Antibiotic underdosing and disposal in NHS organisations across Great Britain

Research Report & Policy Brief

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Glossary

Abbreviation	Definition
ABPI	Association of the British Pharmaceutical Industry
AMR	Antimicrobial resistance
BSAC	British Society for Antimicrobial Chemotherapy
CQC	Care Quality Commission
DHSC	Department for Health and Social Care
DRI	Drug Resistant Infection
HIS	Healthcare Improvement Scotland
HIW	Healthcare Inspectorate Wales
IMG	Injectable Medicines Group
IV	Intravenous
NHS	National Health Service
NIVAS	National Infusion and Vascular Access Society
OPAT	Outpatient Parenteral Antibiotic Therapy
UK	United Kingdom

Executive summary

This report summarises the findings arising from a comprehensive study of antibiotic 'line flushing' and disposal practices in NHS organisations across Great Britain.

'Line flushing' is the act of pushing an appropriate diluent, such as saline, through the tubing connecting patients with infusion bags which contain medicines. Up to 1/3rd of the total dose prescribed by clinicians can remain sequestered in un-flushed tubing, resulting in patients receiving too little of the antibiotic they need to fight infection. This acts as a driver for antimicrobial resistance (AMR), potentially making patients more susceptible to future drug-resistant infections (DRIs) with their associated morbidity, mortality, and costs to the NHS.

In this report, we find that fewer than 1 in 3 (29.1%) responding NHS organisations across Great Britain have an antibiotic line flushing policy.

Of these, only a minority (43.8%) are fully compliant with their own policies.

This means that, overall, only 12% of NHS organisations in Great Britain—fewer than 1 in 8—are fully compliant with their own established antibiotic line flushing policies.

Fewer organisations still have audited compliance in a measurable way: only 1 in 20 (5.1%) responding NHS organisations have done so.

We find that Scotland leads the way in designing and implementing antibiotic line flushing policies, followed by Wales, with English NHS organisations trailing behind.

In addition, we find that a large number of NHS organisations who do not engage in line flushing dispose of antibiotics inappropriately, such as in unsealed containers (e.g. medical waste bags).

From pre-existing contact with frontline health workers, we have found that the practice of pouring remaining antibiotic down the sink is

commonplace. This leads to the exertion of an AMR selective pressure in the hospital effluent and further downstream, in waterways and wastewater treatment plants. However, as such a practice contravenes hospital waste policies, we did not directly survey this as we expected results to be uninformative. Instead, we chose to focus on the approved routes of disposal, such as sealed *vs* unsealed containers. Disposal in unsealed containers may allow for the escape of antibiotic vapours and contamination of wards with aerosolised antibiotic mixtures—as has previously been shown in antibiotic formulation preparation areas.

We find that a substantial proportion of NHS organisations in Great Britain dispose of administration sets in unsealed containers such as medical waste bags.

In addition, we find that a small minority of NHS organisations in Great Britain (up to 17.3%) do so without separating the spike from the administration set, against organisational policies to dispose of spikes in sharps bins and thus potentially causing occupational hazards.

These findings lead us to suggest a set of 5 policy recommendations:

1. **That all NHS organisations implement line flushing policies by late 2024, with support from the Department for Health and Social Care**
2. **That national regulators integrate adherence to line flushing policies into their assessment framework when assessing hospitals**
3. **That Government funds be made available to enable research into underdosing's impact on DRIs and environmental AMR**
4. **That comprehensive training be provided to all appropriate staff surrounding how to dispose of antibiotics appropriately**
5. **That hospitals monitor environmental antibiotics contamination, both in effluent and on wards**

The Office of Baroness Bennett will continue to engage appropriate stakeholders on these issues, with a view to reduce antibiotic underdosing. This will improve patient care, safety, and long-term risks of further development of antimicrobial resistance.

Lay summary

The primary issue that this report considers is that patients are not getting the complete dose of antibiotics that they are prescribed, and that these drugs are often disposed of inappropriately. In the long term, this can cause more people to become infected with drug-resistant infections, or 'superbugs'.

In some areas of care, like cancer or children's wards, there are strict rules about making sure that patients receive the complete dose that a doctor prescribes. However, for adults receiving antibiotics intravenously (1 in every 3 hospital patients at any given time), there are often no specific rules in place. These patients therefore receive too small a dose of antibiotics—which is called 'underdosing'.

Underdosing can happen for a few reasons. The main reason is linked to the design of intravenous administration sets (the tubes and bags used to get drugs into a patient's veins). When the bag of liquid is small and the tube (or 'line') is long, up to 33% of the drug-containing liquid in the bag never makes it into the patient. It stays stuck in the 'line'. In some medical specialties like cancer care, healthcare workers are very careful to not leave any drug in the line, because the drugs are expensive and giving too little could mean the desired impact is not achieved. To make sure patients get the complete dose as prescribed, they 'flush the line', that is, push more liquid into the tube to ensure all drugs within the line are administered to the patient. This guarantees that the patient receives the complete amount of drug they need. Unfortunately, flushing the line is not standard practice in other parts of NHS hospitals.

We wanted to find out how many hospitals have specific rules and regulations (policies) around flushing patients' lines when they give adults antibiotics. We sent out Freedom of Information (FOI) Requests to every NHS acute organisation in Great Britain, asking them a set of questions to help us understand whether they have policies in place. **Our results show that about 70% of NHS organisations don't have any policies in place to make sure patients are receiving the complete dose of antibiotics**.

Almost none of those that do have policies have checked that they are being followed. Many hospitals also get rid ('dispose') of the antibiotics trapped in lines inappropriately, such as by pouring antibiotics down the sink or discarding them into containers that allow antibiotic vapour to seep out.

When antibiotics enter the environment they apply a 'selective pressure', that is, they kill bacteria which are sensitive but do not kill bacteria which are inherently resistant to that antibiotic. This creates a pool of superbugs in the environment which can ultimately lead to more hard-to-treat infections.

Because hospitals do not have policies telling nurses and other frontline staff to flush lines, we should not blame any particular individual or set of individuals. Instead, we must recognise that this is a systemic issue that needs to be broadly addressed across the NHS.

Based on our results, we call for small but meaningful changes throughout the healthcare system, to make sure that every NHS organisation puts in place line flushing and antibiotic disposal policies and monitors their adherence. These changes will ensure that patients receive the correct dose of antibiotics, and that these drugs don't find their way into nature. This will keep patients as safe as possible now and in the future, by reducing the development of superbugs.

We also call on the hospital care regulators in England, Wales, and Scotland to start checking whether an NHS organisation has a line flushing policy in place as part of their overall assessment of how well that organisation is doing. We hope that this report and the results presented will help people all around the UK, not only by ensuring that patients of today get the right dose of antibiotics, but also by preventing the development of superbugs that could infect any one of us tomorrow.

Foreword: Baroness Bennett of Manor Castle

I am delighted to present the latest research report and policy brief published by my Office. The topic of antibiotic underdosing has not received the attention it is due. I am proud that we have been able to gather such robust and detailed data investigating antibiotic underdosing across Great Britain.

This issue cuts across a number of subject areas which I am passionate about: the safety of frontline healthcare workers and their right not be exposed to medicines in the workplace; waterway pollution; the rising tide of antimicrobial resistance, now recognised as a 'grand pandemic'; and the broad issue of the impact of 'novel entities', the level of which has exceeded the planet's capacity to cope.

Based on the data we have gathered and the results we have presented, we hope that relevant stakeholders will step up and empower NHS organisations to design and implement antibiotic line flushing policies. We also hope that they will encourage regulators to monitor adherence and implementation as part of their assessment of care quality.

The publication of this report, while hopefully a landmark in bringing attention to this issue, is not an end in itself. I will continue advocating for concrete action in this area until either this or a future administration enacts change.

Introduction

AMR and DRIs

Antimicrobial resistance (AMR) is a natural phenomenon whereby a micro-organism becomes less sensitive, or entirely insensitive, to compounds which previously killed it or inhibited its growth.[1] For instance, bacteria becoming able to tolerate a dose of antibiotic which would previously have killed them is an example of AMR.

From a human perspective, AMR directly results in drug-resistant infections (DRIs); these are infections which are more difficult or impossible to treat with antibiotics used to date. AMR is as old as micro-organisms themselves and arises from the natural genetic variation in micro-organisms. It is important to understand that AMR is not directly caused by human actions like using antibiotics—merely exacerbated.

Currently the oldest antimicrobial resistance genes identified, found in bacterial samples preserved by permafrost, date back 30,000 years.[2] There are many other observations of antimicrobial resistance which pre-date the widespread use of antibiotics. Genes which cause AMR have been found in a range of ancient samples including mummified remains and permafrost.[3–6] This serves to prove that, while AMR has been anthropogenically exacerbated, it was not first brought about as a result of humans using antibiotics for modern medicine.[7]

However, our overuse and misuse of antibiotics has made bacterial AMR more prevalent. There are more drug-resistant infections now than ever before. In the UK, DRIs already cost the NHS ~£1 billion annually.[8] Globally, bacterial DRIs directly kill ~1.3 million people each year—more than the population of Birmingham.[9] More broadly, these infections are associated with ~5 million total deaths worldwide, of which 1 in 5 are children under 5 years of age.[9]

There are many drivers of AMR which ultimately lead to more DRIs. These are outlined in Figure 1.

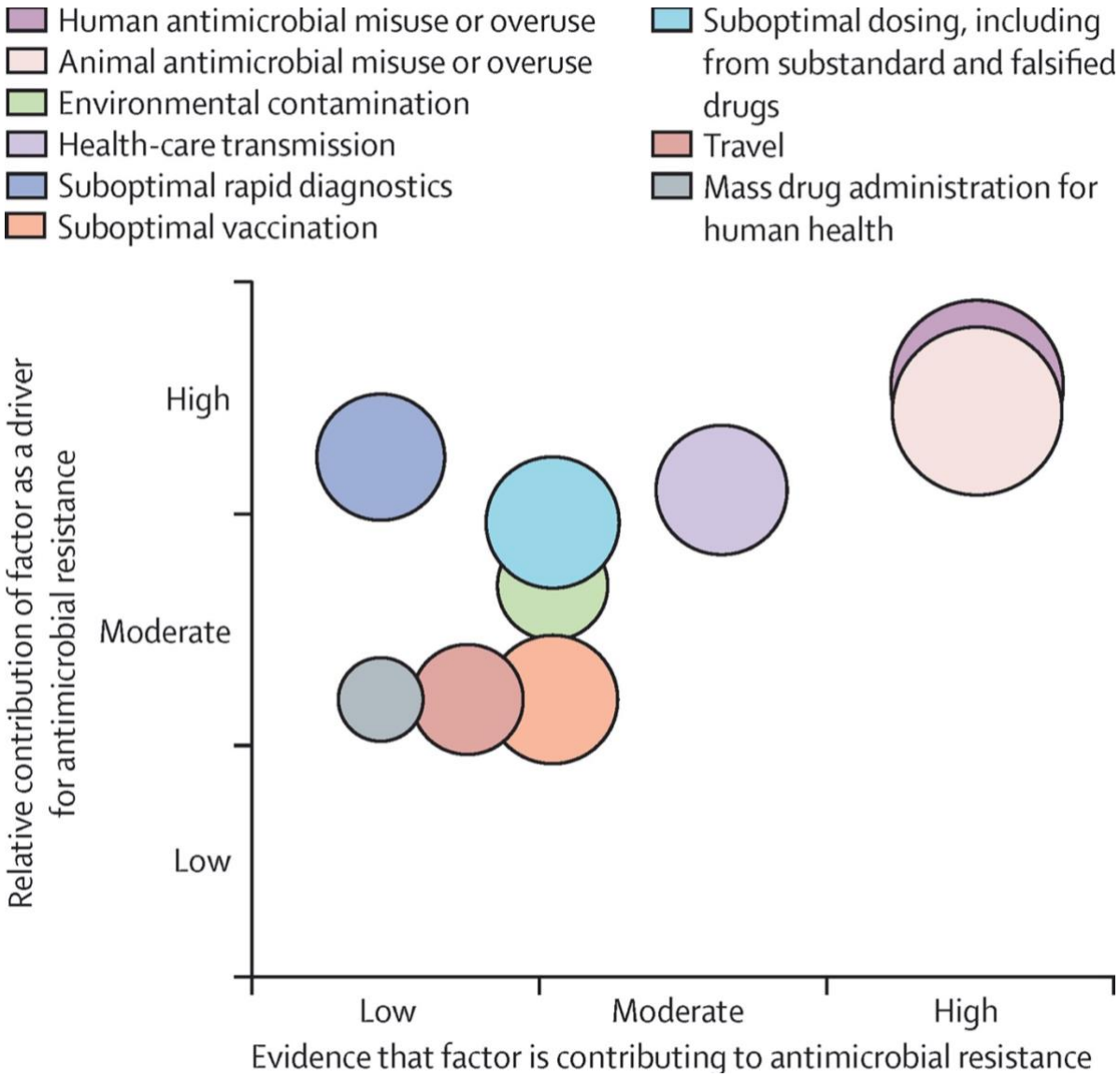


Figure 1: A conceptual framework to identify the relative role of drivers of AMR. Bubble size is proportionate to potential population affected. Reproduced with permission of the copyright holder from Holmes et al (2016).[10]

The relevant AMR drivers considered in this work are the overuse and misuse of antibiotics in human medicine, suboptimal dosing, and environmental spread of AMR through pharmapollution. Reducing the antibiotics used in hospitals and disposed of incorrectly is a crucial strategy for driving down DRIs.

As far as the work herein is concerned, misuse and suboptimal dosing of antibiotics are two sides of the same coin. Indeed, one type of antibiotic misuse is the incomplete administration of an appropriate antibiotic. If patients do not receive the full course they have been prescribed, no matter how carefully the antibiotic has been selected to address the disease, the antibiotic can be said to have been misused.

Underdosing

'Underdosing' is the term used to describe the incomplete administration of a drug to a patient. Ensuring that patients receive the full amount of a drug that they have been prescribed is a fundamental part of healthcare and is widely understood to be a key priority for staff charged with administering intravenous drugs to patients.[11] Failure to ensure complete administration can lead to treatment failure as an immediate worst case scenario and, for some drugs, can have dangerous long-term consequences.[12] Underdosing of antibiotics is particularly concerning because it results in bacteria being exposed to 'subtherapeutic concentrations of antibiotic' and 'drives resistance'.[13] This results in a selective pressure being applied within the patient, which favours the survival of bacteria harbouring AMR genes. Thus, underdosing can directly contribute to hard-to-treat DRIs.

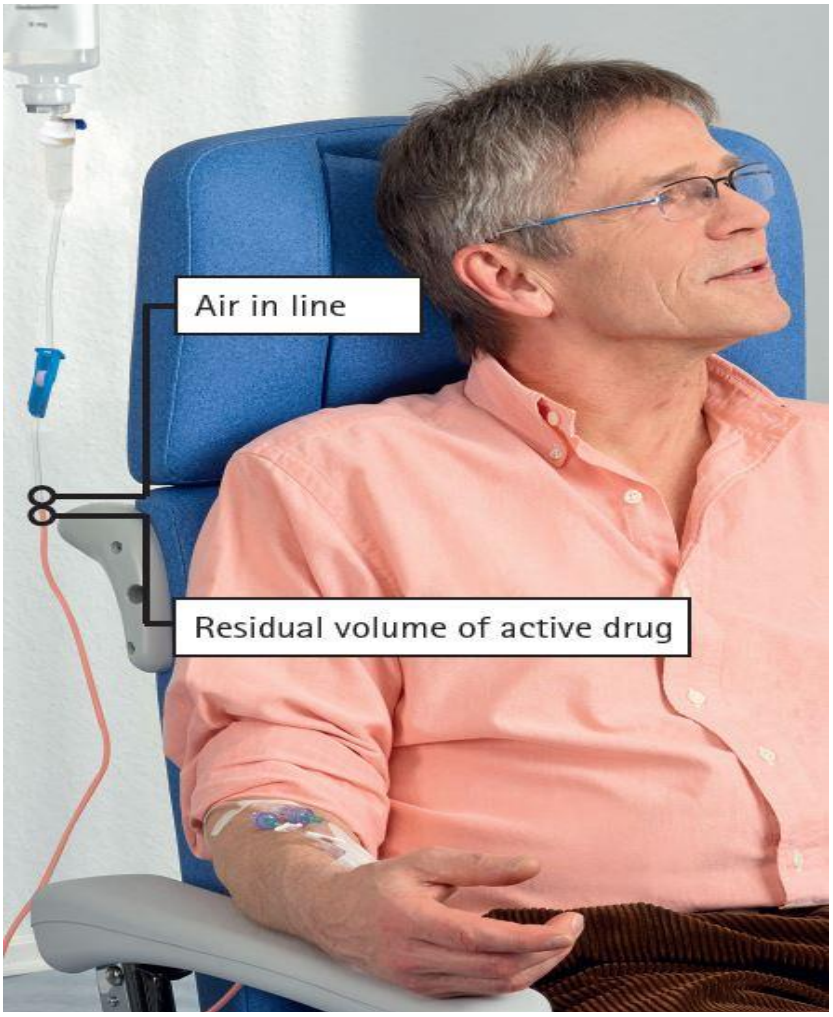


Figure 2: Illustration of the standard set up of an administration set used for intravenous infusions. Reproduced with permission from B Braun Medical Ltd.

Underdosing can occur for many reasons, but the one most relevant to the work herein is the way in which we administer intravenous ('IV') drugs. When a patient requires IV drugs, antibiotic or otherwise, these can be administered in two ways: as a single dose contained in a syringe (known as a 'bolus'), administered as an injection; or as an intermittent dose contained in an infusion bag, administered through a giving set over a defined period. Figure 2 illustrates the latter method of administration. It has long been recognised that bolus administration can result in underdosing if medication remains in the cannula following administration. Hence, there has been UK-wide guidance for nurses to 'flush' this cannula by injecting a small volume of an appropriate diluent after the drug since at least 2006.[12]

Surprisingly, despite the much larger volume of tubing (known as 'lines') involved in drug administration by infusion, guidelines for line flushing were only very recently published. One driving factor behind the creation of these guidelines was the identification by NHS England of a 'risk of harm due to under dosing when the administration of small volume infusions is not followed by a flush'.[14] There are now guidelines from several UK organisations, with recommendations on how to address this issue as outlined below.

The Royal Marsden Manual of Clinical Nursing Procedures, Tenth Edition, Chapter 15:

> *'After completion of an intermittent infusion, an appropriate diluent solution should be administered via the administration set. This is to ensure the full dose of medication has been administered to the patient.'*[15]

The 'Medusa' injectable medicines guide instructions on how to administer intermittent infusions:

> *'Flush the administration set before it is disconnected with sufficient volume of sodium chloride (or compatible diluent) to ensure the total dose is given. Flush at the same rate the medicine was administered.'*[16]

The National Infusion and Vascular Access Society (NIVAS) 'Intravenous Administration of Medicines to adults: Guidance on 'line flushing' Version 3 2021':

''At the end of the infusion, the medicine remaining in the infusion set should be flushed with sodium chloride 0.9% or other compatible diluent, using one of the methods described below.''[17]

These guidelines seek to help ensure that practitioners 'flush the line' of the administration set, thus ensuring that all active pharmaceutical ingredients from the tubing have been administered to the patient. This is because lines can represent a large volume relative to the infusion bag.

As such lines can, and do, trap a substantial proportion of the drug, leading to underdosing. Several national and international studies have aimed to quantify how much drug is leftover in tubing following IV administration of a drug to patients; while figures vary, Table 1 displays the most striking results from studies on antibiotics, which range from 14% to over 33%:

Authors/ Citation	**Location/Department**	**Greatest % of antibiotic discarded (mean or median)**
MacLachlan *et al* (2020)[18]	Hull University Teaching Hospitals NHS Trust Outpatient Parenteral Antimicrobial Therapy (OPAT) team	14.6
Cooper *et al* (2018)[12]	'Large teaching hospital in the UK'	20.8
Plagge *et al* (2010)[19]	University Hospital Basel, Switzerland	32.2
Harding *et al* (2020)	Various hospitals, Ohio, USA	33.5*

*Table 1: Non-exhaustive list of discarded antibiotics doses in the UK. * = theoretical drug loss inferred from volume loss, performed under laboratory conditions.*

Underdosing is an issue beyond the immediate concerns of treatment failure and long-term concerns of AMR: it entails unnecessary costs to the taxpayer. Over 1 in 3 NHS patients is on antimicrobials at any given time;[20] as such, every wasted dose has an associated cost and these costs can quickly become substantial.

MacLachlan *et al* (2020) calculate an **average cost per wasted antibiotic dose of £9.09**, with approximately 1,536 doses wasted per year from underdosing.[18] This amounts to almost £14,000 in losses from underdosing in the OPAT department alone for Hull University Teaching Hospital NHS

Trust, every single year.[18] These numbers were likely skewed upwards because of the inclusion of dalbavancin, a very costly antibiotic. A re-analysis of data from Goodyear et al (2022) indicates **weighted mean costs of £1.29 per wasted antibiotic dose**, resulting in total costs of nearly £11,186 per year across two surgical wards at Salisbury District Hospital.[21] Other unpublished data from an English hospital, in addition to the latest figures from an NHS Wales organisation, indicate costs much closer to the Salisbury data: **on the order of £1—2 per wasted antibiotic dose**, as opposed to the almost £10 figure from the Hull study.

Resolving this issue more widely across departments and across NHS organisations is therefore a low-tech, easy to implement way to save the NHS money while improving patient care.

It is also important to understand that antibiotic underdosing drives AMR in another, less obvious way than through insufficient doses reaching the patient. It is often the case that when drugs remain in a line after administration, this tubing is discarded in conventional waste bags for incineration. However, as liquid waste and sharps are not allowed in conventional incineration bags, the spike is sometimes cut off by nursing staff and disposed of in a sharps bin. The liquid contained in the line is then disposed of either by pouring it down the sink or discarding it into a waste bag—as attested by frontline staff in NHS organisations across the country.

In both of these cases, more than 30% (per Table 1) of any given dose of active antibiotic is discarded, without ever going through a patient.

The active antibiotic either passes into hospital effluent, directly contaminating the environment, or is discarded in a plastic waste bag where it can permeate into the hospital environment via vapours. This has serious consequences for AMR in the environment.

Environmental AMR

It is widely recognised, under the 'One Health' paradigm that human health is intricately linked to environmental and animal health.[22] As shown in Figure 1, environmental contamination is almost as strong a driver of AMR as suboptimal dosing.[10] Incomplete administration, resulting in underdosing and inappropriate disposal of antibiotics, contributes to both,

as illustrated by Figure 3. There is therefore a strong motivation to understand the current NHS-wide policy landscape at an organisational level when it comes to flushing lines and disposing of antimicrobial-laden tubing.

When antibiotics are disposed of incorrectly, e.g., poured down the sink, they are diluted by the rest of the hospital's effluent. This gives rise to sub-inhibitory concentrations in the effluent pipes, and in the waterways downstream of these pipes. The presence of sub-inhibitory concentrations of antimicrobials in the environment creates a selective pressure, which favours the survival and reproduction of bacteria harbouring AMR genes. Improper disposal of antibiotics and contamination of wastewater thus gives rise to an environmental reservoir of AMR organisms and genes. [23,24]

Reported concentrations downstream of hospitals are among the highest detected, other than pharmaceutical manufacturing plants. Several high-quality studies from Germany, Spain, and China have demonstrated substantial quantities of antibiotics in hospital effluent, which are not effectively removed by wastewater treatment plants.[25–27]

It has long been noted that wastewater treatment plants are not suited to removing antimicrobials from our water.[28,29] No infrastructure currently in place anywhere was conceived with the sequestration of small molecules in mind. A response from His Majesty's Government to a Question for Written Answer does not indicate any plans in the UK to retrofit existing infrastructure with this capability. Furthermore, wastewater treatment plants regularly engage in 'bypass' (the release of untreated sewage into the environment), and heavy rainfall can lead to combined sewer overflows which also result in untreated sewage release.[30]

It is therefore imperative to understand how liquid antibiotic waste in un-flushed lines is disposed of, to establish the scale of the issue and help inform guideline development and practice.

There is also mounting concern about the release of vapours from drugs into the atmosphere. Work on drug vaporisation was pioneered initially because of concerns over healthcare worker exposure to aerosolised cytostatic drugs (such as cancer chemotherapy), which can have grave health effects even at very low concentrations. Aerosolised drugs can also deposit on surfaces, multiplying the routes of exposure for frontline

healthcare workers. Although, unlike cytostatic drugs, antibiotics do not cause direct harm (aside from allergy concerns), repeated daily exposure to aerosolised antibiotics could plausibly lead to increased risks of DRI in the future.

Work by Kiffmeyer *et al* (2002) demonstrated that it is theoretically possible for antibiotic aerosol contamination to occur (based on vapour pressures and particle size).[31] A seminal continuation of this work by Sessink *et al* (2019) demonstrated the extent of contamination by key antibiotics upon drug preparation in three countries, using both closed and open drug preparation systems. The average rate of contamination by all antibiotics considered ranged from 71% to 88% of surfaces tested when preparing drugs in the conventional way (as is done by most NHS Trusts currently).[32]

There is another unexplored potential avenue of antibiotic exposure for frontline healthcare workers: vapours from antibiotics discarded into clinical waste bags for incineration. As these are unsealed containers, they do not prevent vapours from escaping, and hence it is possible that the ward atmosphere may become contaminated with antibiotic vapours.

It is therefore paramount to ensure that lines are flushed, to reduce AMR selective pressures applied at multiple levels (see Figure 3).

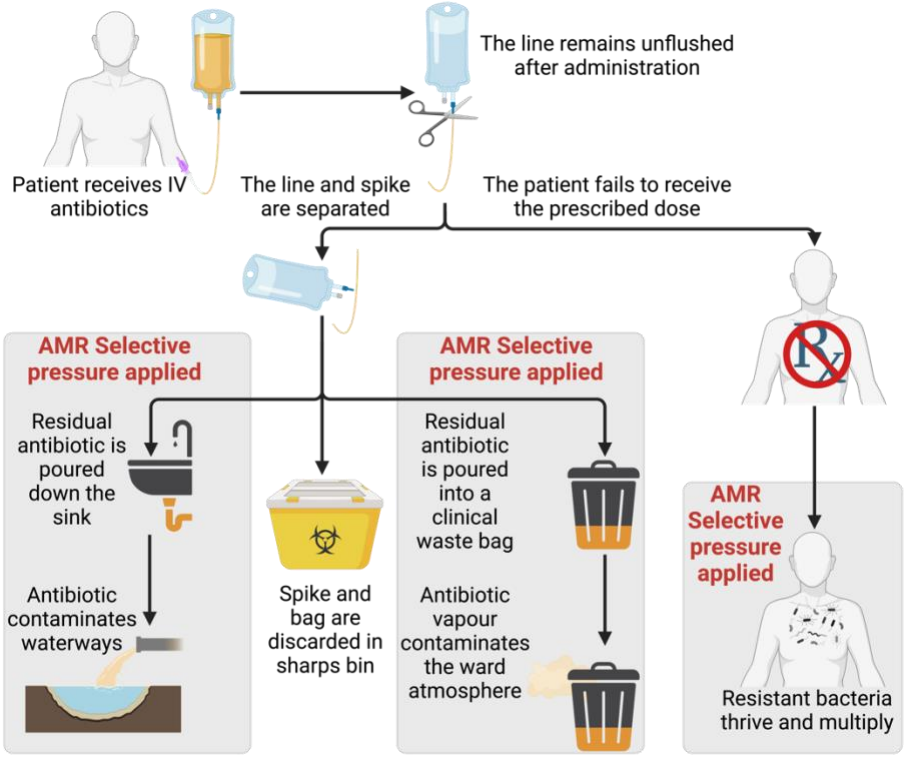


Figure 3: Illustration of the pathways by which underdosing contributes to AMR. Made with BioRender.

Aims of the project

This project aims to establish the following, as regards the administration sets used to infuse IV antibiotics, for every NHS organisation involved in acute care throughout Great Britain:

1. **Whether each organisation has a policy to flush administration sets to give the correct dose of antibiotics** in accordance with guidance from professional bodies for example NIVAS, Royal Marsden, or Medusa guidelines.
   If so, whether each organisation is fully compliant with its 'line flushing' policy, and what line flushing method each one has chosen to employ.

2. **Whether each organisation audits compliance with its policy to flush the administration sets, and if so, the results of this audit.**

3. **What education measures each organisation has put in place to ensure its healthcare professionals understand: the existing guidance around flushing the residual volume of IV antibiotics; the patient risks involved with failing to do so; and the possible consequences for AMR.**

4. **What is each organisations policy regarding disposal of administration sets and residual volume of either the prescribed antibiotic or flushing solution?**

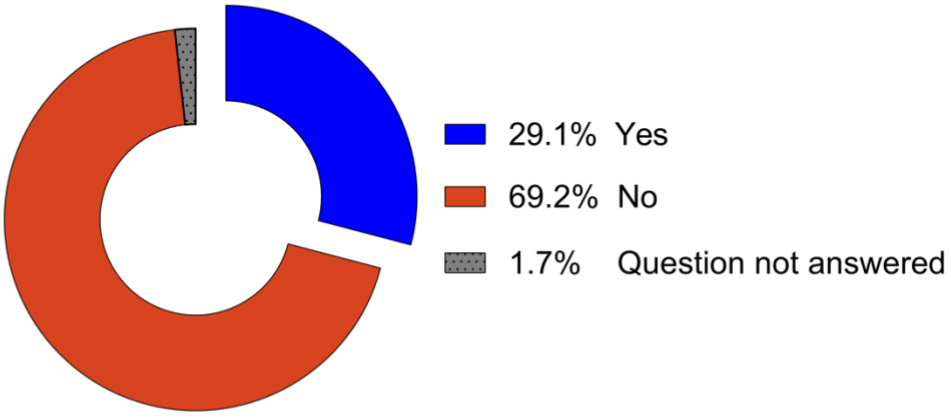
Data were collected through a Freedom of Information Request sent in Summer 2023. Data reflect responses as of November 2023.

Results

Approximately 70% of NHS organisations in Great Britain have no antibiotic line flushing policy

1a. With regards to administration sets (pump and gravity) used to infuse IV antibiotics, does your institution have a policy to flush the administration set to give the full dose of antibiotics in accordance with guidelines?

Just those that responded:



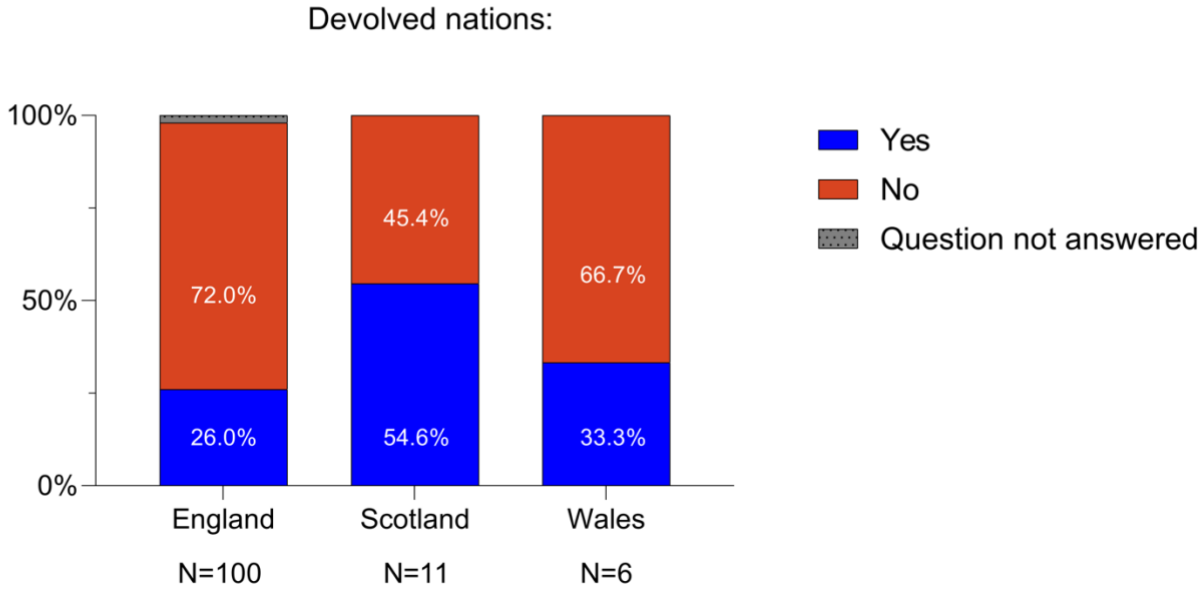
N=117

All of Great Britain

Only 29.1% of the 117 NHS organisations who responded to the Freedom of Information Request by 2023-11-01 have a line flushing policy for IV antibiotics. Given the aforementioned figure of 1 in 3 patients being on IV antibiotics at any given time, this must necessarily entail underdosing on a massive scale in Great Britain. **These results should prompt a serious questioning of regulatory norms in the NHS.**

Scotland leads Great Britain in establishing and implementing antibiotic line flushing policies

1a. With regards to administration sets (pump and gravity) used to infuse IV antibiotics, does your institution have a policy to flush the administration set to give the full dose of antibiotics in accordance with guidelines?

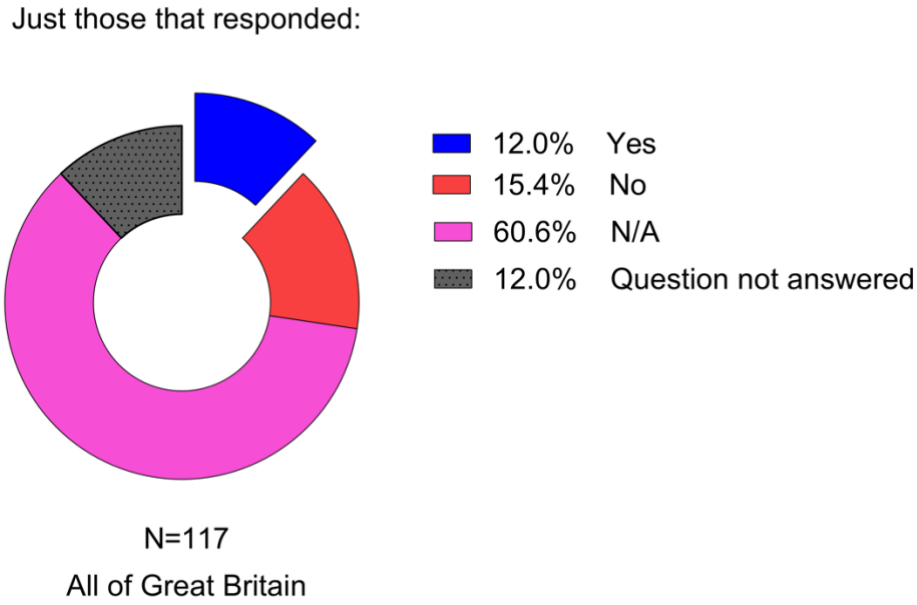


Country-level data shows that there is a heterogeneous distribution of line flushing policies in NHS organisations across the Home Nations. Scotland leads in this field, with over 1 in 2 (54.6%) responding organisations stating that they have an antibiotic line flushing policy in place. In Wales, 1 in 3 (33.3%) responding organisations indicated that such a policy was in place. English NHS organisations lag yet further behind Scotland: only ~1 in 4 (26.0%) report having an antibiotic line flushing policy.

English and Welsh NHS organisations should therefore seek to engage with their Scottish counterparts, to understand how they might design, implement, and audit antibiotic line flushing policies.

Of the 30% of NHS organisations that do have a policy, fewer than half are fully compliant with their own policy

1b.If yes to question 1a, is your organisation fully compliant with your policy to flush the administration set to give the full dose of antibiotics in accordance with guidelines?



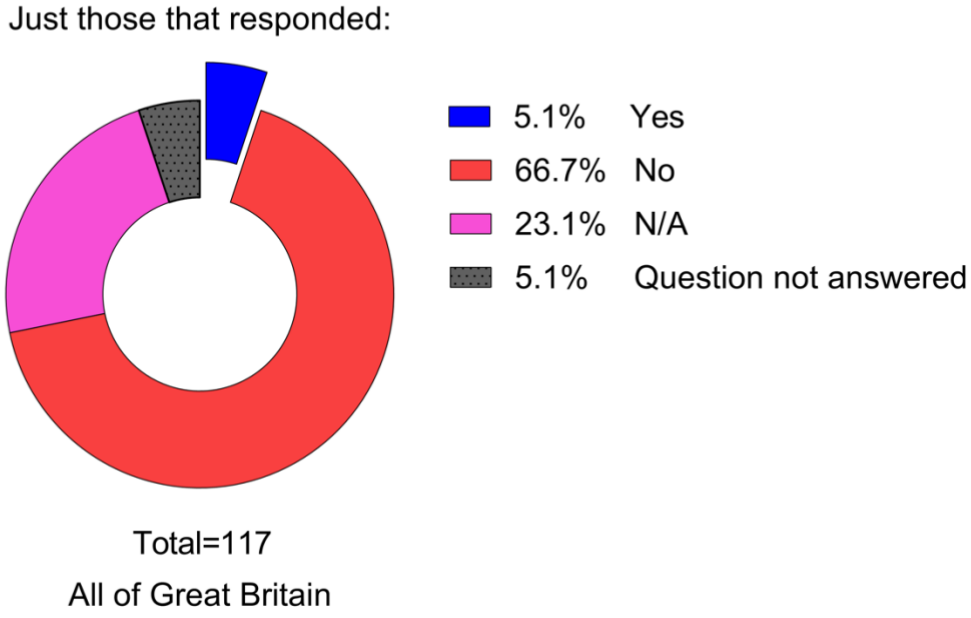
Overall, only ~1 in 8 (12.0%) responding NHS organisations have stated that they not only have an antibiotic line flushing policy, but that they are fully compliant with it.

However, it is important to take into account that most NHS organisations do not have a policy in place. Therefore, considering only those NHS organisations which provided a 'Yes' or 'No' response, fewer than half (43.8%) of those NHS organisations with a line flushing policy are fully compliant with it.

These results highlight how widespread and unaddressed line-flushing-based underdosing is as an issue within the NHS.

Of the hospitals that do have a line flushing policy, almost none audit the compliance with this policy

2a. With regards to administration sets (pump and gravity) used to infuse IV antibiotics, if you do have a policy in place to flush the administration set, have you audited compliance with this policy?



Only 5.1% of all NHS organisations who responded to the Freedom of Information Request indicated that they actively audit and monitor compliance with their own line flushing policies. As this is less than the number stating that they are not compliant, some NHS organisations must necessarily, without an audit, know that they are non-compliant with their own policies.

This indicates that there is an awareness and understanding of the importance of line flushing in underdosing. Despite this awareness, proactive steps are not taken to ensure compliance. **Thus, the relevant national care regulators should ensure compliance to these policies for patient safety.**

Many hospitals are in the process of implementing line flushing policies

One heartening finding is that several NHS organisations have clearly realised the importance of line flushing for IV antibiotic use and are in the process of changing internal policies.

Nine organisations specifically reported that they were already in the process of creating flushing policies, with responses such as:

> *'There is a group being set up with nursing and pharmacy representation to develop [name of NHS organisation] specific guidance in relation to flushing.'*

In addition, the act of receiving and responding to our Freedom of Information Request spurred action in at least four NHS organisations:

> *'Historically the Trust has accepted loss in line, though in light of the NIVAS infusion document – this will be altered moving forward…'*

> *'We don't currently teach how to flush giving sets. I wasn't aware that this was required. I will review our policies and training accordingly.'*

> *'We have currently no education in place. We will work alongside the Practise [sic] Education Facilitators (PEFs) and the IV team to put together a policy and training.'*

'Nothing is currently covered [in training] with regards to AMR. This will be reviewed for potential inclusion going forward.'

A very commonly occurring theme (18 respondents) in free-text responses was that **NIVAS, Royal Marsden and Medusa flushing guidelines are not fully implemented within NHS organisations, but that nursing staff are encouraged to follow them,** and they are referenced in other related policies, e.g.:

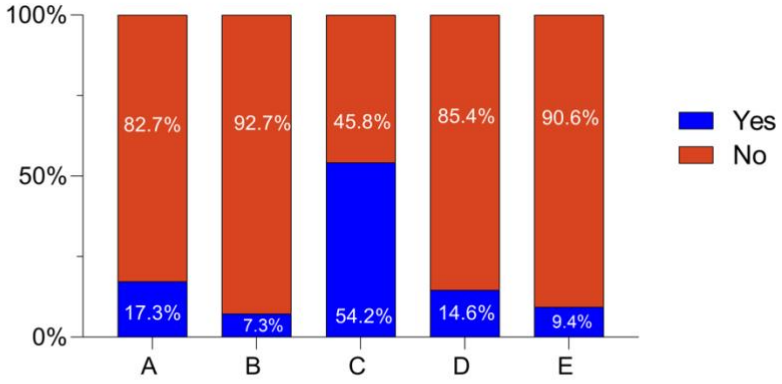
'Staff who have attended the [IV] study day were taught to flushing [sic] through giving sets containing drugs (antibiotics) as per the NIVAS guidance 2021. This method of flushing is also mentioned within the elearning [sic] module…'

'Whilst we follow the Royal Marsden guidance and incorporate into teaching practice the new NIVAS guidance has yet to be implemented across the organisation.'

While all of the above indicates a welcome cultural shift among these organisations, the wider pattern of free-text responses to our consultations mirrored the quantitative data described above. **A significant number of NHS organisations responded that they do not have a policy to flush administration sets, and made no mention of an intention to create such a policy.**

One of these organisations stated that there was limited evidence that flushing provided any clinical benefit. A logical analysis of the basis for clinical practice would indicate that the onus is on practitioners who wish not to flush lines to prove that underdosing a patient by up to 30% is safe, as opposed to having to prove that giving a patient their full dose as prescribed provides a clinical benefit.

Many NHS organisations dispose of waste in inappropriate ways, which might also promote AMR selective pressures



All of Great Britain, just Yes and No responses:

A. Complete administration set (including drip chamber and sharp) is disposed of in a **yellow bag**. (n=98)

B. Complete administration set (including drip chamber and sharp) is disposed of in a **orange bag**. (n=96)

C. Complete administration set (including drip chamber and sharp) is disposed of in a **sharps bin**. (n=96)

D. Drip chamber/sharp are detached from the administration set line and the drip chamber/sharp are disposed of in a **sharps bin** whilst the rest of the administration set is disposed of in a **yellow bag**. (n=96)

E. Drip chamber/sharp are detached from the administration set line and the drip chamber/sharp are disposed of in a **sharps bin** whilst the rest of the administration set is disposed of in a **orange bag**. (n=96)

Over half (54.2%) of responding NHS organisations indicated that the complete administration set was disposed of in a sharps bin. This is likely the safest and most effective method of disposing of administration sets, as it means that the spike does not need to be separated from the line. This means that it is impossible for the remaining antibiotic solution to be poured down the sink.

It is surprising to note that up to 17% of responding NHS organisations dispose of spikes in clinical waste bags as opposed to dedicated sharps bin. This may cause occupational hazards for those handling waste. Another occupational hazard, though with a less solid evidence base, is the disposal of antibiotic-laden administration sets into unsealed containers, which all responding organisations indicated they did.

Recommendations

Based on our findings, we recommend the following five changes to national and local policies:

1. That all NHS organisations implement line flushing policies by late 2024, with support from the Department for Health and Social Care (DHSC)

Though it is heartening to see that many NHS organisations were reviewing their policies at the time of survey, it is striking that almost 70% of organisations did not yet have a policy in place as of November 2023. The risks and costs associated with underdosing are clear, and this should therefore be addressed as soon as possible.

We recommend that every NHS organisation put in place a line flushing policy, complete with a regular audit schedule, by the end of 2024.

As existing policies are in place at 30% of organisations, peer-to-peer knowledge exchange can be employed to help achieve this result at pace. There is a role for DHSC to facilitate this exchange, by leveraging its considerable convening power.

We therefore further recommend that DHSC help stimulate a cultural shift towards full implementation of, and adherence with, line flushing policies, to drive down underdosing.

DHSC should encourage relevant cross-sectoral stakeholders to engage with this process and support organisations in their transition. This could include NIVAS, the Injectable Medicines Guide (IMG) multidisciplinary advisory group (led by Imperial College Healthcare Trust), and the British Society for Antimicrobial Chemotherapy (BSAC).

2. That national regulators integrate adherence to line flushing policies into their assessment of hospitals

Each Home Nation in Great Britain has an independent regulator of care quality. In England, the Care Quality Commission (CQC) is responsible for this role; in Wales, Health Inspectorate Wales (HIW) fulfils this purpose in hospitals specifically; and in Scotland, the regulator is Healthcare Improvement Scotland (HIS).

We recommend that each of these regulators integrate an assessment of line flushing policy and practice at an organisational level into their overall assessment of care quality.

This could, for example, be included as part of the 'medicines governance' assessment currently carried out by the CQC, or the equivalent by other regulators. Consultations should be held between regulators and key opinion leaders/relevant organisations such as NIVAS to inform how best to integrate the monitoring of adherence to line flushing policies into overall assessments of care quality.

3. That funds be made available to enable research into underdosing's impact on DRIs and environmental AMR

In reviewing the state of the art in underdosing studies, it is striking to note how little research exists directly linking underdosing with either worsened outcomes or drug resistant infection. This may in part be driven by ethical concerns preventing randomised controlled trials from being undertaken (i.e. it would be unthinkable for an ethics board to approve research which purposefully provided patients with a dose inferior to that prescribed to compare outcomes).

However, studies have been carried out to monitor the extent of underdosing by harvesting used administration sets and establishing the volume of drug remaining upon being discarded.

We recommend that similar studies correlating the outcomes of patients with the level of underdosing on hospital wards should be commissioned by the relevant health authorities in each devolved administration.

Furthermore, while compelling evidence exists to show that the vapour pressures of antibiotic formulations used in the clinic are low enough for vaporisation to occur, and that contamination with antibiotics is rife in clinical settings, this evidence derives from few academic studies. These tend to focus on contamination from antibiotic preparation as opposed to waste.

We therefore further recommend that central government funds be made available for relevant hospital teams to monitor the vaporisation of antibiotics on wards, particularly emanating from waste bins/bags, and the associated antibiotic contamination throughout the ward.

4. That proper training be provided surrounding how to dispose of antibiotics appropriately

All NHS organisations have robust waste policies already in place, as proper waste disposal is part and parcel of the safe and effective healthcare which the NHS delivers overall. In spite of this, it is striking to note that inappropriate disposal of administration sets used to provide IV antibiotics is non-zero.

We recommend that, coupled with the implementation of an antibiotic line flushing policy as recommended above, dedicated training be provided to frontline healthcare workers on safe and appropriate disposal of antibiotics which may accidentally remain in lines.

In theory, perfect adherence to line flushing policies would render this largely moot, but as observed from our findings, even organisations with

policies in place do not perfectly adhere to them. Thus, frontline healthcare workers should be made aware of how to dispose of antibiotics remaining in lines in the event that a line is not flushed. This would reduce AMR selective pressures by limiting vapour production and ensuring that no antibiotics are poured down sinks, contaminating effluent.

5. That hospitals monitor environmental antibiotics contamination, both in effluent and on wards

This report did not seek to establish whether NHS organisations have undertaken (or regularly undertake) environmental monitoring of contamination by antibiotics. A follow-up study may explore this issue, in order to quantify the extent of the problem as it stands.

However, based on the precautionary principle, we recommend that hospitals put in place measures to monitor environmental contamination by antibiotics. This should cover both effluent contamination (by sampling hospital wastewater) and built environment contamination in wards.

The methods developed by Sessink *et al* (2019) could serve as a basis for establishing the presence of contamination in the built environment. Monitoring of wastewater antibiotics concentrations could be achieved *via* collaborations with local universities or centres of excellence, to ensure that there are not high doses of antibiotics being released in waterways.

We further recommend that data gathered as part of these monitoring exercises be released to the public for general review and analysis by the academic community, and to inform policymakers in their decision-making process.

Conclusion

The findings from this research report indicate that there is a need for concerted, UK-wide action on antibiotic line flushing policies. We call upon relevant stakeholders—in particular the UK Government through DHSC—to do more at all levels:

1. Build the evidence base justifying the importance of line flushing policies by correlating underdosing with drug resistant infection
2. Standardise the design of antibiotic line flushing policies
3. Assist NHS organisations in adapting guidelines intelligently to their patient populations
4. Assist NHS organisations in implementing guidelines and policies, ensuring that internal audits are built into the implementation phase
5. Mandate that national care quality regulators monitor the extent of antibiotic line flushing and hence associated underdosing

Cross-sectoral engagement will be key to the success of this programme of work:

- Third sector organisations, such as NIVAS, BSAC, and the Royal College of Nursing should be called upon to ensure that guidelines are directly applicable to the relevant practitioner populations and serve the long-term AMR and DRI reduction goals of the UK Government
- Industry organisations such as the Association of the British Pharmaceutical Industry (ABPI), in their capacity as representatives of manufacturers of administration sets, should be consulted to ensure that easily flushable lines are available at similar costs to those currently used in NHS organisations in Great Britain.
- Academics should be funded, either by direct commission or through the creation of dedicated funding streams, to carry out further research into hospital contamination by antibiotic vapours and the AMR selective pressures arising from these.

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