all ITU patients with suspected Tazocin sensitive infections, as they are critically unwell and need optimal antibiotic delivery. However, general ward environments do not have the capacity to support continuous infusions. Therefore, the guideline recommends that once a patient is clinically stable and ready for step-down from ITU, their antibiotic regime should be converted back to intermittent dosing to allow the ward to safely continue and complete the prescribed course of Tazocin. This is unlikely to cause harm, as patients are only considered for step-down once they have shown clear clinical improvement and are more stable compared to when they were first admitted and commenced on CTI.

We also designed our audit to measure how many patients would be suitable for CTI; any patient on Tazocin who had documentation in the medical notes advising that they were suitable for stepdown from ITU were marked as unsuitable for CTI.

In our hospital, the digital pharmacy systems order replacements for medications used on ITU, as they are depleted. As such and thanks to the kind help of our pharmacy team we had accurate data for how many Tazocin doses had been used on GCC and CTCC in the last year. Collection of our audit data allowed us to see on average the frequency of dosing and if they would be suitable for CTIs. We also collected data on which unit (GCC or CTCC) the patients receiving Tazocin were in to check a logical distribution of the data. We audited as many days of data as possible from March onwards as clinical workload allowed. Daily handover sheets were reviewed to identify patients prescribed Tazocin. The digital drug charts were used to identify the date of commencing and frequency and medical notes were checked for suitability for CTI.

Patient outcomes

IV to enteral switch project

We modelled a reduction in IV drug usage, using the summary from the critical care pharmacy team.

Several potential patient benefits may result from increasing the use of enteral medications; however, these outcomes are beyond the scope of this project and will not be directly measured. Reduced IV medication use may decrease IV line-related complications, improve the patient experience during rehabilitation, and reduce the total volume of fluid administered, which is an important consideration in critically ill patients. Increased enteral medication use may also be associated with improved progression towards ICU discharge and a reduced need for vascular access devices, potentially lowering the risk of cannula-associated infections.

IV medication will remain available where clinically indicated, including when no enteral route is available or where specific clinical conditions require IV therapy. As the project aims to optimise, rather than eliminate, IV prescribing, no negative patient outcomes are anticipated. These potential benefits and risks will be explored through discussion of the literature rather than project data.

Tazocin Infusions

Lengthier work to measure the patient outcomes from CTI delivery was not within the scope or timeframe of this project. One could investigate mortality data for patients treated with intermittent dose Tazocin vs CTI once the new delivery method is embedded. Reputable research has been used to discuss potential avoided deaths from sepsis from swapping to CTI and data extrapolated to our units.

Population outcomes

IV to enteral switch project

There are no predicted negative population outcomes as the option of IV medication prescription is still available. There are certain groups of patients such as those with learning disabilities or younger patients who may choose to opt for IV medication as opposed to an enteral route and IV medication will be available.

Tazocin Infusions

With previously cited evidence showing improved bacterial killing power of CTI compared to intermittent dosing of Tazocin one could hypothesize that more optimal antibiotic delivery via CTI may reducer antibiotic resistance in the general population however wider reaching study on this hypothesis would have to be performed on a regional scale.

Environmental sustainability

IV to enteral switch project

Equipment common to the administration of all IV medication consists of PPE (gloves and apron), equipment to reduce the risk of infection (chlorhexidine swab), preparation of the medication (syringe and saline) and delivery of the medication (giving set). In addition, each medication has some specific consumables:

- For paracetamol, this is the plastic bottle and medication contained within.
- For phosphate solution, the bottle, medication and 500ml saline.
- For PPIs, the glass vial, container for water for injection and 100ml saline.

The equipment common to each medication delivery and the medication specific equipment and their carbon footprints is summarised in Table 1, alongside the carbon emissions per item and data source.

A cradle-to-grave hybrid approach carbon footprint analysis was used to estimate the items Greenhouse Gas (GHG) emissions. Both IV and enteral administration were carbon footprinted using a process-based carbon footprint analysis. Data was obtained from previous studies by the Centre for Sustainable Healthcare and other references. Where data was not available, calculations were made based on the weight and material of the product and using carbon conversion factors from the 2025 UK Government Greenhouse Gas Conversion Factors database UK DESNZ Database. The analysis included GHG emissions associated with primary materials production, transport, and disposal.

For end-of-life treatment, disposable equipment was assumed to be disposed of as clinical waste, while the packaging waste was assumed to be dry mixed recyclable with the corresponding emission factors taken from Rizan et al., 2020. The carbon footprint of waste disposal of the items was based on Rizan et al., 2020 carbon footprint of high temperature incineration for clinical waste.

For medications, calculations were based on emissions figures sourced from the references. For example, for paracetamol, emissions of 7.8 $kgCO_2e$ per kg of active pharmaceutical ingredient (API) were used. For a 1 g dose of paracetamol, this corresponds to 7.8 / 1000 = 0.0078 $kgCO_2e$ per dose.

Table 1. Items used for delivering IV and enteral medication and their carbon footprint

	Item	Carbon Footprint Per Item ($kgCO_2e$)	References
Common Consumables for IV administration	10ml Syringe	0.033	Previous CSH Green Team Competition
	Chlorhexidine Swab	0.0328	Previous CSH project
	Disposable Apron	0.065	COVID-19 PPE Environmental Impact (Rizan et al., 2021)
	Disposable Gloves (Pair)	0.0520	COVID-19 PPE Environmental Impact (Rizan et al., 2021)
	Giving Set	0.0913	https://cris.brighton.ac.uk/ws/portalfiles/portal/37429056/Rizan_Thesis_Final.pdf
	Saline Ampoule	0.0466	Previous CSH project
	Total	0.3207	
Specific Consumables			
Paracetamol	Paracetamol Solution for Infusion (API)	0.0078	https://pmc.ncbi.nlm.nih.gov/articles/PMC12851279/
	Empty plastic bottle, HDPE, 24g	0.0743	Government GHG Factors 2025
Phosphate	Phosphate Solution (API)	0.843	https://pubmed.ncbi.nlm.nih.gov/38537225/
	Empty plastic bottle, HDPE, 8g	0.0248	Government GHG Factors 2025
	Saline 500ml	0.146	https://cris.brighton.ac.uk/ws/portalfiles/portal/37429056/Rizan_Thesis_Final.pdf
Omeprazole	IV Omeprazole (API)	Unknown	
	Water For Injection 20ml	0.0466	Previous CSH project
	Empty glass vial, 14g	0.0197	Government GHG Factors 2025
	Saline 100ml	0.128	https://cris.brighton.ac.uk/ws/portalfiles/portal/37429056/Rizan_Thesis_Final.pdf
Enteral route	10ml Syringe	0.033	Previous CSH project
	Phosphate	0.0142	https://pubmed.ncbi.nlm.nih.gov/38537225/
	Paracetamol	0.0078	HealthcareLCA Open Database (Drew et al., 2022)
	Oral omeprazole	0.0140	Personal correspondence with manufacturer
	Paper basket for medication, 1g	0.0013	Government GHG Factors 2025

For IV administration, total emissions for the common consumables were calculated by summing the individual components. For each of the medications, this was then added to the consumables specific to each one.

For enteral medications, administration involves dissolving the medication in a non-standard volume of water taken from the patient's drinking jug, which is used for a 24-hour period. The volume of water used typically ranges between 30 and 50 ml, but there is no standardised amount. The dissolved medication is then drawn up into syringes (either 5 ml or 10 ml, again with no standardisation) and administered via the nasogastric (NG) tube. Each syringe is single-use and discarded after administration, and syringes are used for one medication only.

For the purposes of these calculations, a 10 ml syringe was assumed to err on the side of caution. Emissions associated with each additional component were summed together with the medication using previously referenced data sources. The drinking jug was excluded from the calculations, as it is present for all patients and is not specific to medication administration.

Packaging was excluded from the calculations for the enteral route.

Tazocin Infusions

After observations of the current practice of Tazocin delivery an itemised list of consumables was formed and the carbon footprint of these items calculated via the same cradle-to-grave methodology listed for the other project above. The CTI guideline listed all items used to give the CTI hence providing a list for carbon counting via the same methodology. The CTI involves one loading dose of Tazocin before the CTI is started, this loading dose has the same carbon footprint as one dose of Tazocin given by intermittent administration and was calculated as such. The tables representing this data and inventory list can be seen in Appendices 2, 3 and 4.

Economic sustainability

IV to enteral switch project

Cost data for the IV medications and their effervescent counterparts were obtained from the British National Formulary (Table 2).

Table 2: Comparison of costs between IV and enteral medications

Medication name	IV cost	Enteral cost
Paracetamol	£5.30	£0.05
Omeprazole (IV) Lansoprazole (enteral)	£5.20	£0.12
Phosphate	£8.79	£0.25

We identified our project coincided with a change from using phosphate polyfusor to sodium glycerophosphate vials due to a shortage of availability. Although, it was not feasible to see what consumables were used with the phosphate polyfusor, it is assumed it is the same as the paracetamol or omeprazole plus the addition of the phosphate polyfusor. For the carbon footprinting portion of this report, the sodium glycerophosphate vials have been used.

The consumables list for the IV medication had common counterparts across all three medications and then certain consumables which were individual to the medication as seen in Table 3.

Table 3 highlights the cost of the consumables, these were sourced from the BNF, NHS supply chain and a popular medical supplies website (Medisupplies and UKMedi). Some prices were unavailable such as the 500ml bag of saline on the BNF. We did not include the cannula or dressings for this as it was not specific to these medications, cannulas may be used for other medications such as antibiotics or IV fluid administration.

Table 3: Consumables and their cost

Consumable	**Cost**
Disposable apron	£0.84
Disposable gloves	£0.15
Chlorhexidine gluconate and isopropyl alcohol swab	£0.02
10ml syringe	£0.05
Giving set	£2.49
500ml bag of saline	-
100ml bag of saline	£0.89
20ml water for injection ampoule	~£0.38
10ml Saline ampoule	£0.58
10ml enteral NG syringe	£0.24
Paper basket	£0.04

From anecdotal information obtained from our bedside teaching with the critical care nursing staff, giving more enteral medication would be more time efficient as there are less consumables involved

in the preparation of the medications. Time is also saved due to the need to have two nurses check all IV medication prior to administration, whereas with enteral administration this is eliminated. There was great variation depending on the nursing staff available and the experience of the nurses when it came to the timings of preparing the medications for both IV and enteral and therefore it was difficult to obtain a specific average time saved. However, due to the lack of double check, the preparation of enteral medication was quicker for the nursing team.

Tazocin Infusions

The inventory of items used and associated costs for Tazocin intermittent dosing and CTI are listed in table 4 below. The loading dose means patients would receive 1 additional dose in a full course of Tazocin than in current intermittent dosing practice. Data provided by our pharmacy team reported that 1 dose of Tazocin costs £1.71 which was factored into analysis.

Table 4: Consumables used to give Tazocin intermittent doses and CTI

Intermittent Dose	CTI	Cost
Disposable gloves (1 pair)	Disposable gloves (1 pair)	£0.15
Chlorhexidine gluconate and isopropyl alcohol swab	Chlorhexidine gluconate and isopropyl alcohol swab	£0.02
20ml syringe	20ml syringe	£0.07
Unfiltered blunt needle (red)	Unfiltered blunt needle (red)	£0.11
Giving set	Giving set	£2.49
100ml bag of 0.9% NaCl	100ml bag of 0.9% NaCl	£0.89
20ml water for injection ampoule	20ml water for injection ampoule	£0.38
-	250ml bag of 0.9% NaCl	£1.30
1x Tazocin 4.5g vial	1x Tazocin 4.5g vial	£1.71

Social sustainability

IV to enteral switch project

It is inherently difficult to obtain patient opinion on changes to medication in critical care due to most patients being sedated and ventilated and therefore not aware. However, it is prudent to keep patients who have sensory issues and/or other vulnerabilities such as learning disabilities in mind as they may have specific preferences to their medication route which greatly affects their patient journey. Furthermore, patients on critical care who are not sedated and ventilated may have their

own preferences and we must adhere to making their patient journey as suited to them as possible, therefore, they may prefer to have IV medication due to personal choice/may not like the taste/may not want an NG tube and cannot swallow yet.

When doing bedside teaching with the critical nursing staff, we took note of their views and opinions regarding the preparation of different medication types.

Tazocin Infusions

During our observation of current dosing practice discussions with the critical care nursing team about the new CTI option shed light on some unexpected social sustainability benefits for staff which were not anticipated, and these results are discussed.

Results

IV to enteral switch project

Results have been modelled on baseline data collected prior to delivering the intervention. From literature searches, it was not obvious that this type of project has been attempted in other critical care units despite the focus on sustainability in intensive care that is endorsed by the Faculty of Intensive Care Medicine.

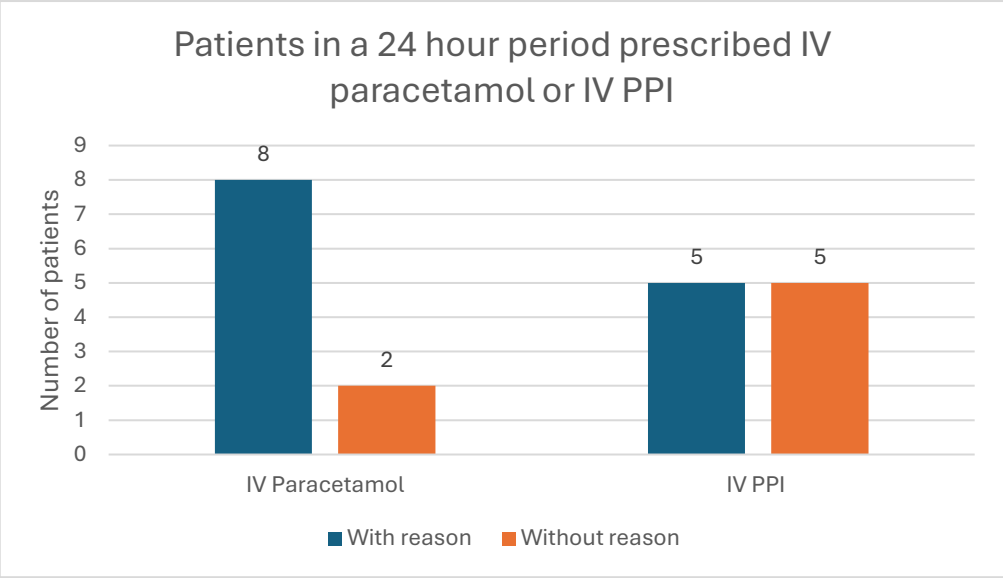
Nguyen et al (2024) identified in a prospective randomised noninferiority trial that enteral phosphate is noninferior to parenteral phosphate in mild to moderate hypophosphataemia. This supports our QI project but only looked at a single medication. There are similar audits and articles (Procter et al, 2018) and (Hunfield et al, 2024) which also support our project but again they look solely at IV paracetamol rather than a group of medication.

On review of the available literature and the size of our critical care units, we envisioned a 30% reduction in the use of IV preparations across our three chosen medications.

Our initial data collection identified the number of patients prescribed IV medications and whether they had a valid reason as mentioned in the measurements section of this report. Figure 2 explains

this data for IV paracetamol and IV omeprazole. There were no patients during this time that were prescribed IV phosphate.

Figure 2: Valid reasoning for prescription of IV paracetamol or IV PPI

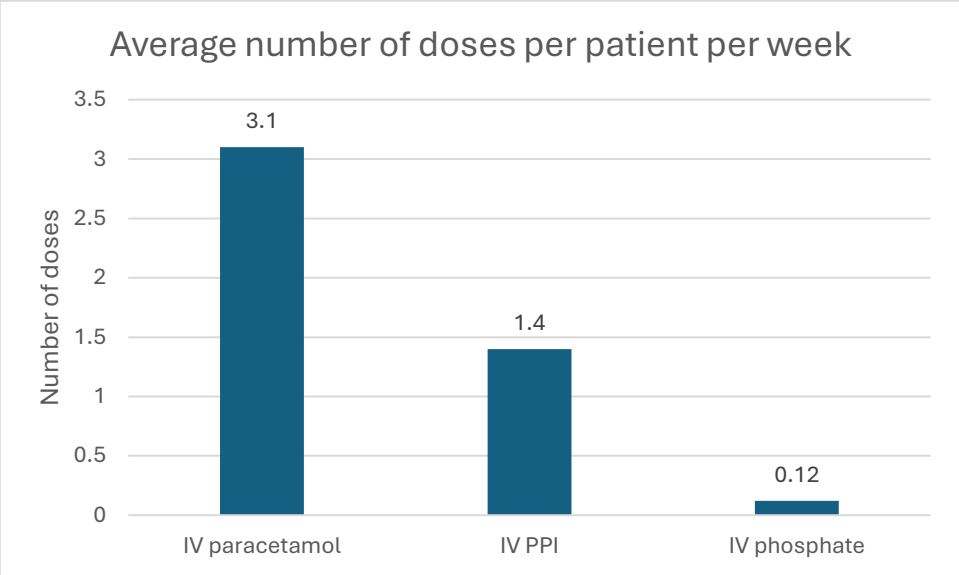


Across both critical care units in a 24-hour period showed that 10 out of 26 patients, had IV paracetamol prescribed. Out of those 10, only two had a valid reason as to why they could not have an enteral route. Similarly, there were 10 patients with IV omeprazole prescribed, where only 5 had valid reasons to not have enteral medication.

This data supported our project aim to optimise the more environmentally sustainable prescription of medications; however it didn't feel representative of our units usual prescribing habits.

We did further baseline data collection to look at the average doses of IV medication that one patient received in 1 week. We reviewed every patient admitted on each unit in another 24-hour period. We retrospectively reviewed their electronic drug charts for the last 7 days and documented the number of IV doses administered. Using this data, we were able to identify an average number of doses for each IV medication patients had in 1 week, as described in Figure 3.

Figure 3: Average doses of IV medications



From this data, we could see that the most commonly prescribed IV preparation was paracetamol but again it did not feel representative of our critical care and therefore we decided that a larger period of data was required. This led us to use the yearly drug usage summary reports from the critical care pharmacy team as shown below in Figure 4 and is summarised in figure 5.

Figure 4: Drug usage summary reports from both critical care units

JAC **DSUM - Drug Usage Summary Report** 28-Apr-2026 Page 1 of 1

List of DECREASE transactions Monthly to March 2026 at All Locations by Drug (A Selection of Drugs ordered: Items within Cost Centre) KOONC28124540

Decrease Transaction Types:

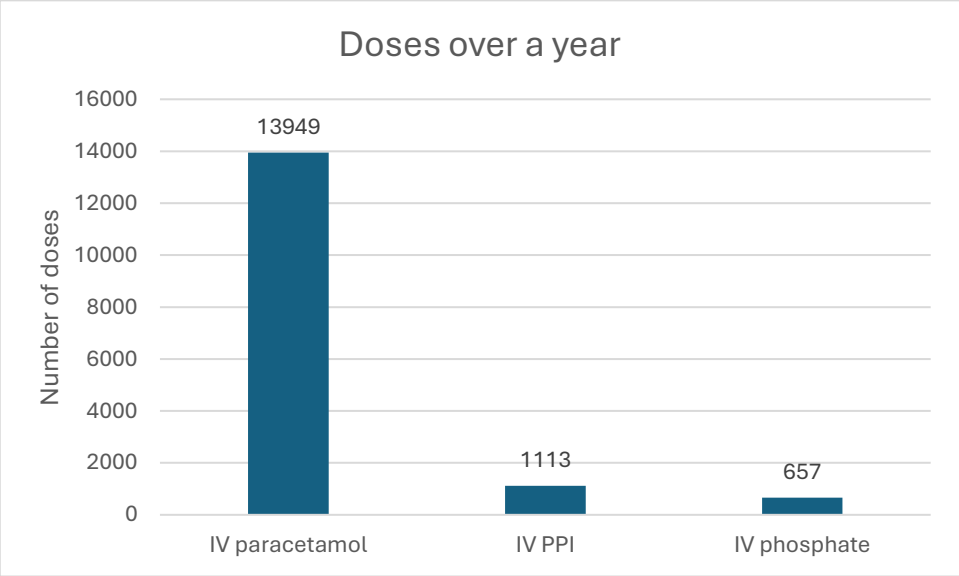
Inpatient Dispensed item	Outpatient Dispensed item	TTA Dispensed item	Clinic Dispensed item
Day Case Dispensed item	One Stop Dispensed item	A & E Dispensed item	Bulk Issues via BISSUE, BCISSU or BWPROF
Stock Adjustments via KADJ or KADS	Stock Adjustments via KADJM	Return of Stock to Supplier via NRTS	Stock Transfers via KTRANS
Requisitions via RTAKE	Raw Materials in Extemporaneous Dispensing	Ingredients used in Aseptics	Credit for Returned Goods
Returned Goods Out	Sale to Purchaser	Raw Materials in Manufacturing	Quarantine Stock

compiled on 28-Apr-2026 at 12:45 by KOONC

		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Total
CARDIOTHORACIC ITU														
OMEPRAZOLE 40 mg Injection 5 x 40mg Vial Pack	Value	232	245	191	259	307	225	239	190	202	233	282	292	2897
	Quantity	34	36	28	38	45	33	36	31	33	38	47	49	448
PARACETAMOL 1 g in 100mL Solution for Infusion 100 mL Vial	Value	0	0	0	0	0	0	543	530	534	4489	4492	672	11260
	Quantity	0	0	0	0	0	0	751	661	664	750	710	836	4372
PHOSPHATES Intravenous Infusion 500 mL Polyfusor	Value	134	0	268	558	313	536	536	290	1340	0	268	0	4243
	Quantity	6	0	12	25	14	24	24	13	60	0	12	0	190
Total for Cost Centre	**Value**	**366**	**245**	**459**	**817**	**620**	**761**	**1318**	**1010**	**2076**	**4722**	**5042**	**964**	**18400**
CRITICAL CARE UNIT COVENTRY														
OMEPRAZOLE 40 mg Injection 5 x 40mg Vial Pack	Value	416	334	239	320	457	382	403	275	386	318	368	396	4294
	Quantity	61	49	35	47	67	56	60	45	63	52	63	67	665
PARACETAMOL 1 g in 100mL Solution for Infusion 100 mL Vial	Value	497	1288	491	490	616	496	667	716	1139	4443	6846	802	18491
	Quantity	828	602	656	817	1026	826	671	613	769	747	1024	998	9577
PHOSPHATES Intravenous Infusion 500 mL Polyfusor	Value	603	1070	1072	1072	1643	938	536	1072	0	1922	679	-179	10428
	Quantity	27	48	48	48	80	42	24	48	0	86	24	-8	467
Total for Cost Centre	**Value**	**1516**	**2692**	**1802**	**1882**	**2716**	**1816**	**1606**	**2063**	**1525**	**6683**	**7893**	**1019**	**33213**
Grand Total	**Value**	**1882**	**2937**	**2261**	**2699**	**3336**	**2577**	**2924**	**3073**	**3601**	**11405**	**12935**	**1983**	**51613**

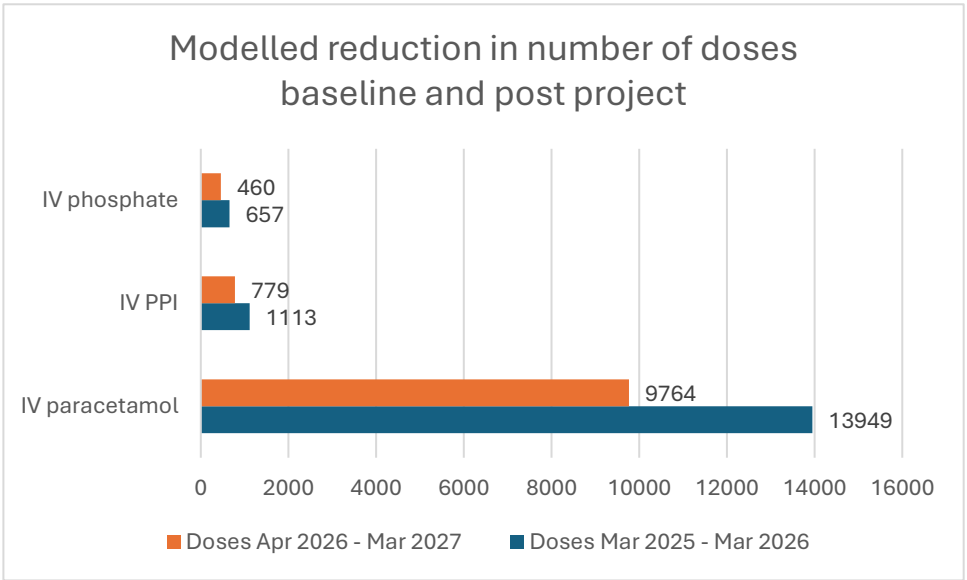
Note: Credits included may relate to transaction types other than those selected. Quantities are shown rounded to whole packs. Values shown are the current values of the transactions.

Figure 5: Yearly number of IV medications used across both critical care units



The data from figure 5 was used to model a 30% reduction in doses that is shown in Figure 6 below. This resulted in a yearly reduction of 197 IV phosphate doses, 334 IV PPI doses and 4,185 paracetamol doses.

Figure 6: Modelled reduction in number of total doses over the course of a year based on a 30% switch to enteral



Tazocin Infusions

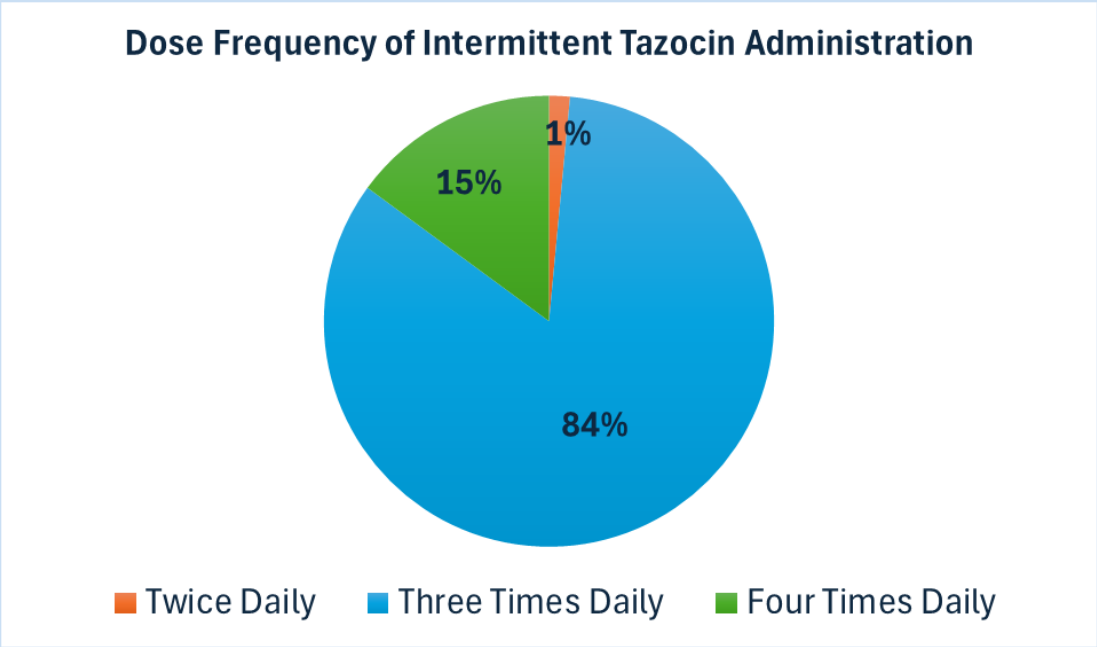
Our audit results on current practice for Tazocin (intermittent dose) administration can be seen summarised in Table 5.

Table 5: Descriptive Tazocin administration data sampled from March to May 2026.

Total days of data sampled	12
Days sampled in March 2026	6
Days sampled in April 2026	4
Days sampled in May 2026	2
Total number of patients on Tazocin	**67**
Total number of Tazocin patients on GCC	45
Total number of Tazocin patients on CTCC	22
Number of patients who would be appropriate for CTI	47
Number of patients who would not be appropriate for CTI	20

A key part of our audit was to collect data on the current dose schedule of intermittent dose Tazocin administration to enable later carbon counting and cost saving analysis for CTI. The proportion of patients on Tazocin on GCC and CTCC approximately matches the proportionate difference in bedspaces present on the units confirming the expected distribution of this data (as we expected Tazocin prescribing practice to be similar on both units). Figure 7 displays the proportion of patients on each dose frequency (across the 67 patients reviewed).

Figure 7: Dose frequency of Intermittent Tazocin Administration across the 67 patients sampled in March-May 2026.



Patient outcomes

IV to enteral switch project

A 30% decrease in the prescription of the three medications, is feasible given that our intervention is ongoing and will continue until at least August 2026 with continuous in-person education sessions, incorporation into induction for new doctors and bedside reminders for the nursing staff. Ultimately, we believe that there will be no predicted negative patient outcomes for the following reasons:

- Enteral paracetamol has an oral bioavailability of 79% and it's onset time is approximately only 15 minutes slower than that of IV paracetamol (Raffa et al, 2018). One could argue that the onset time is insignificant in a sedated and ventilated patient.
- Oro-dispersible Lansoprazole has 80-85% bioavailability and for the purposes of gastroprotection seems adequate for use in critically unwell patients (Wołowiec et al, 2025)
- Enteral phosphate replacement has been found to be adequate for mild and moderate hypophosphataemia in critically unwell patients (Nguyen et al, 2024). Oral bioavailability of phosphate Sandoz tablets is approximately 70% which is sufficient for correction in those with an enteral route.

Reducing the amount of IV medication prescribed, will not be compromising patient care, but will reduce the environmental and economic burden for the critical care units.

Measuring the impact of enteral prescribing on length of stay and cannula-associated infection is beyond the scope of this project. Another potential outcome we considered measuring was the total IV fluid administration saving per patient and whether this would be sufficient to affect mortality figures. However, given differing individual fluid requirements, it was outside the scope of this project to calculate them.

Measuring the impact of increased enteral prescribing on outcomes such as ICU length of stay, cannula-associated infections, and patient mortality is beyond the scope of this project. Although reduced IV medication use may decrease total IV fluid administration, variation in individual patient fluid requirements makes this difficult to quantify within the project timeframe.

Nevertheless, several potential patient benefits may arise from reducing IV medication use. These include reduced fluid administration, fewer IV line-related complications, and a lower risk of cannula detachment during rehabilitation activities (Ji & Won, 2023). Increased enteral prescribing may also

be associated with progression towards ICU discharge and a reduced need for vascular access devices, potentially lowering the risk of cannula-associated infection.

IV medication will remain available where clinically indicated, such as when no enteral route is available or in conditions including severe hypophosphataemia and upper gastrointestinal bleeding. As this project aims to optimise rather than eliminate IV prescribing, no negative patient outcomes are anticipated. These potential benefits will therefore be discussed using the published literature rather than measured directly within the project

Tazocin Infusions

Thanks to the robust data from the previously cited meta-analysis on β-Lactam antibiotic continuous infusions (abdul-Aziz *et al.*, 2024) we know that there is a number needed to treat of 26 (with continuous infusions compared to intermittent dosing) to prevent 1 death. Given that we use 6,600 doses of Tazocin per year (March 2025 – February 2026 data) and a standard course of Tazocin is 1 week, we can combine this data with the dose frequencies audited (in Figure 7 above) to estimate that 305 patients per year are treated in our ITUs with a course of Tazocin. Given the number needed to treat of 26 this is indicative that provision of Tazocin via CTI may save more than 11 lives per year in our ITUs.

Population outcomes

IV to enteral switch project

There are no predicted negative population outcomes associated with our project as the option of IV prescriptions is still available for those who require it.

Tazocin Infusions

As discussed in the measurements section, one could propose that more optimal delivery of Tazocin via CTI may reduce the incidence of development of multidrug-resistant infections (assuming that sub-optimal treatment of a pathogen leaves surviving bacteria to spread resistance). The reduction of spread of multidrug-resistant infections to the population would be an important population benefit however this proposal does make multiple assumptions. It is beyond the scope of this project to evaluate this potential.

Environmental sustainability

IV to enteral switch project

The total emission for common consumable items involved in IV administration is 0.3207 kg CO_2e This result is combined with emissions specific to each of the drugs given (both broken down in table 1). Total emissions per dose of medication is shown in Table 6 for both IV and enteral administration.

Reductions in carbon emissions from switching from IV to enteral routes were calculated for the three medications illustrated in Table 6 with the difference in emissions between each pair calculated. For example, per paracetamol dose given, total emissions by IV administration are 0.403 $kgCO_2e$ and for enteral administration are 0.042 $kgCO_2e$. The difference is 0.36 $kgCO_2e$ per dose.

Table 6. Per-dose carbon emissions of drugs and consumables for IV and enteral administration

	Emissions for IV route per dose ($kgCO_2e$)	**Emissions for enteral route per dose** ($kgCO_2e$)	**Difference in emissions** ($kgCO_2e$)
Carbon emissions per 1g paracetamol ($kgCO_2e$)	0.4028	0.0421	0.36
Carbon emissions from phosphate administration ($kgCO_2e$)	1.3345	0.0846	1.29
Carbon emissions from PPI administration ($kgCO_2e$)	0.5150	0.0343	0.47

The number of doses of each medication used on cardiothoracic and general adult critical care were supplied. To calculate the maximum possible reduction in emissions, the total doses given on each of the units was multiplied by the difference in emissions.

If all doses of IV administrations of omeprazole, paracetamol, and phosphate were converted to enteral routes, the total estimated annual carbon saving would be **6,395 $kgCO_2e$**.

Individually, complete conversion of IV to enteral paracetamol would yield a yearly saving of **5,022 $kgCO_2e$,** omeprazole would yield a saving of **519.35 $kgCO_2e$**, while full conversion of phosphate would contribute an additional **844.87 $kgCO_2e$** saving.

Table 7 uses the difference in emissions between the different routes of administration and multiplies them by the total number of doses ordered by respective units over a 12-month period.

Table 7. Calculating the total reduction in emissions moving from IV to enteral drug administration.

	Total number of doses (Apr 25-Mar 26)	Difference in emissions between IV and enteral administration ($kgCO_2e$)	Total yearly reduction in emissions moving from IV to enteral administration ($kgCO_2e$)
Cardiothoracic ITU			
Omeprazole	448	0.47	209.05
Paracetamol	4372	0.36	1576.84
Phosphates	190	1.29	244.33
Critical Care			
Omeprazole	665	0.47	310.30
Paracetamol	9577	0.36	3454.12
Phosphates	467	1.29	600.54
Combined yearly total			**6,395.18**

However, it is important to recognise that a proportion of patients will continue to require IV medications due to clinical contraindications to enteral administration. As such, achieving a 100% conversion rate is unlikely in practice. Scenario modelling therefore provides a more realistic estimate of potential savings. If **50% of patients** receiving these medications were switched from IV to enteral routes, an annual reduction of approximately **3,197 $kgCO_2e$** could still be achieved. This would increase to **4,796 $kgCO_2e$** if **75% of patients** were able to switch.

Under a more conservative scenario predicted for our units of **30% conversion**, the estimated annual carbon savings would be **1,506.6 kgCO_2e** for paracetamol, **155.8 kgCO_2e** for omeprazole, and **253.5 kgCO_2e** for phosphate, resulting in a combined yearly saving of **1,918.55 kgCO_2e**.

These findings reflect the clinical reality that IV administration will remain necessary for some patients, while demonstrating that even partial uptake of enteral prescribing can deliver substantial carbon savings at scale.

Although switching from IV to enteral phosphate administration results in the largest per-dose reduction in carbon emissions (1.29 kgCO_2e per dose), the overall impact is limited because phosphate is administered relatively infrequently. Approximately 657 doses of phosphate are given per year.

In contrast, switching paracetamol from IV to enteral administration results in a smaller per-dose reduction of 0.36 kgCO_2e. However, paracetamol is administered far more frequently, with nearly 14,000 doses per year. As a result, the total annual emissions reduction achieved by switching paracetamol is substantially greater than that achieved by switching phosphate.

Tazocin Infusions

Carbon emissions were calculated for the delivery of Tazocin via the 3 dose frequencies currently used and the 3 corresponding CTI doses (renal dose, normal dose and high dose). These calculations are shown in Appendices 2, 3 and 4.

Having calculated the carbon footprint of the consumable items used to deliver Tazocin intermittent dosing and CTI, we can deduce the yearly carbon saving from CTI which is demonstrated in Table 8:

Table 8: Weekly and Yearly carbon emissions for each Tazocin treatment regime.

	Total emissions for pathway for 1 week medication $kgCO_2e$	Percentage of patients receiving regime	Yearly emissions (current pathway) $kgCO_2e$	Modelled yearly emissions (new pathway) $kgCO_2e$
Normal Dose Patients:		84		
Current pathway	8.127		2135.29	
New pathway	4.5124			1185.59
High Dose Patients:		15		
Current pathway	10.836		380.56	
New pathway	4.8386			169.93
Significant renal impairment patients (GFR <20ml/min)		1		
Current pathway	4.644		32.60	
New pathway	4.2296			29.69
Total yearly emissions $kgCO_2e$			2548.45	1385.21

As summarised in Table 8 using CTIs would save an estimated 1,163.25 $KgCO_2e$ per year based on the carbon footprint of the consumables. It is worth noting that this assumes 100% of the estimated 305 patients treated with Tazocin in ITU each year are suitable for CTI. This is a fair assumption as the only exclusion criteria for CTI is patients eligible to step down from ITU to the ward and it is logical that when such a patient started a course of Tazocin they were more unwell and thus would have had CTI; it would just be in the last days of finishing the course that they would be de-escalated to intermittent dosing, but would have had the benefit of the majority of a course of Tazocin via CTI already.

A second assumption had to be made as part of data interpretation which was that patients received a 7-day course of Tazocin. Although this is most common, antibiotics are reviewed at day 5 of administration so some Tazocin courses may be stopped at this time. Sometimes Tazocin treatment is initiated but later microbiology results such as blood cultures later indicate another antibiotic would be preferable thus the course would be stopped before 7 days. Sadly, sometimes our patients pass away before completing a 7-day course. This assumption had to be made to permit sufficient

data collection within the allocated time. This means that more patients per year may be treated with Tazocin on our units than the data here indicates making the patient, sustainability and economic impact larger than measured.

It is known to be challenging to accurately measure the carbon footprint of pharmaceutical products, particularly intravenous antibiotics. As such we were unable to measure the carbon footprint of the Tazocin medication itself.

Economic sustainability

IV to enteral switch project

The modelled 30% reduction in prescription of IV medication in terms of financial cost saving (for medications only) is shown below, figure 8 represents our current drug usage costs and figure 9 represents modelled data for 2026/2027.

Figure 8: Current data from drug usage summary reports and it's financial equivalent

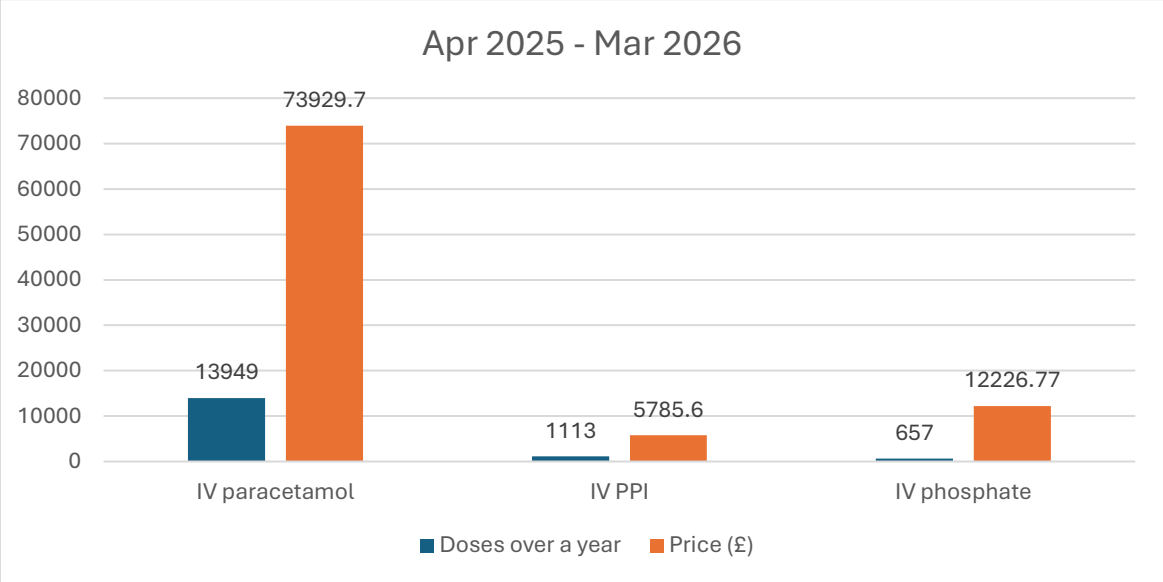
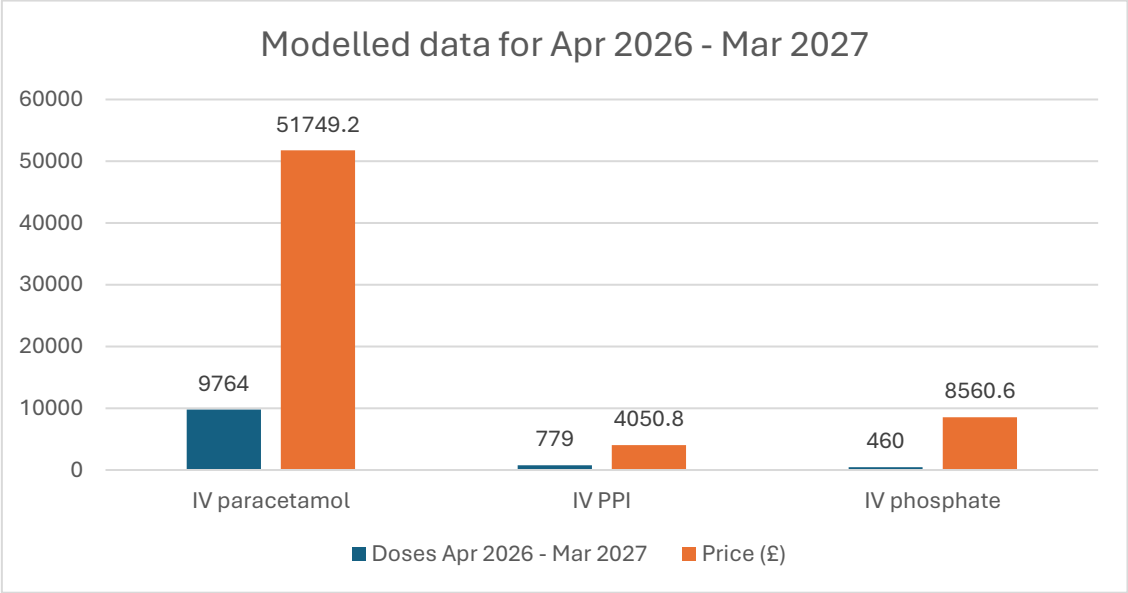
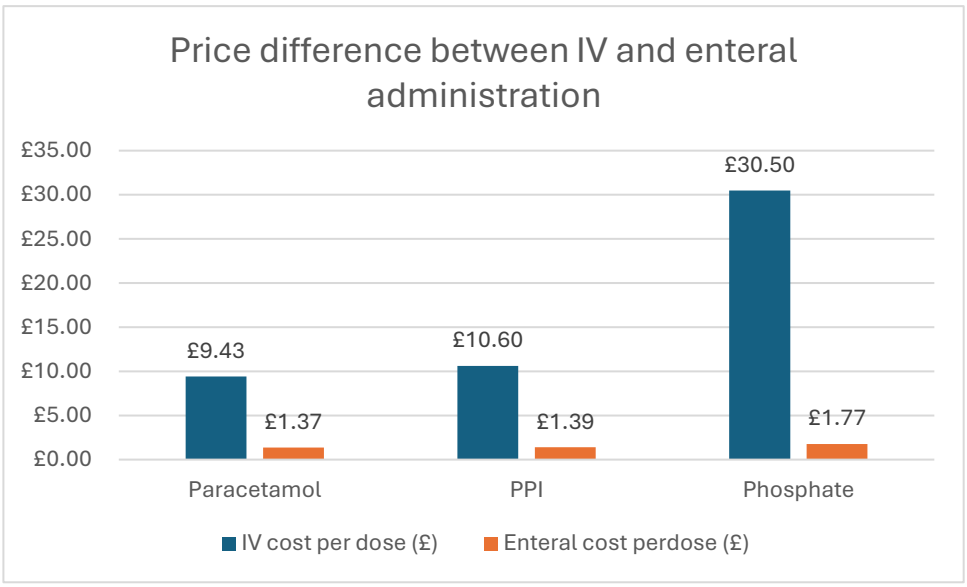


Figure 9: Modelled data for April 2026 – March 2027 with 30% reduction of IV doses



This data has shown that there is a significant financial cost saving to be made with this project and we believe it is achievable. We can estimate the cost saving per dose for medication and consumables as shown below in Figure 10.

Figure 10: Price difference between IV and enteral including consumables



- For one dose of paracetamol switched from IV to enteral we can make a cost saving of £8.06.

- For one dose of omeprazole switched from IV to enteral lansoprazole we can make a cost saving of £9.21.
- For one dose of phosphate switched from IV to enteral we can estimate a cost saving of £28.77. This is only an estimate as it was difficult to find the exact price of a 500ml bag of saline and therefore we can assume that the cost saving would be more than calculated.

We can use the above calculations with the modelled 30% reduction in doses to estimate the amount of money saved in total over the course of the year. For each medication it would be:

- Paracetamol → £33,731.10
- PPI → £3076.14
- Phosphate → £5667.69

This results in an **annual saving of £42,474.93**. Additional financial efficiencies are likely through reduced nursing time due to fewer IV administrations, as well as fewer cannula insertions, leading to potential time and consumable savings. However, these were not formally measured within the scope of this project.

Tazocin Infusions

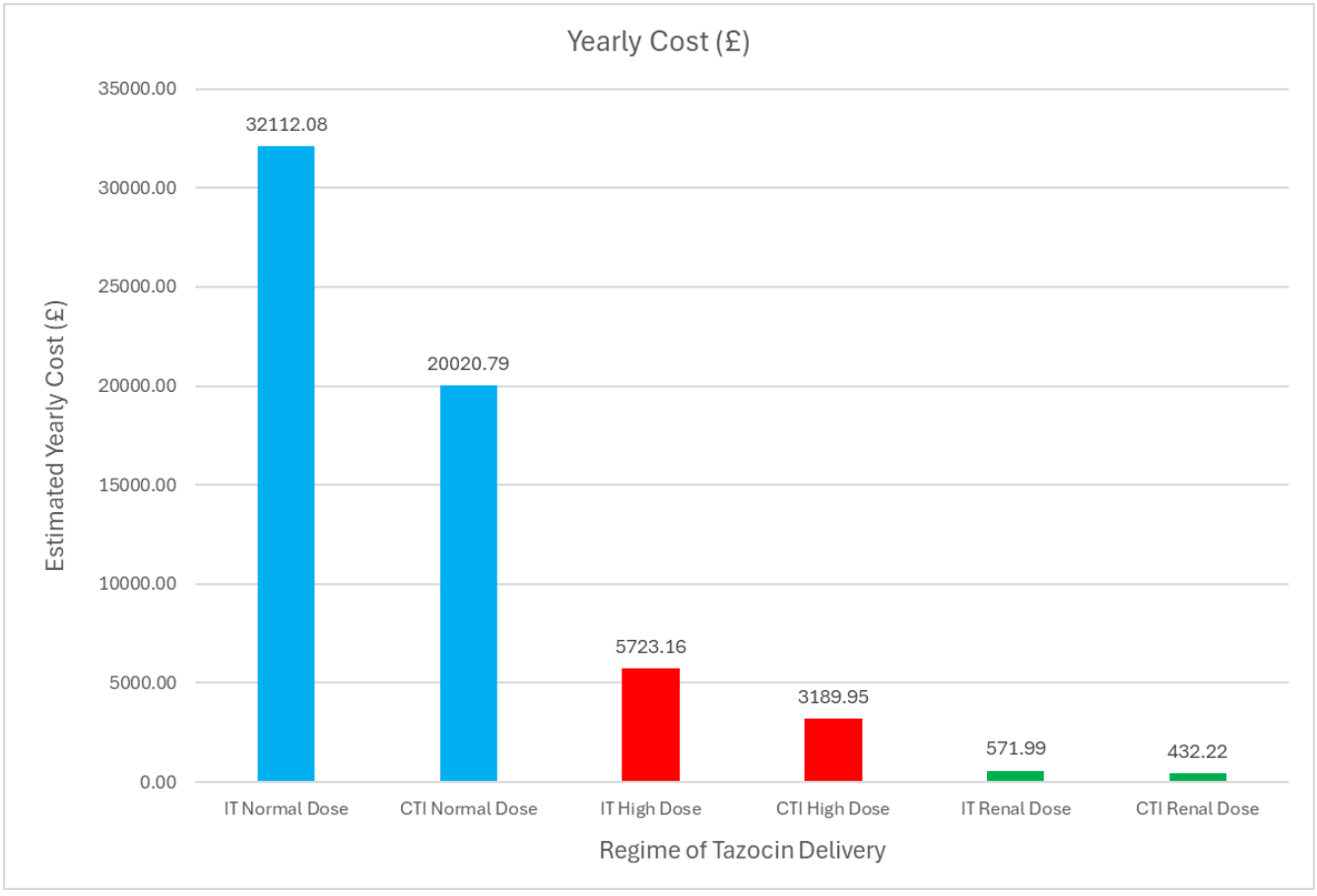
The financial savings were calculated using the individual consumable costs as outlined in measurements table 4, along with consumable quantities shown in appendices 2, 3 and 4. This enabled the cost of a 7-day course of Tazocin to be calculated (table 9) and then be extrapolated to a yearly cost (figure 11).

Table 9: Consumables used (and cost in £) to deliver a full course (7 days) of Tazocin via each regime

Consumables	IT Normal dose	CTI Normal Dose	IT High Dose	CTI High Dose	IT Renal Dose	CTI Renal Dose
Nitrile Gloves	21 (3.15)	8 (1.20)	28 (4.20)	8 (1.20)	14 (2.10)	8 (1.20)
Tazocin 4.5g	21 (35.91)	22 (37.62)	28 (47.88)	29 (49.59)	14 (23.94)	15 (25.65)
20ml Syringe	21 (1.47)	8 (0.56)	28 (1.96)	8 (0.56)	14 (0.98)	8 (0.56)
Unfiltered Blunt Needle	21 (2.31)	8 (0.88)	28 (3.08)	8 (0.88)	14 (1.54)	8 (0.88)
20ml Water for Injection	21 (7.98)	22 (8.36)	28 (10.64)	29 (11.02)	14 (5.32)	15 (5.70)
Alcohol Wipe	21 (0.42)	8 (0.16)	28 (0.56)	8 (0.16)	14 (0.28)	8 (0.16)

Giving Set	21 (52.29)	7 (17.43)	28 (69.72)	7 (17.43)	14 (34.86)	7 (17.43)
100ml NaCl Bag	21 (18.69)	1 (0.89)	28 (24.92)	1 (0.89)	14 (12.46)	1 (0.89)
250ml NaCl Bag	0	7 (9.10)	0	7 (9.10)	0	7 (9.10)
Total Cost (£)	122.22	76.20	162.96	90.83	81.48	61.57
Cost Saving of CTI (£)	-	**46.02**	-	**72.13**	-	**19.91**

Figure 11: Annual Tazocin Costs by Dose Regime and Delivery Method (IT vs CTI, 2025–2026)



Normal dose High dose Renal dose

The projected total **yearly cost reduction is £14,764.30** when comparing CTI to intermittent Tazocin dosing.

Social sustainability

IV to enteral switch project

The consensus from the medical and nursing staff was that they understand the importance of sustainability in the critical care unit and want to help implement changes. This has been the reception from when we have explained our intervention during handover and during bedside teaching with the nurses. There is already a group of nurses who advocate for sustainability in the critical care units and they have been in great support of our project.

From anecdotal information, preparing enteral medication is quicker than preparing IV medications for the nursing staff. Additionally, nursing staff of all levels of experience can prepare enteral medication whereas there is extra training for the preparation of IV medication.

Delivering a more sustainable critical care service is increasingly important to staff, who are keen to engage in environmentally responsible healthcare practices as part of their day-to-day work. Supporting improvements in sustainability not only aligns with wider organisational and NHS goals but also contributes positively to staff morale. Implementing this project is expected to enhance staff satisfaction and engagement, fostering a more motivated and productive workforce.

Tazocin Infusions

Conversations with the critical care nursing team highlighted clear efficiency benefits of continuous infusion. Once established, it requires significantly less time than preparing and administering multiple intermittent doses. Additionally, IV medications require a second safety check; reducing this from 2–4 times daily to a single check for CTI saves staff time and allows greater focus on patient care.

Discussion

These two projects are modelled to deliver **annual savings** (based on 30% paracetamol, PPI and phosphate and 100% Tazocin conversion) of **£57,239 and 3,082 kgCO_2e or 9,173 miles avoided** in a petrol car, whilst delivering no negative patient or population outcomes and delivering social value.

IV to enteral switch project

This project identified frequent use of intravenous paracetamol, phosphate, and proton pump inhibitors in critical care patients despite the presence of feasible enteral routes. The findings highlight an important opportunity to improve prescribing practice with implications for environmental sustainability, healthcare expenditure, and patient safety.

Intravenous medications are commonly initiated appropriately during the acute phase of critical illness due to concerns regarding gastrointestinal absorption, reduced gut perfusion, or inability to tolerate enteral administration. However, this project suggests that IV therapies are often continued after these barriers have resolved. In many cases, they appeared to persist due to clinical inertia and lack of routine review rather than ongoing clinical indication.

From an environmental perspective, IV medications carry a substantially greater carbon footprint than enteral alternatives due to pharmaceutical manufacturing processes and the additional consumables required for administration, including infusion bags, syringes, giving sets, flushing equipment, and plastic packaging. Reducing avoidable IV prescribing, therefore, represents an achievable intervention aligned with the NHS “Greener NHS” strategy and wider commitments towards net zero healthcare.

This project also demonstrated potential financial and operational benefits. Enteral formulations are generally less expensive than IV alternatives and reduce nursing time associated with medication preparation and administration. Furthermore, minimising unnecessary IV therapy may reduce complications associated with intravenous access, including thrombophlebitis, line-associated infection, and fluid burden, thereby promoting patient safety.

Overall, there is a proposed financial annual cost saving of £27,581.47 when calculating with only the medications and **annual cost saving of £42,474.93** including the consumables when considering a 30% reduction in IV doses. There is an environmental **annual saving of 1919 kgCO_2e** or the equivalent to driving 5,711 miles in a petrol car. The difference in carbon savings between paracetamol and phosphate also highlights the importance of considering both the carbon emissions saved per individual dose and the total number of doses administered annually when prioritising medications for route-switching initiatives. Focusing on high-volume medications, even where

per-dose savings are modest, may deliver a greater overall reduction in emissions than targeting low-volume medications with larger per-dose savings.

We can continue to look at the drug usage summary reports on a monthly or 3-monthly basis to ensure by next year we have achieved our desirable reduction percentage.

The findings highlight several behavioural and systems-based contributors to unsustainable prescribing. These include habitual continuation of IV therapy following patient stabilisation, limited awareness of the environmental impact of medicines, and absence of prompts within prescribing workflows to reassess route suitability. Critical care environments are inherently complex, and medication review may be deprioritised during transitions of care or ward rounds focused on acute stabilisation.

A key strength of this project is its focus on a practical and reproducible intervention within routine prescribing practice. Route conversion requires minimal additional resources and may produce cumulative environmental and financial benefits when implemented consistently across critical care services. Importantly, the intervention does not compromise clinical care and may instead promote medicines optimisation.

Limitations of the project include its single-centre design and relatively small sample size, which may limit generalisability. Assessment of enteral suitability was based on clinical documentation and reviewer judgement at the time of data collection, introducing potential subjectivity despite choosing criteria. Additionally, our drug usage summary report showed the information for phosphate polyfusor however the carbon footprint data and costing data is based on vials of sodium glycerophosphate due to a change in the prescribing practice at the time of the project.

Overall, this project demonstrates how small prescribing decisions within critical care can contribute meaningfully to sustainable healthcare delivery. Embedding routine consideration of enteral suitability into prescribing practice may represent a simple but effective strategy to reduce avoidable resource use and support environmentally responsible practices.

Tazocin Infusions

Our project utilised meta-analysis data paired with that collected in our audit of 67 patients to assess the likely impact of bringing CTIs to UHCW ITU on patient, environmental, economic and social sustainability outcomes.

Pharmacy data informed us of the number of Tazocin doses used per year and our audit showed the breakdown on the dose frequency which was utilised on average to deliver a course of these Tazocin doses to patients. The new CTI pathway uses the same 'Normal Dose, High Dose, Renal Dose' categories as our current intermittent dosing hence we could predict from the audit data how many patients can be switched to normal, high or renal dose CTI.

The only exclusion criteria for CTI is if the patient is suitable for step-down from ITU to a ward as wards cannot deliver continuous antibiotic infusions hence the need to switch to intermittent infusions. Our data showed that this was 30% of the patients audited, however this number will vary. Limited ward beds will delay ITU step-downs (and increase this proportion), but when ITU is full step-downs are expedited to improve capacity. It is postulated that all patients when admitted to ITU are critically unwell and thus if initiated on a course of Tazocin it would be preferable in all cases to start CTI in the first instance (given that it has been shown to reduce mortality from sepsis compared to intermittent dosing).

Our analysis of current Tazocin prescription on our units paired with the meta-analysis conclusions allowed us to deduce a likely huge patient outcome benefit of more than 11 lives saved per year from the usage of CTI rather than intermittent dosing.

Emissions calculations for the yearly consumables used for intermittent Tazocin dosing versus CTI showed a clear benefit to the new CTIs as they **saved 1,163 KgCO_2e per year**. The current intermittent dosing pathway produces 2,548.45KgCO_2e per year and the new CTI pathway would produce 1,385,21 which is a 54.36% reduction in the carbon footprint of Tazocin delivery. We acknowledged that due to limitations in the wider literature it had not been possible to calculate the carbon footprint of the actual medication as IV antibiotic emissions calculations are not yet well known (although more information and databases on oral antibiotic emissions are emerging such as the Medicine Carbon Footprint Formulary). As the CTI regime has one more dose of Tazocin in it during the whole week course (an initial loading dose) than the current intermittent dosing regime this may lead to slight over-estimation of the carbon saving. However, we also had to assume all patients receive a full 7-day course of Tazocin. Realistically our standard practice of reviewing antibiotics on day 5 may lead to some Tazocin courses being stopped before 7 days, sometimes they are stopped after a few days due to new microbiological evidence indicating a better antibiotic for that patient and unfortunately some patients pass away before they have had the full 7-day course. This much more common and larger effect on the data would have caused us to under-estimate the

number of patients we currently treat with Tazocin each year (and the number that would be eligible for CTI) hence making our carbon emission savings more likely to be a conservative estimate that may in practice be even larger.

Our economic sustainability benefits were also highly positive. These did include the cost of the extra Tazocin dose given at the start of the CTI regime compared to current practice and due to the significant reduction in consumables required for CTI indicate a **yearly cost saving of £14,764.30.** It is highly encouraging to be able to offer an intervention such as CTI compared to intermittent dosing which will offer a clear patient benefit and likely save live, whilst delivering financial and environmental savings.

It was considered whether having a 24-hour Tazocin infusion running would be a social sustainability burden as it would block a cannula or lumen of a CVC from being used for other medications if they are not compatible. This would increase clinician workload to insert more cannulas and be an extra burden on the critical care nurses. Our pharmacy team advised that 21 medications (many commonly used ones) are compatible to run alongside the infusion which was reassuring.

We also considered if continuous infusion line attachment could hinder physiotherapists from mobilising patients. Due to the safe doses being administered via CTI it can be paused for up to 6 hours and then restarted at a faster rate so that the full infusion still finishes at the expected time. This means it could be paused for physiotherapy or any other intervention where being connected to the infusion line would be burdensome (such as being transferred for a CT scan).

Our IV to enteral switch project has discussed the potential harms of fluid overload to our patient group and the significant volumes of fluid that are given to patients to facilitate administration of intravenous medication. As can be seen from Table 9 we know the number of 100ml and 250ml bags of 0.9% sodium chloride which are needed to deliver each Tazocin regime to patients and we are pleased to report that in the majority of cases CTI presents a reduction in the volume of intravenous fluid delivered which is in line with the principals of our partner project. In all regimes CTI uses 1,850ml of IV fluid to deliver the medication. This is compared to intermittent dosing requiring 2,100ml for normal dose, 2,800ml for high dose and 1,400ml for renal dose. Although there is a 450ml per week increase in the fluid given for renal dose CTI compared to intermittent dosing the option remains to use intermittent dosing if managing the patient's fluid balance is very challenging.

Our audit data showed that only 1.5% of patients on average are on renal dose Tazocin in our ITUs so in most instances this is a reduction in the volume of IV fluid required which is of clinical benefit.

The critical care CTI guideline (which included that sustainability aspects would be considered in the present project) has been reviewed by most clinical teams involved and is in the final stage of approval by the senior hospital team to roll out this new treatment regime as soon as possible to patients.

Conclusions

IV to Enteral switch project

This project identified inappropriate continuation of intravenous medications in critical care patients who were suitable for enteral therapy. Avoidable IV prescribing contributes to increased environmental burden, unnecessary healthcare costs, and potential patient harm associated with intravenous administration. We have demonstrated with our baseline data collection, literature search findings and cost information that we can make a significant financial and environmental change to the operations of both our critical care units at UHCW. This is further highlighted with the reduction in carbon emissions that have been calculated for this project.

Encouraging early transition from IV to enteral medications represents a feasible, low-cost, and sustainable intervention that supports the principles of medicines optimisation and the NHS net zero agenda. Increased clinician awareness, routine medication review, and multidisciplinary stewardship initiatives may help embed more sustainable prescribing practices within critical care settings.

Unfortunately, the project timeline did not allow for sufficient real-time data to be used. However, the drug usage summary reports were suitable to model data.

Further work is needed to quantify the long-term environmental, financial, and clinical impact of these interventions and to ensure that our modelled data has come to fruition by regular review of the drug usage summary reports from the pharmacy team. Overall, this project is in-line with the Faculty of Intensive Care Medicine's drive to become more sustainable.

Tazocin Infusions

We were able to demonstrate a strong likelihood of positive patient impact in our ITUs given the number of patients that we treat each year with Tazocin intermittent dosing and the improved sepsis mortality demonstrated in the literature when CTI is used instead and postulated that it would save at least 11 lives per year in our patient group.

We have shown how this beneficial treatment also represents improved environmental and economic sustainability with a carbon saving of 1,163 KgCO2e per year (a reduction of 54.36% compared to current practice) and a cost saving of £14,764.30. Additional social sustainability benefits were indicated of reduced workload for the critical care nurses with CTIs compared to current practice and reduced frequency of needed 'second checks' (as the medication is started once every 24 hours, not a new administration every 6, 8 or 12 hours) which avoids taking another nurse away from their patient and other tasks as often.

There are clear patient outcome and sustainability benefits from the introduction of CTIs and we have also checked for any potential harms. The medication can easily be paused and disconnected for up to 6 hours if it is precluding pertinent physiotherapy or transfers and reconnected later with the same drug delivery still being provided over that 24 hour period. Furthermore, in most instances it reduces the Tazocin associated fluid volume given to a patient over a week compared to intermittent dosing. In the 1.5% of patients on the renal dose there is a slight increase in fluid volume given but if this makes their fluid balance hard to manage the option for intermittent Tazocin dosing still remains.

Once the CTI guideline has passed the final stages of approval within the hospital we will roll out this beneficial treatment for our patients content with the knowledge that as well as the important mortality benefit it is also providing enhanced environmental, economic and social sustainability.

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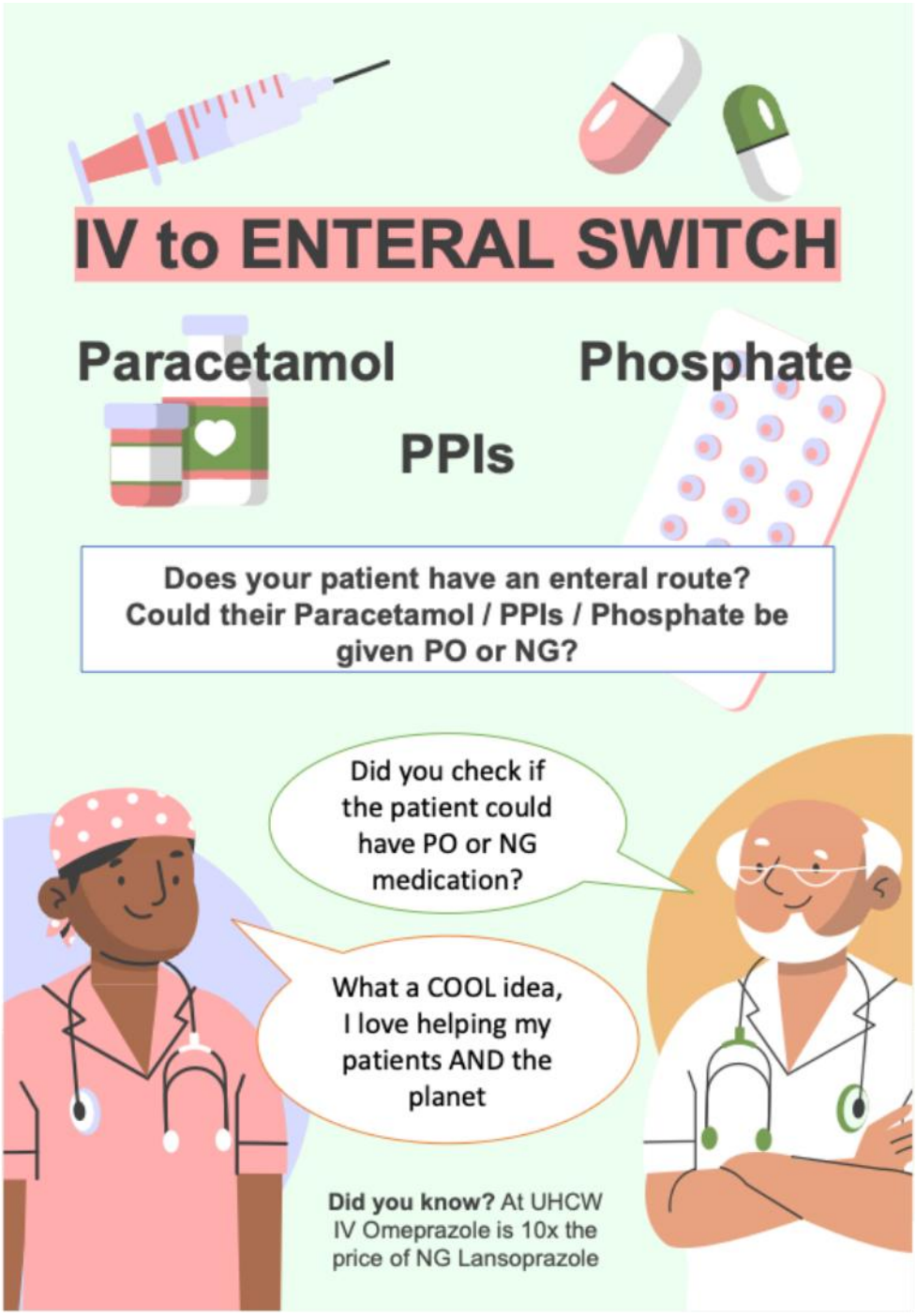
Appendices

Appendix 1: IV to enteral switch poster



Appendix 2: Table: Carbon emissions of consumables used to deliver Tazocin via the 'Normal Dose' regime for current intermittent dose pathway and new CTI pathway.

Normal Dose Patients:			
Current pathway	**Emissions per item**	**Number used per day**	**Total emissions kg CO_2e**
Day 1: 3 X individual 4.5g Tazocin infusions			
1 pair of nitrile gloves	0.0520	3	0.156
1x Tazocin vial (4.5g dose)		3	0
20ml syringe	0.0330	3	0.099
Unfiltered blunt needle (red)	0.0046	3	0.0138
20ml of water for injection (plastic ampules)	0.0466	3	0.1398
100ml 0.9% NaCl Bag for infusion	0.1280	3	0.384
Giving Set	0.09	3	0.27
Alcohol wipe (to clean CVC/cannula port)	0.0328	3	0.0984
Total emissions per day (kgCO_2e)			**1.161**
Total number of days	7 days		
Total (Days 1-7)			**8.127**
New pathway (CTI)			
Day 1: 1X loading dose (4.5g), 1 X 24 hour bag with 3 X 4.5g Tazocin in it			
1 pair of nitrile gloves	0.0520	2	0.104
4x Tazocin vials (4.5g dose)		4	0
20ml syringe	0.0330	2	0.066
Unfiltered blunt needle (red)	0.0046	2	0.0092
20ml of water for injection (plastic ampules)	0.0466	4	0.1864
100ml 0.9% NaCl Bag for infusion	0.1280	1	0.128
250ml 0.9% NaCl Bag for infusion	0.2500	1	0.25
Giving Set	0.09	1	0.09
Alcohol wipe (to clean CVC/cannula port)	0.0328	2	0.0656
Total for day 1			**0.8992**
Day 2-7: 1 X 24 hour bag per day with 3 x4.5g Tazocin in it			
1 pair of nitrile gloves	0.0520	1	0.052
3x Tazocin vials (4.5g dose)		3	0
20ml syringe	0.0330	1	0.033
Unfiltered blunt needle (red)	0.0046	1	0.0046
20ml of water for injection (plastic ampules)	0.0466	3	0.1398
250ml 0.9% NaCl Bag for infusion	0.2500	1	0.25
Giving Set	0.09	1	0.09
Alcohol wipe (to clean CVC/cannula port)	0.0328	1	0.0328
Total emissions per day (kgCO_2e)			**0.6022**
Total number of days		6	
Total emissions days 2-7 (kgCO_2e)			**3.6132**
Total emissions for the week			**4.5124**

Appendix 3: Table: Carbon emissions of consumables used to deliver Tazocin via the 'High Dose' regime for current intermittent dose pathway and new CTI pathway.

High Dose Patients:			
Current pathway	**Emissions per item**	**Number used per day**	**Total emissions kg CO2e**
Day 1: 4 X individual 4.5g Tazocin infusions			
1 pair of nitrile gloves	0.0520	4	0.208
1x Tazocin vial (4.5g dose)		4	0
20ml syringe	0.0330	4	0.132
Unfiltered blunt needle (red)	0.0046	4	0.0184
20ml of water for injection (plastic ampules)	0.0466	4	0.1864
100ml 0.9% NaCl Bag for infusion	0.1280	4	0.512
Giving Set	0.09	4	0.36
Alcohol wipe (to clean CVC/cannula port)	0.0328	4	0.1312
Total emissions per day ($kgCO_2e$)			**1.548**
Total number of days	7 days		
Total (Days 1-7)			**10.836**
New pathway			
Day 1: 1X loading dose (4.5g), 1 X 24 hour bag with 4 x4.5g Tazocin in it			
1 pair of nitrile gloves	0.0520	2	0.104
5x Tazocin vials (4.5g dose)		5	0
20ml syringe	0.0330	2	0.066
Unfiltered blunt needle (red)	0.0046	2	0.0092
20ml of water for injection (plastic ampules)	0.0466	5	0.233
100ml 0.9% NaCl Bag for infusion	0.1280	1	0.128
250ml 0.9% NaCl Bag for infusion	0.2500	1	0.25
Giving Set	0.09	1	0.09
Alcohol wipe (to clean CVC/cannula port)	0.0328	2	0.0656
Total for day 1			**0.9458**
Day 2-7: 1 X 24 hour bag per day with 4 X 4.5g Tazocin in it			
1 pair of nitrile gloves	0.0520	1	0.052
4x Tazocin vials (4.5g dose)		4	0
20ml syringe	0.0330	1	0.033
Unfiltered blunt needle (red)	0.0046	1	0.0046
20ml of water for injection (plastic ampules)	0.0466	4	0.1864
250ml 0.9% NaCl Bag for infusion	0.2500	1	0.25
Giving Set	0.09	1	0.09
Alcohol wipe (to clean CVC/cannula port)	0.0328	1	0.0328
Total emissions per day ($kgCO_2e$)			**0.6488**
Total number of days		6	
Total emissions days 2-7 ($kgCO_2e$)			**3.8928**
Total emissions for the week			**4.8386**

Appendix 4: Table: Carbon emissions of consumables used to deliver Tazocin via the 'Renal Dose' regime for current intermittent dose pathway and new CTI pathway.

Significant Renal Impairment Patients (GFR <20ml/min)	Emissions per item	Number used per day	Total emissions kg CO2e
Current pathway			
Day 1: 2 X individual 4.5g Tazocin infusions			
1 pair of nitrile gloves	0.0520	2	0.104
1x Tazocin vial (4.5g dose)		2	0
20ml syringe	0.0330	2	0.066
Unfiltered blunt needle (red)	0.0046	2	0.0092
20ml of water for injection (plastic ampules)	0.0466	2	0.0932
100ml 0.9% NaCl Bag for infusion	0.1280	2	0.256
Giving Set	0.09	2	0.18
Alcohol wipe (to clean CVC/cannula port)	0.0328	2	0.0656
Total emissions per day ($kgCO_2e$)			**0.774**
Total number of days		7 days	
Total emissions per week ($kgCO_2e$)			**5.418**
New pathway			
Day 1: 1X loading dose (4.5g), 1 X 24-hour bag with 2 X 4.5g Tazocin in it	**Emissions per item**	**Number used per day**	**Total emissions kg CO2e**
1 pair of nitrile gloves	0.0520	2	0.104
1x Tazocin vial (4.5g dose)		3	0
20ml syringe	0.0330	2	0.066
Unfiltered blunt needle (red)	0.0046	2	0.0092
20ml of water for injection (plastic ampules)	0.0466	2	0.0932
100ml 0.9% NaCl Bag for infusion	0.1280	1	0.1280
250ml 0.9% NaCl Bag for infusion	0.2500	1	0.25
Giving Set	0.09	2	0.18
Alcohol wipe (to clean CVC/cannula port)	0.0328	2	0.0656
Total for day 1			**0.896**
Day 2-7: 1 X 24-hour bag per day with 2 X 4.5g Tazocin in it			
1 pair of nitrile gloves	0.0520	1	0.052
2x Tazocin vials (4.5g dose)		2	0
20ml syringe	0.0330	1	0.033
Unfiltered blunt needle (red)	0.0046	1	0.0046
20ml of water for injection (plastic ampules)	0.0466	2	0.0932
250ml 0.9% NaCl Bag for infusion	0.2500	1	0.25
Giving Set	0.09	1	0.09
Alcohol wipe (to clean CVC/cannula port)	0.0328	1	0.0328
Total emissions per day ($kgCO_2e$)			**0.5556**
Total number of days		6	
Total emissions days 2-7 ($kgCO_2e$)			**3.3336**
Total emissions per week ($kgCO_2e$)			**4.2296**

Critical success factors

Please select one or two of the below factors that you believe were most essential to ensure the success of your project changes.

People	**Process**	**Resources**	**Context**
☐ Patient involvement and/or appropriate information for patients - to raise awareness and understanding of intervention ☐ Staff engagement ☐ MDT / Cross-department communication ☐ Skills and capability of staff ☐ Team/service agreement that there is a problem and changes are suitable to trial (Knowledge and understanding of the issue) ☐ Support from senior organisational or system leaders	☐ clear guidance / evidence / policy to support the intervention. ☐ Incentivisation of the strategy – e.g., QOF in general practice ☐ systematic and coordinated approach ☐ clear, measurable targets ☐ long-term strategy for sustaining and embedding change developed in planning phase ☐ integrating the intervention into the natural workflow, team functions, technology systems, and incentive structures of the team/service/organisation	☐ Dedicated time ☐ QI training / information resources and organisation process / support ☐ Infrastructure capable of providing teams with information, data and equipment needed ☐ Research / evidence of change successfully implemented elsewhere ☐ Financial investment	☐ aims aligned with wider service, organisational or system goals. ☐ Links to patient benefits / clinical outcomes ☐ Links to staff benefits ☐ 'Permission' given through the organisational context, capacity and positive change culture.