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Green hospital – medicine with a zero-carbon footprint?

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Competing interests

The Department of Anaesthesiology, Intensive Care Medicine & Pain Therapy of the University Hospital Frankfurt, Goethe University received support from B. Braun Melsungen, CSL Behring, Fresenius Kabi, and Vifor Pharma for the implementation of Frankfurt's Patient Blood Management program.

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KZ leads as CEO the Christoph Lohfert Foundation as as well as the Health, Patient Safety & PBM Foundation.

Keywords

Volatile Anaesthetics – TIVA – Green Hospital – Carbon Footprint – Waste Prevention

Summary

The European Union is currently reassessing inhalation anaesthetics for their potential detrimental effects on the environment. Other drugs used in modern anaesthesiology are also subject to a similar assessment. Being almost the last cross-sectional specialty in a highly specialized small-scale medicine, anaesthesiology is becoming increasingly aware of its responsibility towards patients and the environment. However, there is a lack of well thought-out strategies in the balancing act between individual risk-benefit considerations for the respective patients and ecology. A discussion of inhalation anaesthesia versus TIVA is certainly the wrong approach to finding a solution to the problem. Ecological issues just cannot and must not be limited to the reduction of gas anaesthesia. German hospitals are generating tons of waste similar to household waste, but also infectious waste. Hospitals are in general already considered to be the fifth largest waste producer in Germany. Theoretically, up to 90 % of all plastic materials, packaging and glass waste could be recycled. This could be a starting point that can be realized immediately and with ease, also as much as the collection and reprocessing of volatile anaesthetics is concerned.

Introduction

Increasingly, we are becoming aware of the effects of inhalation anaesthetics on the environment. As almost the last interdisciplinary field in a highly specialised small-scaled medicine, the field of anaesthesiology is increasingly becoming aware of its responsibility towards patients and the environment. However, there is a lack of well thought-out strategies balancing the act between individual risk-benefit considerations for the respective patients and ecology. Not at least on the part of politics, supposedly simple solutions are postulated too often and dogmatically codified in regulations and laws. A good example of the complexity of the corresponding issues is the German electromobility. If we consider the lack of charging infrastructure, the limitations for long-distance travel, the threat of regional or even nationwide blackouts and an increasing share of conventional power generation with predominantly fossil fuels, it becomes clear that prompt, singular electromobility cannot achieve its goals at all, nor can it be ecologically sensible. At the same time, possible alternatives, such as the menthol fuel cell, are more or less ignored. Accordingly, our answers for the field of anaesthesiology will be neither simple nor uniform, but by no means dogmatic.

TIVA – the alternative to anaesthesia with volatile anaesthetics?

Inhalation anaesthesia versus TIVA – since the mid-1990s of the last century, this question has been regularly published from a wide variety of perspectives and was sometimes discussed emotionally. The focus was not only on postoperative nausea and vomiting (PONV) or questions of tolerability, side effects and haemodynamics. Very early on, the use of propofol for TIVA was intended to reduce the burden on the workplace and the environment. The research group "Anaesthesia and the Environment", founded in 1990 at the University Hospital Ulm, took up this aspect [1]. The research group quickly came to the conclusion that the exclusive use of propofol must be reconsidered in order to avoid the environmental impact of volatile anaesthetics. A complete switch from inhalation anaesthesia to TIVA would increase water pollution and would not lead to a solution but only to a shift of the environmental problem.

The decisive factor was that propofol is excreted partially unmetabolised [2]. Non-metabolised drugs enter waste water as bioactive substances and are considered the most difficult substances to biodegrade [3]. For the most part, propofol is hepatically glucuronidated or oxidised to various quinol compounds [4]. However, so-called structurally related substances, i. e. conversion products, metabolites and conjugates are also more than relevant for the ecology. These can have comparable effects to the parent compound, but higher or lower effects are also possible. Propofol, an alkylphenol, and its degradation products end up in the waste water of clinics and thus in the drinking water cycle via sewage treatment plants. Although phenol and its decomposition products are considered to be substances that are highly hazardous to water [5], precise information on their toxicity, harmful threshold values and lifespan in wastewater is lacking [6]. Alkylphenols are known to have intrinsic oestrogen-like activity in wastewater; their half-lives are unknown [7]. Even traces of phenol make drinking water completely undrinkable due to their unappetising odour [8]. The problem is exacerbated when propofol residues are disposed of via the sink and fed directly into the water cycle. To reduce drinking water contamination, the medication residues should be added to incineration waste. The difficulty of analysing hospital wastewater is illustrated by a study from 1998, in which the amount of phenol determined was 0.132 mg/l, slightly above the normal domestic water pollution [9]. However, this study by Gartiser and colleagues was probably conducted in a hospital where propofol was not used for anaesthesia [10]. Similarly, there are indications that de-glucuronidation may occur in waste water, as in one study the propofol concentration leaving waste water treatment plants was higher than in the incoming water [11]. In line with the 2022 World Federation of Societies of Anaesthesiologists consensus statement on the principles of environmentally sound anaesthesia, we need more robust research on pharmaceuticals and their metabolites in the water cycle [12].

Recycling – more than just separate disposal?

At the moment, the big question always being asked is whether the glass is half full or half empty. The truth is that it has not yet been possible to reintroduce desflurane into the product cycle. The main reason for this is the time-consuming approval process for pharmaceuticals. However, the solution currently in place at ZeoSys is a decisive step in the right direction: The reprocessing of anaesthetic gases is planned in a plant in Lückenwalde that has already been certified by the supervisory authorities in accordance with § 13 of the German Medicines Act and the pharmacological approval is currently in progress. The process has a modular decentralised plant for recycling as its vision, thus avoiding long transport routes. And already the recycled amount of collected anaesthetic gases is at about 99 %. Of course, after extubation, exhaled anaesthetics can no longer be collected and thus complete collection of the gas is impossible. The recovery rate also appears disappointing at first [13]. However, the filter system must also be completely filled with anaesthetic gases. Here, further innovations from the industry are necessary and in development.

Inhalation anaesthesia – a phased-out model?

Without doubt, the environmental impact must also be taken into account when selecting the individually suitable anaesthetic procedure. In contrast to conventional inhalation anaesthetics, the inert gas xenon does not cause any environmental pollution and has long been considered an almost ideal anaesthetic. In addition to its anaesthetic and analgesic effects, xenon has been shown to have cardio- and neuroprotective effects [14–16]. However, xenon has not been able to establish itself in everyday clinical practice due to its high cost and the lack of availability of special anaesthetic respirators. In the near future, however, the combination of the noble gases xenon and argon could play an important role. In 2014, Kristensen et al. highlighted the importance of developing organ-protective strategies for general anaesthesia [17]. The focus here, in light of an ageing population, was the fact that ageing is associated with a progressive loss of functional reserves in several organ systems and that the extent and onset of these changes varies greatly between individuals. For these reasons, various clinicians and researchers have focused on techniques to prevent adverse events after surgery and general anaesthesia, ranging from mild physical challenges to neurocognitive disorders. One study examined the cognitive status of a group of subjects exposed for several days to a breathing gas mixture of oxygen (14 %), nitrogen (33 %), argon (54 %) and CO_2 (0.24 %), followed by several days of exposure to hypoxic conditions [18]. Participants performed better on cognitive tests and reported various physical benefits when breathing the first mixture compared to the hypoxic conditions.

In 2007, Pagel et al. hypothesised that noble gases other than xenon can also protect the heart muscle [19]. In rabbits, Pagel and his team demonstrated that the application of argon prior to prolonged coronary artery occlusion protects the heart muscle from infarction.

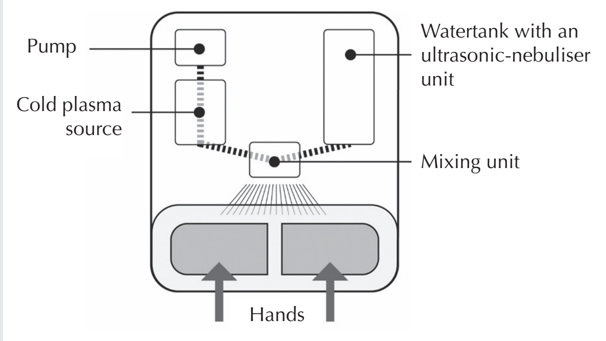
More recently, Grüne et al. have highlighted the "accumulating data" demonstrating the neuroprotective effects of argon and emphasised the need for additional studies of its cerebrovascular and cerebrometabolic effects [20]. Grüne investigated the effects of hyperventilation versus hypoventilation in anaesthetised patients using parameters of circulation and cerebral metabolism. The patients were examined after short-term mechanical ventilation with 70 % argon and 30 % O_2. No effects on the cerebral circulation or the global oxygen and glucose metabolism could be detected. Thus, this study also showed that argon should be further explored as a promising candidate with organ-protective effects due to the lack of cerebrovascular and cerebrometabolic effects. In an interesting review article, Nepoli et al. postulated that the sum of preclinical and clinical data warrants the move to clinical trials on the role of argon in organ protection [21]. In this review, 55 articles found that ventilation with argon at a concentration of 20–80 % led to a reduction in cell death, a reduction in infarct size and improved functional recovery after ischaemia.

From an ecological and medical point of view, it would now be time to research new gas combinations to increase organ protection, e. g. combinations with argon.

Has the future of green anaesthesia already begun?

Ecological issues cannot and must not be limited to reducing gas anaesthesia. In German hospitals, tonnes of waste similar to household waste, but also infectious waste, are produced. Hospitals are already the fifth largest producer of waste in Germany [22]. Whether and to what extent infectious or household-type waste can be separated at an early stage and thus, at least theoretically, recycled, depends largely on the judgement of the respective user on site. In practice, however, it has been shown that fears, for example related to the perceived risk of infection, prevent rational waste separation. Theoretically, up to 90 % of all plastic materials, packaging and glass waste could be recycled. This could be a starting point that is immediately and easily realisable at every clinic and outpatient clinic.

Fig. 1



Schematic structure of a cold plasma nebuliser for hand disinfection.

But also other developments are more than interesting in this area of conflict between medical necessity and ecology. For example, instead of conventional hand disinfection using substances containing alcohol, a new cold plasma fogging process can be used as an alternative. Here, water vapour and oxygen from ambient air is used and converted into so-called hydroxyl radicals at a special plasma source. A low painless current flow at a defined voltage then leads to the desired reaction [23]. The generated plasma is fed into a mixing unit where it is mixed with tiny aerosols, which are created from stabilized distilled water and generated with the help of an aerosol generator. The mixture is then 'nebulised' onto the hands in the hand chamber. In the process, some of the hydroxyl radicals dissolve within the aerosol droplets, so that the to be disinfected hands are brought into contact with both a gas phase and a liquid phase of water.

The active ingredient is produced on the spot in the device and does not require any additional chemicals. With the help of the refillable water tank, around 2,000 disinfection cycles can be carried out, which theoretically corresponds to more than 15 plastic bottles of 500 ml hand disinfectant. The simplified internal hospital logistics and the reduced ecological footprint for delivery alone can provide small innovative building blocks on the way to a green anaesthesia.

Ecology in the present – a forced wait?

Ecology in anaesthesiology has many facets and is not limited to the use of volatile anaesthetics. Waste avoidance and waste separation also by no means describe our only possible approaches in anaesthesia, pain therapy, intensive care and emergency medicine. However, suitable (partial) solutions from the industry need time due to their complexity and high regulatory hurdles within the approval processes. Therefore you need to show the necessary awareness in this balancing act between individualised anaesthesiology and ecology, have the courage to differentiate, stay in a critical dialogue and do not believe easy answers.

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