ASSESSING PIPED NITROUS OXIDE CLINICAL USE, WASTAGE AND ENVIRONMENTAL IMPACT: A SUSTAINABILITY QUALITY IMPROVEMENT PROJECT, ANAESTHETICS TEAM

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Background:

The National Health Services (NHS) has set an ambitious goal to become the world's first net-zero health service and to achieve net-zero direct emissions, by 2040. NHS contributes approximately 5% to the national carbon emission, where anaesthetic gases accounts for around 2% of the NHS emissions. More specifically nitrous oxide (N_2O) accounts for at least 80% of the total anaesthetic gas footprint[1-3].

A recent audit conducted by the NHS Lothian uncovered significant flaws in N_2O manifold management, utilisation, and leakage. These discoveries led to the decommissioning of N_2O at one of the sites and 98% reduction in cylinder turnover in another Lothian Trust site[4]. Another audit conducted at the Cardiff and Vale University Health Board (CVUHB), identified that only 2.5% of the total purchased N_2O was used for the patients. Whereas 97.5% of the N_2O was wasted owing to leakage and inefficiencies, thus, suggesting using N_2O portable cylinders instead of piped N_2O which were found to be 74% more efficient[5].

The Christie NHS Trust has approved the "Sustainable Development Management Plan 2021-2024" and the trust is ready to embrace the commitments set-out in achieving a net-zero NHS. A key component of the proposed plan is to explore options to reduce use of anaesthetic gases. However, there was no audit conducted to assess piped N_2O related emissions. As anaesthetists we were well placed to lead this project.

Specific Aims:

To assess piped N_2O usage and wastage in the anaesthetic clinical practice to identify and explore ways to reduce its environmental (Trust N2O emissions) and financial impact.

Methods & Measurements:

The project was completed in the Christie NHS Foundation Trust Theatres and Proton Beam Therapy Unit (PBTU).

Clinical and social impacts:

1- **Cross-sectional Survey:** A survey (Appendix 1) was conducted among all full-time independent anaesthetic practitioners, including consultant anaesthetists and SAS anaesthetists, to assess the use of N2O in anaesthetic clinical practise at The Christie. The Christie Trust has anaesthetic service provision agreement with the University Hospital South Manchester (UHSM) and the Royal Manchester Children's Hospital (MFT/RMCH), therefore, they were also included for the survey. The responses were gathered and analysed using Microsoft XL.

Environmental and Financial Impact:

2- **Technical Survey:** In the second phase data was collected from the estate, pharmacy, and anaesthetic machines.

I. **Estate:** Details of the N_2O cylinder manifolds were gathered and their respective serving areas were identified. Nitrous oxide cylinder turnover data and information related to leak test practices were collected by the relevant estate personal interview. Unfortunately, no logs were available for review.

II. **Pharmacy:** Details of N_2O cylinders ordered by the pharmacy for last 24 months were requested and average yearly consumption was estimated.

III. **Theatre & Anaesthetic Machine Data:** With the help of medical physics and Drager® (anaesthetic equipment provider) representative, logs were reviewed for all the anaesthetic machines at the main theatres and PBTU. N_2O consumption data was collected and average consumption per ventilated hour was calculated.

Total General Anaesthetic (GA) hours were calculated from theatre logs by calculating the duration for all GA cases conducted over 12 months (01/10/2021 x 30/09/2022)

Total consumption of N_2O, in Litre (L) at the main site was estimated using the following formula;

Average N_2O (L) use / ventilated hour* x Total number of GA hours in 12 months = Total N_2O clinical use over 12 months (L)

*It was assumed that all patients underwent surgeries under GA were ventilated

Environmental impact: CO2e was calculated based on one Kg of N2O = 298 kg of CO2[6]

Financial impact: N_2O Financial cost: was calculated using BOC price list available on the website[7]

Results:

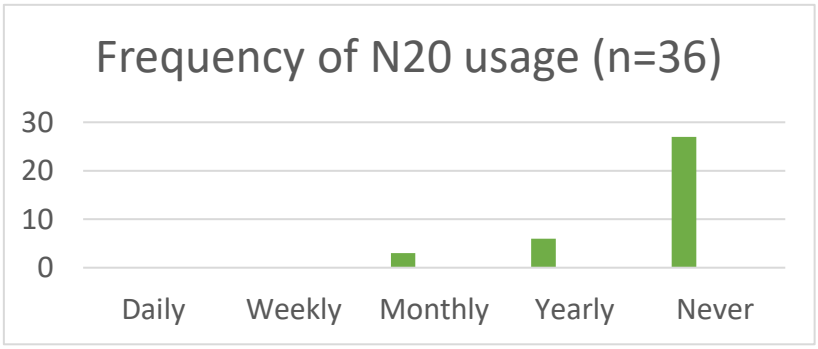
Social Outcomes: The project was appreciated by the department, and informal feedback from the colleagues indicates that it has raised awareness of N_2O emissions and highlighted the need to transition towards greener anaesthetic practices.

Patients Outcomes: There is no expected negative outcome of this project on patients.

Cross-sectional Survey results: A total 36 anaesthetists responded to the proforma, with a breakdown of role and location summarised in table 1.

Total Anaesthetists surveyed (36)	SAS: 8/36 (22%)	Consultant: 28/36 (78%)
Response Rate	The Christie NHS	24/27 (88%)
	UHSM	5/6 (83%)
	MFT / RMCH	7/29 (24%)

Out of 36 respondents, 64% of anaesthetists had never used N_2O at the Christie, 36% had used it occasionally (monthly or yearly). No one used N_2O daily or weekly as shown in the graph below.



- Eighty four percent (30/36) of the anaesthetists do not intend to use N_2O in the future, while 16% (6/36) intended to continue using it.
- Ninety seven percent (35/36) anaesthetists were in favour of a transition to N_2O free anaesthetics in the future.
- All (36/36) the anaesthetists were happy to use N_2O via cylinders only if the need arises.

Technical Survey Results:

The technical survey results reinforce the clinical survey results highlighting an overall minimal use of N_2O in clinical practice.

I. **Estate:** There are two N_2O cylinder manifolds at The Christie NHS Trust which contains size G cylinders. One of the manifolds is dedicated for PBTU, while the other serves the rest of the hospital. Its piped supply is used at the main theatres, brachytherapy unit, and PBTU. The cylinder turnover is very low. Estate does not perform routine leak tests and no logs were available for review.

II. **Pharmacy:** Pharmacy data suggests an estimated turnover of 15 N_2O size G cylinders over the last 12 months period. This finding supports the numbers provided by the estate.

III. **Theatre & Anaesthetic Machine Data:**
Estimated N_2O consumed per ventilated hours (main site) = 1.01 L (72%)
Estimated N_2O consumed per ventilated hours (PBTU) = 0.385 L (28%)
Total GA hours last one year combined (main site) = 6667 hours
Estimated N_2O consumed (main site) = 6733 Litres = < 1 Size G N_2O cylinder / year
No data was available from the PBTU for total GA hours over 12 months.

Environmental Impact

- Estimated N_2O Consumed (main site) = 9000 x 11 L = 99000 L = 11 Size G cylinders per year
- Estimated Clinical Use (main site) = 6733 L = < 1 Size G cylinders per year
- Lost to the atmosphere = 92,276 L = 182 Kg per year (93% of total ordered for the main site)
- N_2O x 298 (Releasing 1 kg of N_2O into the atmosphere is equivalent to releasing 298 kg of CO_2).
- 182 x 298 = **54,236 kg CO2e saved per year**. This is equivalent to 156,209 miles driven in an average car, or 394 return trips from Manchester to London.

Financial Impact

- Size G N_2O Cylinder Cost for the main site (as per BOC website) = £296.17 / cylinder
- Total N_2O Size G cylinders ordered for the main site = 11 x £3257.87 / year
- Total N_2O Size G cylinders consumed for the main site = 1 x £296.17
- Total estimated financial loss = £ 2961.7
- Investment Cost for installing size E N_2O cylinders on all the anaesthetic machines = £80 x 16 cylinders = £1280 cost
- Net savings = **£1681.7 per year**

Discussion:

Based on the above findings the following recommendations were made to the anaesthetic department:

- Decommission N_2O manifold at the main site which consumes approximately 70% of the N_2O with no clinical benefit.
- Keep portable N_2O cylinders to be made available to use when required.
- Further discussions with MFT/RMCH anaesthetic department to achieve consensus regarding decommissioning of PBTU manifold.
- Reassess N_2O consumption after 12 months of implementing changes

The recommendations were largely agreed by the department without any resistance, however, some of the anaesthetists were keen to have N_2O cylinders available all the time on anaesthetic machines and be ready to use when required. Therefore, a decision was made to install size E N_2O cylinders on all the anaesthetic machines. The recommendations were agreed by the pharmacy and recommendations have been forwarded to the medical gases committee for final approval. Any gas left in cylinders is not recycled by the company but released into the atmosphere.

Our results show significantly less use of N_2O in clinical practice at The Christie compared to the other NHS trusts. A similar survey conducted recently at the CVUHB showed that 47% of the anaesthetists never used N_2O and 29% used it occasionally[5]. However, a survey conducted at The Royal Alexandra Children's Hospital, Brighton & Sussex demonstrated significant use of N_2O in clinical practice, where it was used in 55% of the GA cases[8].

This stark difference in clinical use in different NHS trusts can be attributed to the type of surgical procedures and the patient population they cater. The Christie is a highly specialised cancer hospital, and the main theatres are primarily involved in the adult, mostly elective, cancer surgeries. Most of the other NHS trusts, on the other hand, have obstetric or paediatric surgical units where N_2O is still regarded unavoidable. The paediatric patients undergoing PBT, at The Christie, usually have long term indwelling catheters and thus, mostly, avoid the need for inhalational induction (which mostly requires N_2O).

Another, intriguing aspect is the clinical benefits of Total Intravenous Anaesthesia (TIVA) in cancer surgeries, ranging from reduced incidence of post operative nausea and vomiting to increased overall survival, potentially leading to a shift in clinical practice towards TIVA and away from inhalational anaesthesia[9, 10].

Analysis of the data collected from the estate, pharmacy, and anaesthesia machines estimated that only 7% of the total purchased nitrous oxide was used in the clinical practice for the main site. This finding reinforces the results of the clinical survey.

A similar audit conducted at the CVUHB identified significant leaks from the manifold system and found that only 2.5% of the total purchased nitrous oxide reached out to the patients. The board conducted a pilot project, where portable E size cylinder was used for N_2O and found it to be 74% more efficient[7].

Another project at the NHS Lothian identified a wastage of 80% at one of the manifolds and revealed that wastage from the piped manifold systems is a far more significant problem than that of persistent clinical usage and therefore decommissioned some of the manifolds[4].

Based on the above findings, which suggest minimal clinical use and significant manifold / pipeline leaks, in the context of positive outcomes of decommissioning of the manifolds at other NHS trusts, recommendation was made to decommission one of the main manifolds which consumes approx. 70% of the total purchased N_2O. Nitrous oxide cylinders will be installed on the anaesthetic machines for when clinical need arises. Further audits will be conducted to analyse ongoing clinical use with an aim to achieve nitrous oxide free anaesthesia.

Limitations:

- The response rate for the clinical survey was poor from MFT/RMCH anaesthetists and therefore does not reflect the majority in that group.
- There were no logs available to review at the estate and thus the estate data is based on the relevant personnel interview rather than physical records.
- The N_2O cylinder data received from the pharmacy was used to estimate average yearly purchase of nitrous oxide.
- Data for the total number of GA hours was not available for PBTU, therefore, it was not possible to calculate total N_2O clinical use at PBTU.

- Due to ongoing estate operations, it was not practically possible to run a whole site N_2O leak test and therefore, leak is estimated only for the main site by subtracting estimated clinical use from the total purchased N_2O cylinders for the manifolds.
- Average N_2O consumption was calculated by assuming that all patients were ventilated throughout the surgery which could have resulted in an over estimation of N_2O use.

Challenges:

The project had various dimensions and needed a significant involvement of multiple departments. Clinical survey was conducted in three different settings, and it was challenging to get a good response rate. Support and coordination were required from the non-clinical departments including medical physics, Drager® (anaesthesia equipment provider), estate and pharmacy. Gathering data was time consuming and at some departments the required record / data was not available.

Future Goals:

- Decommissioning of N_2O main manifold (agreed by the anaesthetic department, pharmacy and now waiting for final approval from the medical gases committee)
- Further meetings and responses from the MFT/RMCH anaesthetists and decommissioning of the PBTU N_2O manifold
- Audit of N_2O cylinder use next year to assess clinical use with an aim to move towards N_2O free anaesthesia.

Conclusions:

Despite challenges and limitations, the project is a first of its sort at The Christie NHS trust and has established minimal use of N_2O in anaesthetic clinical practice by analysing it from multiple dimensions. It has also highlighted that 93% of the purchased N_2O is lost to the atmosphere due to potential leaks in the pipeline-manifold system.

By decommissioning one of the main manifolds and replacing anaesthetic machines with Size E N_2O cylinders, the trust can save an estimated 54.23 tonnes of CO_2 emissions with some financial savings.

Although this project is a small step in the right direction, the trust has a long way to go to achieve nitrous oxide free anaesthesia.

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Appendix 1: Cross-sectional Survey

Serial Number:	Anesthetist SAS / Consultant
Have you ever used N2O at The Christie Theatres as part of the anesthetic	Yes / No
How often do you use N2O at The Christie theatres	Daily / Weekly / Monthly / Yearly / Never
Are you planning to use N2O at The Christie theatres in future	Yes / No
Would you support a transition to N2O free anesthetic at The Christie theatres	Yes / No
Would you be happy to use N2O via cylinders only (if required)	Yes / No