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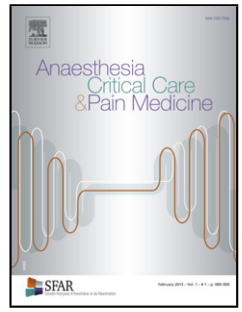

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Professional practice guidelines: Eco-Responsible Optimization of Choice and use of Drugs and Medical Devices in operating theaters or interventional sector

Delphine Cabelguenne[1]PhaD, PhD, Hélène Beloeil[2] MD, PhD, Aurelie Bros[3], Pierre Cassier[4], Claire Chapuis[5] PhaD, Benoit Chauveau[6] MD, PhD, Assia Daikh[7] PhaD, Cédric Dananché[8] PhaD, PhD, Lise Durand[9], Martin Dupuy[10], Florence Lallemant[11], Christophe Lambert[12] PhaD, PhD, Abir Petit[13] PhaD, Mathieu Pioche[14] MD, PhD, El Mahdi Hafiani[15] and Patrick Pessaux[16] MD, PhD, by Collectif d'Ecoresponsabilité en Santé (CERES) and Association Française de Chirurgie (AFC), Euro-Pharmat-Société Pharmaceutique Française des Dispositifs Médicaux (Euro-Pharmat-SPFDM), Société française d'Anesthésie et de Réanimation (SFAR), Société Française de Chirurgie Rachidienne (SFCR), Société Française d'endoscopie Digestive (SFED), Société Française d'Hygiène Hospitalière (SF2H), Société Française de Pharmacie Clinique (SFPC), Société Française de Radiologie (SFR), Société Française des Sciences de la Stérilisation (SF2S).

1 : Quality Department, Le Vinatier Psychiatrie Universitaire Lyon Métropole, Bron, France
2 : Anesthesia and Intensive care Department, CHU Rennes, Université de Rennes, Inserm OSS 1242, CIC 1414, Rennes, France
3 : Service Pharmacie-Stérilisation, Hopitaux Universitaires de Strasbourg, Strasbourg, France
4 : Institute of Infectious Agents, Hospices Civils de Lyon, Lyon, France; CIRI, Centre International de Recherche en Infectiologie, Université de Lyon, Inserm, U1111, Université Claude Bernard Lyon 1, CNRS, UMR5308, ENS de Lyon, Lyon, France.
5 : Service de Pharmacie clinique, Pôles Pharmacie et Anesthésie-Réanimations, CHU Grenoble Alpes, France
6 : Radiology Department, CHU Estaing Clermont Ferrand, Clermond Ferrand, France
7 : Service Dispositifs Médicaux, Pôle Pharmacie, CHU Grenoble Alpes, France
8 : Service Hygiène, Épidémiologie, Infectiovigilance et Prévention, Hospices Civils de Lyon, France ; CIRI, Centre International de Recherche en Infectiologie, Université de Lyon, Inserm, U1111, Université Claude Bernard Lyon 1, CNRS, UMR5308, ENS de Lyon, Lyon, France.
9 : Pharmacy Department, Clinical Pharmacy unit, CHU Rennes, Rennes, France
10 : Department of Neurosurgery, Clinique de l'Union, Toulouse, France.
11 : Service des urgences chirurgicales et déchocage, Hôpital Salengro, CHRU Lille, Lille France.
12 : Stérilisation centrale, CH Métropole savoie, Chambery, France
13 : Secteur des Dispositifs Médicaux Stériles, Pôle Pharmacie, CHU Amiens, France
14 : Endoscopy, Hôpital Edouard Herriot, Hospices Civils de Lyon, Lyon, France
15 : Groupe des anesthésistes réanimateurs de l'Hôpital Privé d'Antony, Antony, France.
16 : Service de Chirurgie Viscérale et Digestive, Nouvel Hôpital Civil, Strasbourg, Inserm U1110, France

Corresponding author:
Patrick Pessaux
Service de chirurgie viscérale et digestive
Nouvel Hopital Civil
67091 STRASBOURG, FRANCE

ABSTRACT

Objectif: To provide recommendations for eco-responsible optimization of choice and use of medicines and medical devices.

Design: A committee of 16 experts brought together by CERES and from SPFDM/Euro-Pharmat, SFAR, SFCR, SFED, SF2H, SFPC, SFR, SF2S has been set up. A policy for declaring links of interest was applied and respected throughout the process of creating the reference system. Similarly, it has not provided any funding from a company marketing a health product (drug or medical device). The committee had to respect and follow the GRADE® method (Grading of Recommendations Assessment, Development and Evaluation) to assess the quality of the evidence on which the recommendations were based.

Methods: The recommendations were formulated by identifying 4 different fields: practice of care (optimization of medicines and medical devices), packaging (reduction of the environmental impact of medical devices), organization of care (integration of environmental criteria) and waste management (reduction, sorting and recovery). Each question was formulated according to the PICO (Patients, Intervention, Comparison, Outcome) format. The analysis of the literature and the recommendations were carried out according to the GRADE® methodology.

Results: The experts' synthesis work resulted in 46 recommendations validated after one round of voting. For all questions, since the GRADE grid ® method could not be applied in full, the recommendations were formulated in the form of expert opinions.

Conclusion: From a strong agreement between experts, we were able to formulate 46 recommendations for eco-responsible optimization of the choice and use of medicines and medical devices.

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Keywords: recommendation, sustainable development, operating room, environmental impact, interventional sector, medicines, drugs, medical devices, ecological design of care, packaging.

INTRODUCTION

The healthcare sector is a major contributor to greenhouse gas (GHG) emissions through the production, distribution, and use of pharmaceuticals and medical devices (MDs). In France, the sector represents approximately 8% of the country's GHG emissions, with around 50% derived from pharmaceuticals and MDs.

The environmental footprint of medicines and MDs can be attributed to many different factors. In the first instance, the manufacturing process requires complex, fragmented industrial operations that not only consume primary resources and energy but also generate GHGs. The fine chemicals used to produce the active ingredients, the formulation of the medicines, and the packaging of health products are particularly energy-intensive, as are the sterilization processes. Secondly, the distribution of these products relies on extended, fragmented logistics networks that call on multiple international—often just-in-time—shipments, which magnifies the carbon footprint. Waste derived from healthcare, most notably single-use medical devices (SUDs) and product packaging, is a major driver of pollution. This waste requires dedicated processing channels, which are themselves resource-intensive. Finally, regarding halogenated anesthetic gases or NO_2, with a strong greenhouse effect, they are not metabolized, and it is estimated that more than 95% of the gas used during an operation is directly released into the atmosphere.

In response to these challenges, healthcare professionals can activate various strategic levers aimed at reducing the carbon footprint of pharmaceuticals and MDs. The first is based on optimizing the prescription and use of medicines by promoting good prescribing practices. The proliferation of SUDs has led to a vast increase in waste production. While these devices are often vital for hygiene and safety reasons, it is likely that reusable alternatives exist in many areas. For this approach to be viable, highly effective procedures must be developed to recondition these MDs (such as washing, disinfection, and sterilization), while preserving safety standards and minimizing energy consumption and logistical roadblocks. Finally, it is clear that pharmaceutical and MD packaging must be scaled back and redesigned. Packaging contributes significantly to the environmental footprint of pharmaceuticals, driven in part by the large-scale use of plastic materials and the proliferation of multi-component packaging. Another promising avenue is the optimization of supply chains and distribution flows. Streamlining transport flows and storage processes can lead to a substantial drop in GHG emissions from pharmaceuticals and MDs.

Healthcare facilities and professionals must address these emerging challenges. In response, the Collectif d'ÉcoResponsabilité En Santé (CERES) has proposed a framework for the eco-efficient optimization of the selection and use of medicines and MDs. The aim is to provide a tool for minimizing the environmental impact of surgical and interventional procedures and to standardize practices while guaranteeing optimal patient care.

These recommendations reflect a consensus among the multi-disciplinary experts who were rigorously selected for their expertise and active engagement in their respective professional bodies. The diverse profiles of the contributors ensure a holistic approach geared towards clinical realities that incorporate the latest scientific advances. This work is dedicated to the continuous improvement of healthcare delivery while reinforcing best practices.

PURPOSE OF THE RECOMMENDATIONS

The aim of these Professional Practice Guidelines (PPGs) is to establish a decision-making framework that supports **the sustainable optimization of the selection and use of pharmaceuticals and MDs** while simultaneously safeguarding patient safety and clinical effectiveness. Anesthetic gases are a major contributor to the environmental footprint of perioperative care. Halogenated anesthetics and nitrous oxide (N_2O) are potent greenhouse gases, and leakage from piped N_2O systems further increases their environmental impact. These issues are addressed in dedicated national and international anesthesiology guidelines, which promote strategies to reduce or avoid their use. Given the specificity and existing body of recommendations in this field, anesthetic gases were deliberately excluded from the scope of the present work, which focuses on the eco-responsible optimization of the choice and use of medicines and medical devices in operating theaters and interventional settings. The group of experts was committed to developing a concise yet strategic set of recommendations focusing on four predefined areas.

These recommendations target **all professionals engaged in care practices in the operating theater or interventional suite**. They provide practical solutions for balancing clinical performance and environmental responsibility.

METHOD

1. General organization

These recommendations stem from the work carried out by a group of experts brought together by CERES. This group included members of various professional bodies affiliated with CERES, who were invited to provide their input based on their particular area of expertise. Prior to taking part, each expert completed a conflict-of-interest declaration.

The process was structured around the following steps:

1. The organizing committee defined the goals of the recommendations and the methodology used.
2. The scope of the recommendations and the questions to be explored were established prior to being validated by the group of experts.
3. The questions were reworded in **PICO** (Population, Intervention, Comparison, Outcome) format following an initial meeting.

2. Scope of the recommendations

The experts were unanimous in deciding to focus on the following four key themes:
Area 1 – Care practices
Area 2 – Packaging of MDs
Area 3 – Organization of care and logistics
Area 4 – Waste management
The four areas covered by the recommendations were selected based on their homogeneity.

3. Literature review

An extensive literature review was conducted to inform the development of these professional practice guidelines. The review followed a systematic and pragmatic approach, adapted to the heterogeneity of the available evidence in the field of environmental sustainability in perioperative care. Searches were performed in international databases (MEDLINE/PubMed, EMBASE, Scopus, Cochrane Library, and Trip Database) and supplemented by regulatory documents, professional society guidelines, and relevant grey literature. The search covered publications from January 2000 to December 2024 and was structured around predefined thematic areas corresponding to the scope of the recommendations.

Eligible studies included randomized controlled trials, observational studies, cohort studies, case series, life cycle assessments, and relevant narrative reviews published in English or French. Articles focusing exclusively on topics outside the perioperative or interventional setting were excluded. At least two reviewers independently screened titles and abstracts for each thematic area, followed by full-text assessment of selected articles. Discrepancies were resolved through discussion and consensus within the expert group.

The selection process and reporting were guided by the principles of the PRISMA statement. Given the diversity of study designs, outcomes, and methodologies, a quantitative synthesis or meta-analysis was not feasible. The primary objective of the review was to identify, appraise, and synthesize the best available evidence to support the formulation of expert recommendations rather than to produce a standalone systematic review. Consequently, the review protocol was not prospectively registered in PROSPERO.

4. *Analysis and formulation of the recommendations.*

The **GRADE®** (Grade of Recommendation Assessment, Development and Evaluation) method was used to:

- Assess the quality of the available evidence.
- Assign a recommendation level based on qualitative and quantitative analysis.

The evaluation criteria were determined in advance as follows:
- Primary evaluation criteria: clinical effectiveness and patient safety (importance: 7)
- Secondary evaluation criteria: environmental impact with life cycle analyses when available (importance: 5), reduction of GHG emissions (importance: 5), and usage characteristics (ease of use) (importance: 4).

Given the limited availability of robust studies to support the most critical evaluation criteria (*e.g.*, patient safety), the recommendations were reformulated as **Professional Practice Recommendations (PPGs)**.
The recommendations were worded using the following expressions:

- "The experts suggest doing"
- "The experts suggest not doing"

5. *Consensus development process*

The recommendations were developed using a structured Delphi-based consensus process coordinated by a steering committee convened by CERES. The steering committee defined the scope of the recommendations, validated the clinical questions, and oversaw the methodological framework. The expert panel was composed of 16 members selected for their recognized expertise in perioperative and interventional care, pharmacy, sterilization processes, infection prevention, and medical device management. Panelists were nominated by their respective national professional societies, ensuring multidisciplinary representation and coverage of different clinical settings.
Evidence identified through the literature review was synthesized by the steering committee for each thematic area and summarized in standardized evidence briefs that were circulated to all panelists prior to the voting process. Each recommendation statement was discussed and rated independently using a 9-point Likert scale. One Delphi round was performed; statements that did not reach predefined consensus criteria (agreement ≥70% and disagreement ≤20%) were reworded based on panel feedback and resubmitted for a subsequent vote. During this iterative process, statements could be clarified or modified, but no new thematic questions were introduced beyond the predefined scope. This structured approach ensured transparency, reproducibility, and balanced integration of scientific evidence and expert judgment.

RESULTS

1. Scope of the recommendations and related questions

Area 1: Care practices

1. For patients requiring injectable medicines, does extemporaneous preparation reduce the environmental impact without compromising patient safety, as compared to systematic pre-preparation?
2. For perioperative patients capable of receiving oral administration, does the use of solid oral forms (tablets, capsules, or pouches) help minimize the environmental impact without compromising clinical effectiveness, as compared to the use of oral solutions or parenteral forms?
3. For patients who require sterile MDs during invasive medical procedures, does the use of sterile reusable medical devices (RMDs) that are compliant with reprocessing regulations and protocols help minimize the environmental impact without compromising patient safety, as compared to the use of single-use (SU) sterile MDs?
4. For patients scheduled for invasive interventional procedures, does reducing waste by avoiding the advance desterilization of single-use or reusable MDs help minimize the environmental impact without compromising patient safety, as compared to the systematic practice of advance desterilization?
5. For patients scheduled for invasive interventional procedures, does reducing the number of RMDs in specialized surgical procedure trays—combined with optional additional trays—help lower the environmental impact without compromising patient safety, as compared to using trays containing a large number of devices, including those used less frequently?

Area 2: Packaging of MDs

6. For patients who require MDs, can revising the sterility requirements based on the devices' intended use help minimize the environmental impact without compromising patient safety, as compared to systematic sterility?
7. For sterile RMDs used in clinical care, does extending the use-by date (UBD) after sterilization—based on studies in real conditions and a risk analysis—help reduce unnecessary reprocessing while preserving sterility and safety, as compared to dates that are set empirically?
8. For sterile MDs, does the use of single packaging (SBS), compared to double packaging (SBS plus protective packaging), help preserve aseptic safety while simultaneously reducing the environmental impact and related costs?
9. For MDs, does the choice of packaging tailored to the frequency of use and user practices help preserve aseptic safety while simultaneously reducing the environmental impact, as compared to non-specific standardized packaging?
10. For implantable and non-implantable MDs, do electronic instructions accessible *via* QR codes help minimize the environmental impact while simultaneously ensuring convenient, secure access to instructions for use, as compared to systematically-provided printed instructions?
11. For MDs in the form of standard sets or custom packs, does periodically evaluating their composition help address clinical needs more effectively, while simultaneously reducing costs and their environmental impact, as compared to not reassessing them systematically?

Area 3: Organization of care

12. Does incorporating environmental criteria into the purchasing strategy for medicines and MDs help minimize the environmental impact without compromising the quality of care, as compared to a strategy based exclusively on cost and clinical performance?
13. Does the active participation of healthcare professionals in the eco-design of care help minimize the environmental impact without compromising the quality and safety of clinical practices, as compared to their non-participation?
14. Do eco-friendly practices that incorporate responsible resource management help reduce the environmental impact without compromising the quality of care?
15. Does assessing the clinical appropriateness of interventional procedures help reduce the environmental impact without compromising the quality of care and patient safety?
16. Does optimizing logistics flows (such as centralizing stocks and limiting urgent orders) help reduce the environmental impact while simultaneously ensuring the availability of the required products?

Area 4: Waste management

17. Can the reduction, systematic sorting, and repurposing of waste derived from MDs help limit the environmental impact while safeguarding health safety?
18. Does limiting the production of healthcare waste with infectious risk (henceforth referred to as IHW) through the strict application of its definition help reduce the environmental impact while safeguarding health safety?

2. Summary of results

A total of **46 recommendations** were formulated after one round of scoring. There was **strong consensus** across all the recommendations.

CERES invites all healthcare professionals to implement these recommendations to combine environmental responsibility and quality of care. At the same time, individual practitioners must tailor these recommendations to their specific clinical and organizational settings.

Area 1: Care practices: eco-responsible optimization of pharmaceuticals and MDs.

Question: For patients requiring injectable medicines, does extemporaneous preparation reduce the environmental impact without compromising patient safety, as compared to systematic pre-preparation?

Recommendation 1:
Recommendation 1.1 The experts suggest that, for patients requiring injectable medicines in the operating theater outside of emergency situations, extemporaneous preparation helps reduce the environmental impact without compromising patient safety, as compared to systematic advance preparation.
Recommendation 1.2 The experts suggest that in emergency situations requiring pre-injectable medicines, the use of pre-filled syringes, where available, helps reduce the environmental impact without compromising patient safety, as compared to systematic preparation in advance.
Expert opinion: STRONG AGREEMENT

Rationale:

Significant waste of pre-prepared injectable medicines that go unused has been reported in numerous, typically single-center, studies [1–10]. In the operating theater environment, where injectable medicine use is high, propofol, ephedrine, atropine, and rocuronium are among the agents with the highest average wastage rates [6,9]. This waste varies greatly depending on the studies and the medicines, ranging from 4% for neostigmine to 100% for adrenaline [8].

<u>**Environmental impact**</u>

According to the UK Health Alliance on Climate Change (UKHACC), the production and disposal of the active ingredients in ephedrine and rocuronium might produce around 100 kg of CO_2 equivalent per ton. An estimated emissions scale for commonly used injectable medicines assigns these values ranging from 10 (succinylcholine) to 1,000 (morphine) [11]. In addition, according to the 2014 Swedish *Environmentally Classified Pharmaceuticals* classification, propofol poses a low toxic risk to the aquatic environment, although its potential for poisoning aquatic organisms is high (scoring 3/3) due to its bioaccumulation and persistence in soil. The environmental risks associated with other injectable medicines cannot be definitively excluded [12].

When medicine residues persist in the environment, there is a risk that they will contaminate water intended for human consumption since treatment plants do not eliminate them in their entirety [13]. It is essential, therefore, to reduce the production of unused preparations at source; they must otherwise be disposed of *via* specific channels for hazardous chemical waste (*waste from medications* stream) [11,12,14]. In addition, a syringe that has been prepared and then discarded constitutes avoidable plastic waste [15].

<u>**Bacteriological risks**</u>

Advance preparation of syringes (often followed by storage in a refrigerator, which is mistakenly regarded as safe) can also pose a risk of bacterial contamination. Several studies report low contamination rates (2-3%), with limited inoculum (100 CFU/mL), consisting primarily of bacteria from skin microbiota [16–19].

Supply challenges

Supply shortages affecting injectable anesthetics, especially neuromuscular blockers, highlight the need to limit waste [20].

Several strategies can be considered to tackle these problems:

1. **Extemporaneous preparations**: Prepare medicines only when it is certain that they will be administered to the patient [11].
2. **Pre-filled syringes**: Use pre-filled syringes, especially in emergency situations, in order to reduce the risk of contamination and waste (where available)[1,5,14,15,21].
3. **Tailored medicine allocations**: Choose smaller pack sizes (*e.g.*, propofol 200 mg/20 mL, remifentanil 1 mg) to avoid throwing away unused volumes [12,15,22].
4. **Standardization and adjustment of protocols**: Prioritize preparations using entire vials, as studies have shown that this reduces medicine-induced iatrogenesis and waste, especially when there are shortages (*e.g.*, sodium heparin in syringe pumps) [22].
5. **Emergency medicines available but not opened**: Keep emergency medicines easily accessible without opening them, and avoid storing medication with similar packaging next to each other in order to minimize the risk of mistakes [11,20,23].
6. **Proper elimination of Propofol:** In cases where a propofol syringe has been prepared but is ultimately not administered, disposal through the incinerated pharmaceutical waste stream ensures appropriate elimination of propofol residues and minimizes the risk of environmental contamination, particularly soil pollution.

In addition to supporting eco-responsible practices, these measures improve patient safety and offer economic advantages [1,12].

Question: For perioperative patients capable of receiving oral administration, does the use of solid oral forms (tablets, capsules, or pouches) help minimize the environmental impact without compromising clinical effectiveness, as compared to the use of oral solutions or parenteral forms?

Recommendation 2
The experts suggest that, in perioperative patients where oral administration is possible, the use of solid oral forms for medications with the same bioavailability, regardless of the pharmaceutical form (tablets, capsules, and pouches) for delivering medicines, as compared to oral solutions or parenteral forms, helps reduce the environmental impact without compromising clinical effectiveness.
Expert opinion: STRONG AGREEMENT

Rationale:

Oral administration may not be appropriate in all perioperative situations. Intravenous administration remains necessary in patients with impaired consciousness, inability to swallow, high risk of aspiration, severe postoperative nausea or vomiting, gastrointestinal intolerance, or in emergency settings where rapid onset of action is required. In such contexts, parenteral administration is justified on clinical grounds and should not be delayed for environmental considerations. Conversely, when these contraindications are absent and bioavailability is equivalent, oral administration should be favored, as it offers a substantial reduction in environmental impact without compromising clinical effectiveness.

The administration of analgesics serves as a practical example—and helps generalize—the differentiated ecological impact of the administration routes for all medicines. A number of medicines are administered, most often parenterally, in the context of multimodal post-operative analgesia.

According to Davies *et al.*, the devices required for the intravenous administration of 1 g of paracetamol (hypodermic needles, syringes, tubing, etc.) result in the emission of 263 **g of CO_2 equivalent** and consume **6.2 L of water**. The administration of 50 mg of ketoprofen by the same route generates 256 **g of CO_2 equivalent** and uses **4.9 L of water.** In comparison, the oral administration of paracetamol (1 g) and ketoprofen (50 mg) results respectively in the emission of only **6.6 g of CO_2 equivalent** and the consumption of **1.08 L of water** for each. These figures underscore the ecological and economic value of pre-emptive analgesia, which promotes the administration of analgesics *via* the oral route during premedication [24]. In overall terms, the carbon impact of parenteral administration is estimated **to be more than 10 times higher** than for oral administration. This difference extends to all pharmaceuticals, factoring in the carbon footprint of the medicines themselves (which varies depending on the packaging: blister packs, plastic bags, or glass bottles) and the administration devices used [24].

Another study has demonstrated that oral administration of acetaminophen and ketoprofen reduces carbon emissions and water consumption significantly compared to intravenous administration. An extrapolation to the French national level could prevent the emission of 2,900 to 3,700 tons of CO_2 equivalent and save 58,000 to 74,000 m^3 of water every year [25].

Question: For patients who require sterile MDs during invasive medical procedures, does the use of sterile RMDs that comply with reprocessing regulations and protocols help minimize the environmental impact without compromising patient safety, as compared to the use of SU sterile MDs?

Recommendation 3:
The experts suggest prioritizing the use of sterile RMDs rather than SU devices in invasive medical procedures to reduce the environmental impact without compromising patient safety in the following circumstances:

1. ***Availability and compliance***: RMDs are available and meet the regulations and established reprocessing and traceability protocols, most notably compliance with the Spaulding classification and the best processing practices set out by SF2H and SF2S.
2. ***Suitable organization***: Healthcare facilities have systems in place for ensuring the suitable reprocessing of RMDs after use, including approved infrastructure and processes for cleaning, disinfecting, and sterilizing.

Expert opinion: STRONG AGREEMENT

Rationale:

Recommendations issued by the **UKHACC**, the Société Française de Chirurgie du Rachis (SFCR), and the **Société Française d'Anesthésie et de Réanimation (SFAR)** encourage the use of sterile RMDs rather than SUDs, where available and when the organization is equipped to ensure safe reprocessing[11,26,27]. For example:

- The SFCR's "Green Bloc" checklist for spinal surgery recommends prioritizing re-sterilizable devices such as suction cannulas, surgical light handles, screws, rods, and bipolar forceps [26].
- In addition, the SFAR highlights the need to encourage the use of reusable devices to reduce the ecological footprint of medical practices, provided that their reprocessing complies with safety and quality of care standards [27].

The 2022 SF2H **guide to best practices for processing RMDs** [28] reiterates that the Spaulding classification distinguishes three categories of MDs depending on the biological tissues they come into contact with:

1. **Critical MDs**: Devices introduced into the vascular system or in contact with sterile tissues or cavities must be sterilized; if sterilization is not feasible, sterile single-use devices must be used, in accordance with Article R 6111-21 of the French Public Health code [29]. If sterilization is not possible, high-level disinfection may be considered as a temporary solution.
2. **Semi-critical MDs**: Devices that come into contact with mucous membranes or damaged skin require at least intermediate-level disinfection, for example, *via* a thermal or chemical washer-disinfector or by immersion. If disinfection is carried out manually, immersion is strongly recommended over wet wiping.
3. **Non-critical MDs**: Devices that come into contact exclusively with intact skin or that have no patient contact only require low-level disinfection *via* immersion, disinfectant wipes, or thermal washer-disinfectors.

These recommendations are designed to incorporate sustainable practices into medical care while complying with safety and regulatory requirements. By integrating RMDs into an appropriate framework, it is possible to reduce the environmental footprint without compromising the quality of care [29]. Life-cycle assessment data exist showing the environmental benefit of using sterile RMDs rather than SU devices in invasive medical procedures [30,31]. In the absence of robust and standardized life cycle assessment methodologies for all medical devices, eco-responsible strategies should be tempered. Environmental considerations must never override medical decision-making or compromise patient safety. Clinical effectiveness, reliability of devices, and adherence to established safety standards remain the primary determinants of practice. Eco-responsible approaches should therefore be implemented selectively, only when the available evidence is consistent, reproducible, and demonstrates no loss of clinical performance or safety. For certain categories of medical devices, comparative studies yield divergent results depending on the device type, manufacturer, or context of use, underscoring the need for cautious interpretation. In such cases, medical judgment and patient safety must prevail, and environmental criteria should be considered as complementary—not determinant—factors in clinical decision-making.

Although reusable medical devices are promoted to reduce environmental impact, long-term data on their durability, functional performance, and failure rates after repeated reprocessing remain limited. Repeated cleaning, disinfection, and sterilization cycles—particularly high-temperature protocols used in France to mitigate the risk of prion transmission—may alter device integrity over time. Consequently, the adoption of reusable devices should be accompanied by systematic monitoring of device performance and failure rates across successive reprocessing cycles. This monitoring requires close collaboration between clinical teams, sterilization units, pharmacists, and biomedical engineers to ensure traceability, timely identification of device degradation, and withdrawal of devices when safety or reliability may be compromised. Such an approach is essential to ensure that environmental sustainability efforts never conflict with patient safety or the quality of care.

Question:
For patients scheduled for invasive interventional procedures, does reducing waste by avoiding advance desterilization of single-use or RMDs lower the environmental impact without compromising patient safety, as compared to the practice of systematic advance desterilization?

Recommendation 4:
The experts suggest avoiding advance desterilization of MDs, whether they are single-use or reusable, in order to reduce the environmental impact without compromising patient safety.
Expert opinion: STRONG AGREEMENT

Question:
For patients scheduled for invasive interventional procedures, does reducing the number of RMDs in specialized surgical procedure trays—combined with optional additional trays—help lower the environmental impact without compromising patient safety, as compared to using trays containing a large number of devices, including those used less frequently?

Recommendation 5:
The experts suggest reducing the number of RMDs in surgical trays to the bare minimum, with optional additional trays, in order to limit the environmental impact of procedures without compromising patient safety.
Expert opinion: STRONG AGREEMENT

Rationale for recommendations 4 and 5:

Between 50% and 80% of solid waste is generated before the patient enters the operating theatre [32]. Before choosing a specific item of equipment or strategy, priority should be given to cutting the number of MDs that might be wasted. This waste includes devices:

- Whose **expiration date has passed**.
- **That have been inadvertently desterilized**.
- **That have become obsolete** as a result of developments in surgical or anesthetic techniques, or a change of supplier.

<u>**RMDs**</u>

In a 2019 retrospective study by Laurut *et al.*, 6.9% of **implantable devices (IMDs) (1,995 out of 29,073) in an orthopedic surgery operating theater were desterilized without being implanted, and without the option of resterilization** [33]. A study by Bravo *et al.* into hand surgery has shown that RMDs packaged in instrumentation trays were often unused, generating an avoidable environmental and economic impact [34].

In 2022, Holland *et al.* showed that only 13 to 22% of RMDs contained in the trays were actually used. The authors recommended adjusting the composition and limiting it to the bare minimum [35]. The design of surgical trays for ancillary equipment is one solution for cutting the carbon footprint and the cost of sterilizing surgical instruments [36]. Other authors have developed a mathematical optimization model for orthopedic surgery that can be used to adjust the contents of surgical trays as a means to reduce costs and the environmental impact [37].

Cutting the number of RMDs to their strict minimum in trays used for surgical or interventional procedures, with optional additional trays, seems to be an effective strategy for reducing the environmental impact of most procedures.

SUDs

In a 2024 study conducted by pharmaceutical and obstetric anesthesia teams, revising the kits for epidural anesthesia led to an annual reduction of 425 kg of CO_2 equivalent and 400 kg of N_2O equivalent (2,354 kits) [38,39].

Planning and anticipation

1. **Pre-procedure planning**: Focus on planning only the required equipment at a short meeting with the team,[40,41] avoiding the advance desterilization of devices.
2. **Device optimization**: In digestive endoscopy, where ecological planning has resulted in a **10% reduction** in the number of devices used during the second study period [42].
3. **Interventional radiology – Digestive endoscopy**: An updated list of consumables for each intervention helps optimize practices [43] by setting apart:
   - The **MDs that need to be systematically prepared**.
   - The MDs **available as needed**.

Role of hospital staff and stakeholders

- **Dedicated staff**: Education, reminders of best practices, inventory management, and support when suppliers or MDs are changed [44].
- **Pharmaceutical team**:
  - Optimization of the ordering circuit and inventory management.
  - Standardization of practices with operators: surgeons, qualified operating theater nurses, anesthesiologists, qualified nurse anesthetists, radiologists, *etc*.
  - Streamlining MD supplies (SU, RMD, IMD) and developing intervention preparation wraps [38].

Area 2: Packaging of MDs Reviewing practices to reduce the environmental impact.

Question: For patients who require MDs, does revising sterility requirements based on their intended use help minimize the environmental impact and logistical roadblocks without compromising patient safety, as compared to systematic sterility?

Recommendation 6:
The experts suggest reassessing the sterility requirements of MDs based on their intended use with the aim of reducing the environmental impact and logistical constraints while maintaining an optimal level of safety for patients, under the following conditions: **1. Rigorous analysis of infectious risks.** **2. Identification of devices that may be apt for eco-responsible alternative solutions.** **3. Implementation of protocols tailored to specific clinical contexts.**
Expert opinion: STRONG AGREEMENT

Rationale:
The SF2H's 2022 guide to best practices re-emphasizes the Spaulding classification, which defines the three categories of MD based on the biological tissues they come into contact with (see rationale for Recommendation 3) [28].

Regarding the clinical appropriateness of the sterility of certain types of RMD as determined by their intended use:
A range of devices (including laryngoscope blades and endoscopes) is widely used in healthcare facilities due to their availability in single-use formats—whether sterile or not. The main reason is ease of use, given the constraints posed by reprocessing these MDs after use.
SU laryngoscope blades could be replaced by reusable blades, as was the case prior to the 2000s, and should not require sterile conditions given their semi-critical nature [45,46]. However, the "mad cow" crisis and the associated risk of the transmission of prion diseases *via* these blades prompted the use of single-use—or even sterile—blades for invasive procedures involving NCTA risks [47]. At present, although the incidence of new variants of Creutzfeldt-Jakob disease shows ongoing signs of decline (no cases have been reported in France since 2019), the HCSP recommends that the risk prevention measures described in Instruction 449 are still applicable. It also encourages healthcare facilities and professionals to maintain and strengthen the screening of patients and at-risk procedures [48]. Due to the carbon cost of SU devices that has to factor in manufacturing, transport, storage, and disposal, in practice, the SFAR recommends the use of reusable fiber-optic metal blades with a manufacturer's guarantee of 1,000 sterilization cycles [46]. Laryngoscope blades are managed in the same way as other reusable medical devices in the operating theatre. After use, they undergo thorough cleaning and disinfection by immersion in a detergent–disinfectant solution, followed by sterilization in a steam autoclave at 134 °C for 18 minutes (Figure 1). In Nîmes University Hospital (CHU), a prospective study with an ecological and economic objective was carried out in 2020-2021 [49]. One of the measures assessed was the transition from single-use laryngoscope blades to reusable blades. The authors of this study estimated that for an annual consumption of 17,184 blades, there would be a yearly reduction in water consumption of 222 m^3 and a reduction of 26.5 tons of CO_2 equivalent. Transitioning from SU blades to reusable blades was the second most effective measure for reducing emissions after the introduction of waste sorting at the exit of operating theaters. In addition, the same authors confirmed that after three uses, reusable

blades are the preferred option in spite of the environmental impact of the sterilization process [50].

According to the UKHACC, switching from SU to reusable laryngoscope blades could reduce the carbon footprint of these MDs by up to 50% [51].

Question: For sterile RMDs used in clinical care, does extending the UBD after sterilization—based on studies in real conditions and a risk analysis—help reduce unnecessary reprocessing while preserving sterility and safety, as compared to dates that are set empirically?

Recommendation 7:
The experts suggest extending the UBD of RMDs after sterilization in order to reduce the environmental impact, while maintaining an optimal level of safety for patients, under the following conditions: **1.** **Scientific evaluation**: Based on specific studies in real conditions demonstrating that sterility can be preserved beyond the durations currently defined. **2.** **Risk analysis**: This is carried out by the designated pharmacist to assess the steps that could compromise sterile integrity, factoring in handling, storage, and transport. **3.** **Regulatory compliance**: Based on the requirements of NF EN ISO 11607 standards and best sterilization practices. **4.** **Collaboration with manufacturers**: Request data from manufacturers confirming that the barrier properties of packaging are preserved for up to 12 months or beyond, provided there is no breakage or deterioration.
Expert opinion: STRONG AGREEMENT

Rationale:

To date, there is still little scientific data for setting the UBDs for RMDs after sterilization. At present, numerous facilities set these UBDs by applying the scale provided in the appendix to the guide for controlling reprocessing applied to RMDs [52] and the standards in the NF EN ISO 11607 series [53,54]. This dated, empirical scale is based in particular on the type of material that makes up the packaging system (containers, wraps, or sleeves), the means of transport (cabinets or bins), and the storage location of the sterile RMDs. Although highly empirical, this scale nevertheless underscores the main stages that might jeopardize the integrity of the sterile conditions: handling, transport, and storage. While the various packaging systems on the market that are employed must comply with the applicable standards [55–63], the preservation of their characteristics and properties in real-life conditions is rarely studied. These tests consist of packaging, sterilizing, and handling the RMDs on a regular basis (*e.g.*, weekly) to simulate real-world conditions and analyze the preservation of sterility over time. The percentage of sterile packs is determined at the conclusion of these analyses. In a study presented in 2016 [64], 30 treatment trays packaged in single paper and plastic pouches were sterilized, stored, and handled weekly; they were then opened after three, six, and 12 months. The results showed that sterile conditions were preserved over all the periods studied for 100% of the samples for a period of up to 12 months. Another study published in 2018 assessed the sterility of pouch and sleeve packaging (but not their contents) after different storage durations: 6, 9, and 12 months. The results showed that the sterility of the SBSs was preserved after 6 months of storage, with more mixed outcomes after 9 and 12 months. In a study published in 2024 [65], a team of researchers sought to re-evaluate the UBD of RMDs by means of a risk analysis and an assessment of the preservation of the sterile conditions of the RMDs over time.

The risk analysis identified four failures and 68 potential causes. At the same time, the methodology of standard NF EN ISO 11737-1 was employed to test the sterility of 256 RMDs [66]. The cultures retained their sterility for all the containers and folded wraps tested at six months and beyond, as well as for the pouches at two and four months and after over one year of storage [67]. Some authors even report that the integrity of surgical packaging can be preserved for at least two years [68]. These different results show that rigorously conducted tests can extend the UBDs of sterilized RMDs. Although these real-world condition tests are difficult to perform across all healthcare facilities and are not required by current standards, they can nevertheless be requested from manufacturers. Today, some manufacturers claim that the barrier properties of their packaging and sterile conditions are preserved for up to 12 months, provided the barrier is not damaged or broken. Since the failure of the sterile barrier is linked primarily to an incident rather than the aging of the materials, the designated pharmacist will determine the date following a risk analysis that factors in every stage of the RMD's lifecycle [69]. It should be emphasized that extending UBDs makes it possible to minimize the unnecessary reprocessing of RMDs that expire too early, thereby reducing the associated environmental impact (water, energy, and transport consumption).

Question: For sterile MDs, does the use of single packaging (SBS), compared to double packaging (SBS plus protective packaging), help preserve aseptic safety while simultaneously reducing the environmental impact and related costs?

Recommendation 8: **The experts suggest the following recommendations designed to reduce the environmental impact while simultaneously maintaining optimal patient safety:**
Recommendation 8.1 To prioritize the use of sterile MDs in single packaging in operating theaters when: Tests show that single packaging or an SBS provides sterility preservation equivalent to that of double-packaged devices (SBS plus protective packaging) in compliance with NF EN ISO 11607-1 standards. Single packaging almost always meets the criteria for safe use and aseptic presentation at the point of use for sterile MDs.
Recommendation 8.2 To adopt a differentiated approach depending on the context: Use single packaging in operating theaters for certain devices and in interventional areas where the environmental risks are lower. Reserve double packaging for devices at increased risk of contamination in the event that the sterility barrier is broken (*e.g.*, implants) and for sensitive invasive procedures.
Recommendation 8.3 To promote dialogue about local practices in the operating theater by reassessing the systematic need for double packaging for certain types of sterile MDs.
Recommendation 8.4 To encourage further research to assess the ecological, economic, and aseptic impact of different packaging configurations, focusing on how single packaging impacts waste reduction.
Expert opinion: STRONG AGREEMENT

Rationale:

The packaging system is defined by the NF EN ISO 11607-1 standard as the combination of an SBS and protective packaging designed to preserve sterile conditions until the point of use [53]. Its purpose is to preserve the sterility and aseptic presentation of the sterile device at the point of use. The SBS is the minimal packaging that prevents the penetration of microorganisms and enables the aseptic presentation of the product at the point of use [53]. The protective packaging is designed to prevent damage to the SBS and its contents from assembly to the point of use. These definitions apply to SUDs manufactured by the industrial sector as well as to RMDs produced in sterilization units.

The notion of "double packaging" reflects the definitions found in the Pharmacopoeia [70], where the concept of primary packaging serves as a barrier to microorganisms, and secondary packaging ensures the protection of sterile MDs in their primary packaging.

The use of the double packaging concept depends enormously on the habits and practices of users, particularly in operating theaters in France [71].

Regulation (EU) 2017/745 focuses more on the usability of MDs with the goal of eliminating or reducing the risk of contamination of RMDs and, by extension, the risk of patient infection. This objective applies equally to packaging: the NF EN ISO 11607-1 standard [53] introduced a requirement for usability evaluation for the aseptic presentation of terminally-sterilized RMDs. This requirement focuses specifically on the SBS in an attempt to reduce the risk of contamination. In addition, many SUDs (such as needles, syringes, scalpel blades, *etc.*) are presented and marketed in minimal packaging. Suppliers of SU surgical drapes also offer a range of products without "transfer squares" (crepe paper), including surgical gowns and universal sets, without in any way compromising patient safety.

For RMDs, the concept of "double packaging" is grounded in the theoretical principle of discarding the outer (protective) packaging prior to entering the operating theater in order to protect the air from environmental contamination. According to an SF2S survey, this practice is only observed in 15% of operating theaters in France [71]. Accordingly, the legitimacy of continuing this type of practice needs to be examined, especially since the use of sterilization containers for RMD packaging in reality constitutes only a single SBS. There is, therefore, a tension between the use of single rigid packaging with the sterilization containers and double packaging (two flexible packaging items, such as wraps or pouches). The concept of two bonded packaging wraps, opened simultaneously in the operating theater, is used today in many facilities. A study carried out in an Australian hospital on 1,197 sterile MDs confirmed that single-stage packaging poses no greater risk of bacterial contamination than double-packaging methods [72]. Although there is no national recommendation in support of single or double packaging for SUDs or sterile RMDs, many healthcare facilities have implemented the following dichotomy: using double packaging in operating theaters and single packaging in care units or interventional settings. Analyzing the real needs in operating theaters could drastically reduce the environmental impact and amount of waste generated, particularly since blue sterilization wraps alone account for 19% of operating theater waste in the United States [73].

In Nîmes University Hospital (CHU), a prospective study with an ecological and economic objective was carried out in 2020-2021 [49]. One of the measures evaluated was the discontinuation of double packaging of MDs for almost 4,000 kits used in urological and general surgery. This measure led to an annual reduction of 511 kg of CO_2 equivalent.

Question: For MDs**,** does the choice of packaging tailored to the frequency of use and user practices help preserve aseptic safety while simultaneously reducing the environmental impact, as compared to standardized packaging not specific to local practices?

Recommendation 9: **The experts suggest the following recommendations designed to reduce the environmental impact while simultaneously maintaining optimal patient safety:**
Recommendation 9.1 To tailor the packaging of MDs to usage practices by assessing the weight and size of packaging in order to minimize the materials used without compromising the quality and safety of the devices; and by optimizing packaging based on the frequency of use and the specific requirements of local users.
Recommendation 9.2 To encourage manufacturers to design eco-responsible packaging by prioritizing recyclable or low environmental-impact materials as well as reducing the overall weight of the packaging.
Recommendation 9.3 To promote the international standardization of packaging practices for MDs distributed globally in order to limit superfluous over-packaging.
Recommendation 9.4 To introduce environmental impact studies on packaging as a tool for guiding manufacturers in their choices and to encourage the transition to sustainable packaging.
Expert opinion: STRONG AGREEMENT

Rationale:

The manufacturer should choose the packaging of health products in sync with the frequency of use and the practices of users. The key difficulty is rooted in the fact that health products are not always exclusively reserved for distribution in France (this is especially the case for MDs, often manufactured by multinational companies in factories located far from their points of use). Pioche *et al.*, in their study on the environmental impact of endoscopic capsules, showed that the weight and carbon footprint of these MDs, regardless of the suppliers, were, for the most part, linked to packaging. In fact, the weight of the packaging of these MDs ranges from 43g to 74g, and from 0.25kg to 0.35kg of CO_2 equivalent, depending on the suppliers. The capsule itself weighs 4g regardless of the product reference, with a carbon footprint of 0.04kg in CO_2 equivalent during the manufacture of the device and 0.4kg in CO_2 equivalent during its transport to the healthcare facility [74]. Similar results have been reported for intraocular implant packaging, with the weight varying from 29 g to 80 g [75].

Question: For **implantable and non-implantable** MDs, do electronic instructions accessible *via* QR codes help minimize the environmental impact while ensuring convenient, secure access to instructions for use, as compared to systematically-provided printed instructions?

Recommendation 10: **The experts suggest the following recommendations designed to reduce the environmental impact while simultaneously ensuring easy, safe access to instructions for use:**
Recommendation 10.1 To replace printed instructions for implantable and non-implantable MDs with electronic instructions of use (eIFU) wherever this is permitted by European regulations, in particular by: - Encouraging the use of QR codes on MD trays for quick access to electronic instructions. - Providing an option to request a paper version of the instructions for users who may need it.
Recommendation 10.2 To restrict the number of printed instructions when they are still necessary by recommending a single printed set of instructions per tray containing several devices, instead of one leaflet per unit.
Recommendation 10.3 To work closely with manufacturers to fast-track this transition.
Expert opinion: STRONG AGREEMENT

Rationale:

Manufacturers' instructions detailing the IFU are needed by users. They are often multilingual and use large amounts of paper. Given the worldwide shortage of paper, they should be replaced by their electronic equivalent.

European regulations allow this under Commission Implementing Regulation EU 2021/2226, which lays down the rules for implementing Regulation (EU) 2017/745 of the European Parliament and of the Council [76]: "Instructions for use displayed electronically by the device, stored on portable electronic media provided by the manufacturer with the device, or made available *via* software or a website." The FDA in the United States anticipates that the Center for Devices and Radiological Health (CDRH) will authorize manufacturers to supply the required user information in commonly used electronic formats, such as Adobe Acrobat® or Rich Text Format®. Manufacturers may provide the required information as a downloadable file from a website, on a compact disc (CD), or by means of another commonly used storage medium (*e.g.*, an external USB drive), provided it is made directly accessible to the purchaser of the product.

For implantable MDs, it is now permitted to provide instructions *via* an eIFU QR code, thereby eliminating the need for a paper leaflet. However, it must be possible to provide printed instructions on request. It is of vital importance to ask manufacturers to provide these eIFU for implantable devices and to insist that the same approach is also used for non-implantable devices since this would result in significant paper savings. Where a QR code is not provided, manufacturers should revise their packaging practices by including a single printed instruction per tray containing multiple units rather than one notice per MD (if this is not already the case).

The weight of non-preloaded intraocular lens (IOL) packaging ranges from 29 g (Zeiss Lucia®) to 80 g (RxSIGHT LAL®); a substantial part of the weight of IOL packaging is attributable to the paper IFU [75,77].

Although electronic instructions for use may reduce paper consumption and transport-related impacts, digital storage and access also have an environmental footprint related to energy use and data infrastructure. Comparative life-cycle assessment data between printed and electronic formats in healthcare remain limited. Consequently, this recommendation is primarily supported by regulatory developments and the expected reduction in material use, while acknowledging the need for further life-cycle analyses.

Question: For invasive MDs used **in the form of standard sets or custom packs,** does periodically evaluating the clinical appropriateness of their composition based on user needs and evolving practices help minimize the environmental impact, lower hospital costs and address clinical needs more effectively, as compared to a lack of systematic re-evaluation?

Recommendation 11: **The experts suggest the following recommendations designed to reduce the environmental impact and cut hospital costs while simultaneously meeting clinical needs:**
Recommendation 11.1 To conduct a periodic assessment of the clinical appropriateness of custom packs in consultation with the relevant users and stakeholders in order to: o Tailor their composition to the real needs of users and to changes in medical practices. o To identify and dispose of unused components in order to reduce waste and related costs.
Recommendation 11.2 To promote the design of ecological and economical custom packs by: o Prioritizing materials with low environmental impact, such as recyclable polypropylene, and by restricting the use of cotton textiles to essential situations only. o Optimizing pack size and weight.
Recommendation 11.3 To deploy performance monitoring for custom packs by measuring: o Their environmental impact (reducing waste, CO_2 emissions, and water consumption). o Achieving savings in operating theater costs and preparation time. o User satisfaction regarding their suitability for clinical needs.
Recommendation 11.4 To anticipate needs and secure supplies by: o Working closely with suppliers to avoid shortages of "custom" sets that are strictly specific to one facility. o Preparing alternatives in the event of changes in practices or the composition of packs.
Expert opinion: STRONG AGREEMENT

Rationale:

The standard set or custom pack consists of a selection of predefined MDs for use during surgical procedures. This industrial assembly combines the MDs strictly needed for an intervention in a single package in order to limit the use of items presented in individual packaging. By limiting the number of individual packages, these custom packs help standardize practices *via* the pre-selection of MDs. They also save time during preoperative preparations and reduce the volume of packaging waste [78].

A 2022 study was designed to reduce operating theater waste, improve the environmental impact, and save the hospital money. A total of 35 general surgery operations were tracked using two standard packs ($89.51 or $93.68 per case, with each weighing 23.2 pounds). The new pack ($46.88 per case, 20.8 pounds) was subsequently used successfully in 9 cases. The projected savings from replacing the new pack were $45,719 a year, with an annual waste reduction of 2,437 pounds. In this way, single, practical adjustments to standard single-use surgical packs can have a significant impact on waste reduction and generate cost savings [79].

Another study investigated the design and environmental impact *via* a lifecycle analysis of 15 delivery packs from different hospitals in the United States [80]. Each of the custom packs was weighed and categorized according to the composition of the materials. The average weight was 1.25 kg, consisting of 58% polypropylene (PP) and 20% textiles (towels, gauze, and compresses). The lifecycle analysis of each of the items shows that cotton textiles account for the highest environmental impact, even though they weigh less than PP.

In Nîmes University Hospital (CHU), a prospective study with an ecological and economic objective was carried out in 2020-2021 [49]. One of the measures assessed aimed to reduce the weight of waste. The authors of the study estimated that, for a total of 1,500 packs used in neuro, digestive, and gynecological surgery, there would be an annual reduction in emissions of 1,800 kg CO_2 equivalent and approximately 50m^3 of water consumption.
The use of new custom packs must be coordinated with users in order to meet their needs; it must also be reassessed on a regular basis with all stakeholders in response to changes in practices and supplier offerings. The potential risk would be to generate waste inadvertently due to a composition that is unnecessary and unsuitable for all users.
It follows that staff support must be anticipated when deploying the sets. It is often more difficult to remove unnecessary components than to add new ones. Custom packs can be another disproportionate source of waste; redesigning them can reduce excess waste and related costs. It is also important to remain alert to "custom" sets that are produced strictly for a single facility due to the potential consequences of supply shortages.

Area 3: Organization of care: integrating environmental criteria into management strategies.

Question: In healthcare facilities, does incorporating environmental criteria into the **strategy for purchasing medicines and MDs** help minimize the environmental impact while simultaneously maintaining the quality and safety of care, as compared to a procurement strategy based exclusively on cost and clinical performance criteria?

Recommendation 12: **The experts suggest the following recommendations designed to reduce the environmental impact and cut hospital costs while simultaneously meeting clinical needs:**
Recommendation 12.1 To incorporate environmental criteria into purchasing strategies by evaluating offers on environmental indicators such as: o The environmental impact of production, packaging and transport. o The quantity and type of waste generated after use. o The availability of collection and recycling pathways for used products.
Recommendation 12.2 To encourage collaboration with suppliers by negotiating solutions to reduce needless packaging and offer formats tailored to real needs.
Recommendation 12.3 To prioritize grouped and local purchases wherever possible to minimize transport and logistics-related impacts.
Expert opinion: STRONG AGREEMENT

Rationale:

A 2023 report published by The Shift Project think tank assesses GHG emissions arising from **purchases of MDs** at **10.2 Mt of CO2 equivalent**—*i.e.*, over **21% of emissions from the health sector [81].** Staff can minimize these emissions, in particular purchasing managers, who play a pivotal role in selecting products. Purchasing is the **cornerstone of an eco-design approach to healthcare** since it directs the sourcing of health products and shapes the volume of waste generated.

As part of the quest for efficiency in public procurement, environmental criteria combining sustainable development and economic viability should be prioritized. It is possible to promote sustainable purchasing by incorporating additional, simple, and easily-documented environmental criteria that help limit costs for both the supplier and buyer [82].

<u>**Eco-design based on standard ISO 14062**</u>

According to ISO 14062, eco-design aims to "integrate environmental aspects into the design and development of products" [83]. This process draws on a global analysis of the **lifecycle of products**.

All health products follow a lifecycle based on the concept of “from the cradle to the grave” [84]: extraction of raw materials, design, infrastructure (including construction and maintenance of production tools, and water and energy consumption), research and development activities, marketing and regulatory matters, supply chain, use, and disposal. It is crucial to include strategies from the point of purchase of health products **that promote**: **reuse**, repurposing, **recycling,** and even **valorization**.

Challenges of responsible purchasing

Responsible purchasing involves close collaboration between companies that manufacture healthcare products, purchasers, and the operators who perform surgical or interventional procedures. While waiting for a carbon or environmental toxicity scoring system for every healthcare product, buyers should incorporate environmental criteria when assessing offers [80]. Piffoux *et al.* suggested a scoring system for the “smallest tray of medicines” for a given active ingredient based on a given pharmaceutical formulation (factoring in excipients) in order to compare the carbon footprint of medicines (so-called solid forms) [85].

These criteria may include:

- The **distance between the production and formulation sites for pharmaceuticals or the sterilization site for sterile MDs, and the place of consumption or use**.
- **Supply chain optimization**
- **Packaging tailored** to the intended use (*e.g.*, a tray of 50 dressings for a foreseeable 7-day treatment or packaging medication in a tray of 30 tablets for treatments that typically require 14 tablets).
- The **type and total weight of plastic waste** generated after use.
- The availability or provision of a **collection, recycling, or recovery channel**.

The circular economy concept applied to healthcare

The basic concepts of the circular economy must be applied to health products based on this order of priority [86]:

1. **Refuse**
2. **Reduce** (without needless substitution!)
3. **Reuse**
4. **Recycle**
5. **Repair before recycling**

Question: Does the active participation of healthcare professionals in the eco-design of care help reduce the environmental impact without compromising the quality and safety of clinical practices, as compared to their non-participation?

Recommendation 13: **The experts suggest the following recommendations designed to reduce the environmental impact and cut hospital costs while simultaneously meeting clinical needs:**
Recommendation 13.1 To actively involve healthcare professionals in the eco-design of care by: • Involving staff in the assessment of real needs to tailor the choice of products and practices to clinical uses. • Raising awareness among staff about environmental issues *via* training and communication activities.
Recommendation 13.2 To promote the adaptation of clinical practices by: • Restricting the use of non-essential or redundant pharmaceuticals and devices. • Conducting periodic reviews of practices to identify areas for ecological improvement.
Recommendation 13.3 To deploy monitoring tools aimed at identifying and reducing unnecessary procedures by prioritizing the analysis of professional practices.
Recommendation 13.4 To support local initiatives by prioritizing pilot projects driven by healthcare professionals in order to test and validate eco-responsible solutions tailored to the clinical context.
Expert opinion: STRONG AGREEMENT

Rationale:

Building the circular economy into the purchasing strategy for health products is essential but does not go far enough. It is the duty of every healthcare professional to **rethink their practices** and for every healthcare facility to support **organizational and procedural changes** in order to reduce the environmental impact of care delivery.

<u>**Organizational changes**</u>

Given the complex nature of healthcare procedures and the multiplicity of stakeholders, changes must be considered in **a multi-professional framework** while also safeguarding the quality and safety of care. These developments include:

- The **choice of RMDs,** tailored to post-use processing capacities (high-level disinfection and sterilization), active patient lists, and circuits.
- **The choice of medical equipment that supports eco-responsible practices,** including its installation with the aim of ergonomic optimization and reducing consumable volumes (positioning of respirators and syringe pumps, pooling of suction jars, and the selection of injectors and contrast products).
- **Anticipating MD needs**, including IMDs, with the emphasis on resource efficiency.
- **Planning** surgical and interventional procedures while anticipating cancellations to optimize the use of the technical platform [86].

The SFAR and SF2H experts recommend using specific reusable clothing, including headgear and footwear, in order to reduce their environmental impact while complying with infection prevention requirements [87]. Several studies have shown that the establishment of dedicated "green teams" in operating rooms, combined with structured staff education, can effectively promote changes in clinical practices and reduce the environmental impact of care. These initiatives have been associated with modifications in anesthetic strategies, including the discontinuation of high-impact volatile agents, reduced use of halogenated anesthetics, and broader adoption of low-emission practices, without compromising patient safety or quality of care. Such multidisciplinary approaches support behavioral change, facilitate local ownership of sustainability initiatives, and represent an effective organizational lever for implementing eco-responsible practices in perioperative settings [88].

Some sterile SUDs can be reloaded several times during the same procedure [89]. For example:

- **Rechargeable clips**: A rechargeable clip applicator weighing 4 g can place 5 to 10 clips, whereas its single-use equivalent produces 86 g of waste per use.
- **Plastic prostheses**: Reloading one carrier for multiple prostheses cuts waste compared to using pre-assembled devices (*i.e.*, multiple individual carriers).

In radiology, pairing multi-patient injectors with multi-dose vials of contrast agents helps reduce waste from unused volumes. This addresses an issue identified by 163 radiologists after packaging had been reduced and products recycled [90–92].

These initiatives, shared among professionals, are of vital importance for cutting the environmental impact without compromising the quality and safety of patient care [49].

<u>Changing habits in the care pathway</u>

At each stage of the care pathway, several levers can be used to adjust practices and behaviors:

- **Team dynamics**: Enhanced collaboration and communication among healthcare professionals fosters a more rational, responsible use of medical products.
- **Awareness-raising**: Educational initiatives designed to provide surgical staff with information about the climate impact of surgery are one of the most effective levers for lowering the carbon footprint of surgical care.
- **Organizational commitment**: The introduction of "eco-responsible" teams headed by multi-disciplinary leaders is an effective strategy for launching a sustainability program in surgery [93].

Question: Does the take-up of eco-responsible practices that incorporate responsible resource management help minimize the environmental impact without compromising the quality of care?

Recommendation 14: **The experts suggest the following recommendations designed to reduce the environmental impact and cut hospital costs while simultaneously safeguarding the safety and quality of care for patients:**
Recommendation 14.1 To optimize the use of resources in healthcare. o To reduce water consumption. o To prioritize biodegradable or low-environmental impact products. o To pool equipment where feasible.
Recommendation 14.2 To encourage medical-ecological innovation: o To support research into the environmental impact of medical practices and health products. o To promote therapeutic choices that reduce ecological impacts while delivering equivalent quality of care.
Expert opinion: STRONG AGREEMENT

Implementation of eco-responsible practices

Each surgical handwash using traditional soap consumes an average of 18.5 L of water per wash. In a facility performing 15,500 annual interventions, using hydroalcoholic products (HAPs) would save 931,938 L of water every year [94]. The use of hydroalcoholic products is associated with a substantial reduction in water consumption and wastewater generation compared with traditional handwashing. However, comprehensive life-cycle assessment data comparing hydroalcoholic products with soap-and-water hand hygiene remain limited. Consequently, while water savings are well documented, further studies are needed to evaluate the overall environmental balance, including the production, packaging, and disposal of hydroalcoholic solutions.

The SFED also suggests measures for minimizing water consumption during the processing of endoscopes [95]. Moreover, many surgical professional bodies—such as the SFCR—recommend following the recommendations of the SF2H in their “Green Bloc” checklist: avoiding cleansing the skin if it is healthy, prioritizing washing with PHA after a single water rinse, and reducing unnecessary anatomopathological samples [96,97].

The SFAR and SF2H experts recommend using specialized reusable garments, including headgear and footwear, to reduce the environmental impact of clothing while meeting infection prevention requirements [87].

Low-impact equipment, medicines, and MDs

The polyethylene glycols (PEGs) widely used in colonic preparations are not biodegradable, whereas magnesium picosulfate and magnesium citrate are. Research is required to assess whether substitution does or does not reduce the impact of colonic preparations [98].

Some sterile SUDs can be reloaded several times during the same procedure [89].

For example:

- **Rechargeable clips**: A rechargeable clip applicator weighing 4 g can place 5 to 10 clips, whereas its single-use equivalent produces 86 g of waste per use.
- **Plastic prostheses**: Recharging one carrier for multiple prostheses reduces waste, as compared to using pre-charged devices.

In radiology, the number of unused volumes can be reduced by using multi-patient injectors combined with multi-dose vials of iodinated contrast products. This addresses an issue identified by 163 radiologists following the reduction of packaging and the recycling of products [90-92].

Question: Does assessing the clinical appropriateness of interventional procedures help reduce the environmental impact without compromising the quality of care and patient safety?

Recommendation 15: The experts suggest the following recommendations designed to reduce the environmental impact and cut hospital costs while simultaneously safeguarding the safety and quality of care for patients:
Recommendation 15.1 To reduce unnecessary medical procedures by applying national and international clinical recommendations strictly.
Recommendation 15.2 To raise awareness among healthcare professionals about the ecological impact of unnecessary actions, particularly regarding consumption, waste generation and carbon footprint.
Recommendation 15.3 To deploy monitoring tools aimed at identifying and reducing unnecessary procedures by prioritizing the analysis of professional practices.
Expert opinion: STRONG AGREEMENT

Rationale:

Precision medicine that adheres rigorously to the recommendations and which does not use superfluous tests or unnecessary precautions would make a significant contribution to reducing the environmental impact of our practices while safeguarding patient safety [99]. Given the complex nature of the procedures and the diverse profiles of the actors, it is important to plan evolving practices as part of a multi-professional approach, while simultaneously guaranteeing the quality and safety of patient care. These measures include reassessing the clinical appropriateness of medicine prescriptions and medical procedures (such as biological or anatomical pathological analyses [100,101] or endoscopic procedures [102]) by incorporating environmental indicators [103].

A 2018 retrospective study conducted in Vancouver analyzed biological samples taken from patients admitted for emergency visceral surgery. Among 83 patients with no acute complications, it was estimated that the samples taken for three out of four patients were not required [104]. Biological and histological analyses have a substantial ecological and economic impact. They are considered unjustified in over 20% of cases for digestive biopsies, according to Gordon *et al.* [100]. Forty-nine percent of preoperative hemostasis tests for tonsillectomy do not adhere to the recommendations and are considered unnecessary [101]. Reducing these unnecessary samples would cut the use of SUDs such as forceps, trocars, and needles, as well as bottles of preservative solutions (formalin) and personal protective equipment for healthcare professionals [100].

In digestive endoscopy, 56% of gastroscopies and between 23% and 52% of colonoscopies are considered avoidable [105]. The Société Française d'Endoscopie Digestive (SFED) defines an unnecessary endoscopic examination as [43]:

- a procedure that is known not to change a patient's health status or therapeutic decision;
- a procedure that could be replaced by a non-invasive alternative;
- a procedure with an unfavorable benefit-to-risk ratio.

In radiology, following the recommendations strictly for imaging examinations (*e.g.*, ultrasound, CT, or MRI) not only reduces costs and waste, but also avoids unnecessary additional examinations and consultations. A U.S. study showed that 52% of emergency scans for assessing acute pancreatitis were unnecessary and had no effect on the length of hospital stay. These non-essential tests incur an annual cost of $1 million [106]. It is also vital to prioritize imaging methods that have the lowest environmental impact, provided they offer equivalent diagnostic quality. According to the American College of Radiology, reevaluating imaging practices could see 48% of patients undergoing more environmentally-friendly exams, in the process reducing annual U.S. energy consumption by 24 to 240 million kWh [107]. Optimizing examination protocols—such as those used in CT imaging—through collaboration among application engineers and radiologists helps reduce the carbon footprint, electricity consumption, and costs. In 2020, the lack of a "standby" or "off" mode for radiology equipment led to an energy loss of 49 TWh in Europe. Activating these modes after one hour of inactivity could cut consumption by 45% [108].

Each surgical handwash using traditional soap consumes an average of 18.5 L of water per wash. In a facility performing 15,500 annual interventions, using hydroalcoholic products (HAPs) would save 931,938 L of water every year [94]. The SFED also suggests measures aimed at limiting water consumption during the processing of endoscopes [SFED]. Moreover, many professional surgical bodies—such as the SFCR—recommend following the recommendations of the SF2H in their "Green Bloc" checklist [96]: avoiding cleansing the skin if it is healthy, prioritizing washing with HAPs after a single water rinse, and reducing unnecessary anatomopathological samples.

Optimizing operating programs by cutting the number of cancellations and anticipating unforeseen events reduces energy consumption. **Changes in habits and behaviors** can be introduced on the basis of **recommendations made by recognized professional bodies at each step of the care pathway**. They act as a guide for developing eco-responsible practices, particularly in areas such as digestive endoscopy, where pilot projects—*e.g.*, procedure planning and pre-procedure briefings—have been shown to reduce carbon emissions by 10% [27,42,87].

Question: Can optimizing the logistics flows of medicines and MDs, including centralizing stocks and limiting the number of urgent orders, help reduce the environmental impact and costs while ensuring the availability of essential care products?

Recommendation 16: **The experts suggest the following recommendations designed to reduce the environmental impact and cut hospital costs while simultaneously meeting clinical needs:**
Recommendation 16.1 To streamline the internal logistics circuit by deploying: o Centralized logistics platforms tailored to the specific needs of facilities. o Order recommendation software to limit supply-related failures.
Recommendation 16.2 To cut the volume of urgent orders by limiting them exclusively to unforeseen needs rather than to compensate for structural weaknesses in the supply chain.
Recommendation 16.3 To establish partnerships with suppliers designed to optimize transport in order to reduce empty hauls and minimize CO_2 emissions.
Expert opinion: STRONG AGREEMENT

Rationale:

Optimizing the logistics flows of medicines and MDs depends on adapting to the infrastructure and resources specific to each healthcare facility, such as logistics platforms, centralized storage, or the use of order recommendation software.

Limiting urgent orders

Rigorous order management is crucial. Urgent orders, which are handled by the pharmaceutical team, should respond as a priority to unforeseen needs rather than to supply chain failures. By reducing these orders, facilities cut costs and reduce the carbon footprint associated with multiple, unscheduled deliveries. Although healthcare-specific life-cycle assessment data are limited, optimizing logistics by reducing multiple unscheduled deliveries is expected to lower transport-related emissions and packaging waste. This recommendation is therefore based on established principles of sustainable supply chain management, while acknowledging the need for future quantitative assessments.

Partnerships for environmentally-responsible logistics.

Many suppliers nowadays offer logistics flow optimization solutions that form part of an economic and ecological approach. These “win-win” partnerships benefit healthcare institutions and suppliers alike:

- **Planning and anticipating supplier orders:** to reduce the impact of transport by limiting the number of journeys required and optimizing the load capacity, thereby avoiding near “empty” shipments.
- **Reducing packaging materials**: to cut the use of plastic for protecting MDs (padding) and limiting the amount of cardboard packaging.

In addition to reducing the ecological footprint left by facilities, this approach prioritizes more sustainable management of resources while guaranteeing the continued quality and availability of products.

Area 4: Waste management Reduction and repurposing of healthcare waste.

Question: Does the reduction, systematic sorting and repurposing of waste generated by MDs and health products help lower the environmental impact while simultaneously safeguarding health safety?

Recommendation 17: The experts suggest the following recommendations designed to reduce the environmental impact while simultaneously safeguarding health safety:
Recommendation 17.1 To reduce waste at source by limiting the use of non-essential MDs and packaging, and prioritizing reusable or rechargeable MDs whenever possible.
Recommendation 17.2 To implement systematic waste sorting by installing clearly-marked sorting bins near care areas and by raising awareness and training healthcare professionals about the importance of sorting and the available recycling streams.
Recommendation 17.3 To prioritize waste repurposing in close collaboration with suppliers and recyclers to facilitate the recycling of plastics, metals, and other materials.
Recommendation 17.4 To promote cutting-edge solutions, such as recycling single-material plastics and sterilization devices or packaging made from polypropylene.
Recommendation 17.5 To support changes in the regulations by advocating for legislation that encourages simplified packaging and by promoting clear information on the recyclability of devices and their packaging.
Expert opinion: STRONG AGREEMENT

Rationale:

The circular economy is founded on the principles of minimizing the consumption of primary resources and cutting waste. A product's circularity potential, including its packaging, will rely on the ability of operators to sort it and recycle the materials contained in it [109]. For healthcare products, operators could opt for ranges and suppliers that, for the equivalent quality of care, prioritize product lines that generate less waste and environmental toxicity or offer potential for repurposing. This is what the UKHACC suggests in Recommendation R6.7 on optimizing waste, with training activities for surgical and anesthesia teams on sorting and selecting the appropriate channel, as well as choosing contracts with suppliers capable of recycling healthcare products—including their packaging—with recycling potential and facilities [85].

Sorting

Waste sorting is a prerequisite for recycling or repurposing. It is important to remember that Decree No. 2016-288 of March 10, 2016, known as the "5-stream sorting obligation decree", requires the sorting at source of non-hazardous waste in five categories: plastics, paper/cardboard, glass, wood, and metals. This obligation was reinforced by Decree No. 2020-950 of July 16, 2021, and will be expanded, from January 1, 2025, to include textile waste [110].

In Nîmes University Hospital (CHU), a prospective study with an ecological and economic objective was carried out in 2020-2021 [49]. One of the measures assessed was designed to optimize waste sorting at the exit point of rooms. Based on a total of 21,000 clinical interventions, the authors of the study estimated there would be an annual reduction in emissions of 169 tons of CO_2 equivalent and approximately 250 m^3 of water consumption. This measure alone makes it possible to cut emissions by over 80%.

The barriers to recycling identified among health professionals responsible for waste sorting include: lack of time, insufficient training and motivation, fear of infectious contamination, and inadequate space for bins and containers. Labeling sorting bins, combined with ongoing staff training, is essential to the success of recycling programs.

Recycling

Plastic recycling rates are estimated at 30% in Europe and 15% globally. The difficulty in recycling plastics from healthcare products is due primarily to the fact that MDs often consist of different types of plastics: their composition (including additives), recycling techniques and potential, and CO_2 and N_2O emissions during incineration vary from one plastic to another [78]. Polyethylene terephthalate (PET) is a recyclable plastic that accounts for around 40% of the plastics found in an operating theatre [111].

Furthermore, the process of reducing weight may go hand-in-hand with a transition to more complex materials with a more toxic carbon footprint. Clear labeling would make it easier to sort and recycle waste.

For single-use sterilization packaging, there is a distinction between wraps and pouches and paper/plastic sleeves, two materials that are generally difficult to separate, which makes it harder to sort them in the operating theater and complicates their recycling possibilities. The packaging wraps are made mainly of polypropylene (PP), which allows them to be recycled for other uses ("downcycling"). In the United States, these blue sterilization wraps account for up to 19% of total operating theater waste, generating substantial disposal costs [32]. A 39-day pilot study conducted in a neurosurgery unit in Florida collected 1,247 pounds (565 kg) of sterilization wraps, which were then resold to recyclers for a saving of almost $32,000. The authors extrapolated this potential benefit to the entire hospital, estimating $174,240 in annual cost savings [32]. Another prospective study conducted in Cork Hospital's maternity ward in Ireland estimated that 711 kg of PP wraps could be recycled annually in their gynecology block, equivalent to 2.2 tCO_2 equivalent [32]. While it is now becoming technically and economically feasible to recycle sterilization packaging wraps, the use of reusable containers, whose environmental equivalence is achieved after 68 uses [112], is an attractive alternative for minimizing the environmental impact of sterilization packaging.

Repurposing

Repurposing channels cover stainless steel, aluminum, copper, and even precious metals.

If a packaged MD has been opened by mistake and desterilized, it can nevertheless still be used in training conditions, for example, procedural simulations on models. This avoids the need for new sterile MDs for these training sessions—thereby reducing their environmental impact—when the devices used are often the same as in clinical practice (sterile, with multiple layers of packaging, instructions, *etc.*) [113].

Gadolinium-based contrast agents injected during CT scans or MRI are quickly excreted through the urinary system, with the gadolinium then finding its way into wastewater, generating environmental toxicity. Procedures for collecting patient urine up to 4 hours after injection have been implemented or are under evaluation with the provision of dedicated containers and the organization of a circuit involving the reprocessing of patient urine. The potential for recovery is real: 85% of the gadolinium found in contrast products urinated by patients is released into the natural environment [108].

Repurposing, combined with energy cogeneration resulting from the incineration of waste (as is the case of plastics), may also involve repairing MDs [78]. The UKHACC advocates repairing and recycling, in particular for steel MDs such as surgical scissors (MAYO, METZENBAUM), which, if refurbished, could cut the carbon footprint by 20%. However, this advantage is offset by the additional carbon footprint generated by transport to the repair facility and the re-certification of the MD [32].

In practice, although there are a number of pathways and bodies for recycling and repurposing MD waste and packaging, significant efforts are still required to make recycling easier. It is difficult at times to obtain information about the recyclability (or not) of MDs and/or their packaging. The compositions are often complex with multi-material plastics, making recycling impossible. Forthcoming regulatory developments (including the implementing decrees of the AGEC law[114]) will need to move towards boosting recycling possibilities. Nevertheless, we should remember that recycling is not the perfect solution for reducing the environmental footprint: the process itself requires the use of energy resources (for waste transportation and treatment) and, as the saying goes, "the best waste is waste that is not generated".

Lastly, implementing a repurposing circuit helps bring different health professionals together around a common, ethical cause, while also contributing to the social dimension of sustainable development.

Question: Does limiting the production of IHW through the strict application of its definition help reduce the environmental impact and costs without compromising health safety?

Recommendation 18: **The experts suggest the following recommendations designed to reduce the environmental impact while simultaneously safeguarding health safety:**
Recommendation 18.1 To apply the regulatory definition of IHW strictly by classifying as such only waste that poses a real, documented risk of infection in accordance with the recommendations of the High Council for Public Health (HCSP).
Recommendation 18.2 To convert certain types of IHW into non-hazardous healthcare waste (NHHW), where possible, by employing neutralization techniques (e.g. crushing and disinfection) for waste without proven infectious risk; and by solidifying non-pathogenic biological liquids using gelling powders to integrate them into the NHHW stream.
Recommendation 18.3 To train staff in good sorting practices by distributing educational tools on the distinctions between IHW and NHHW, and by fostering a culture of rigorous sorting tailored to a facility's local requirements.
Recommendation 18.4 To conduct regular audits that verify the conformity of waste sorting and classification practices, identify opportunities for reducing IHW, and evaluate possibilities for recycling or recovering NHHW.
Expert opinion: STRONG AGREEMENT

Rationale

Healthcare waste (HCW) may have infectious, radioactive, cytotoxic, and chemical hazardous properties. Waste that does not have these dangerous properties is called non-hazardous healthcare waste (NHHW, formerly called household and similar waste). IHW has a considerable environmental cost and produces three times as much GHG as NHHW [115].

Two main elimination channels are possible for infectious healthcare waste:

Incineration: This consists of thermal treatment by incineration at 850°C. The energy generated during combustion is typically repurposed.

Neutralization: This involves pre-treating waste using disinfection devices (shredding followed by physical or chemical disinfection) so that the "neutralized" residue can subsequently be disposed of *via* the NHHW stream (*i.e.*, incineration or landfill).

Three main means of elimination are possible for NHHW:

Incineration: The methods (thermal combustion at 850°C) are the same as for infectious healthcare waste, but the environmental footprint and economic cost of this stream are lower, particularly due to non-specialized transport.

Landfill disposal: waste stored in a dedicated site following compaction.

Recycling and repurposing: HCW defined as non-hazardous must respect the facility's selective sorting channels in order to comply as a minimum with Decree No. 2016-288 of March 10, 2016, known as the "5-stream law": paper/cardboard, metal, plastic, (non-medical) glass and wood; and Decree No. 2021-950 of July 16, 2021, also known as the "5-stream law" [110]: paper/cardboard, metal, plastic, glass, wood and mineral and plaster fractions in the event of construction work. As of 2025, the "textiles" stream has been added. In fact, packaging in the broad sense of MDs should, wherever possible, be systematically sorted within the facility if its composition corresponds to one of these streams. Finally, the WEEE directive of July 4, 2012 [116] on the disposal and recycling of electrical and electronic equipment waste also applies to healthcare facilities. In theory, MDs that feature electronic components are eligible for this stream.

It should be noted that the disposal of some types of MD may also fall under specific provisions related to their toxicity: waste with chemical and toxic risks, radioactive waste, or even anatomical parts (Infectious Healthcare Waste Technical Guide [117]). Moreover, pharmaceutical residues, if not disposed of in a suitable pathway, are a source of environmental pollution [118].

Adapting the definition of IHW to comply with the regulations

In accordance with the regulations, and in the context of its waste sorting and treatment policy, each facility may define—and precisely classify—healthcare waste based on its potential infectious risk with the goal of reducing the volume of infectious healthcare waste generated.

The wording of the French regulations regarding the definition of infectious healthcare waste is particularly broad. It is based more on the potential danger than on the estimated risk, leaving room for various interpretations. The following are mandatorily considered IHW:

- Injury-causing waste posing a risk of harm: sharp or cutting materials and equipment intended for disposal, regardless of whether or not the waste has been in contact with a biological product, must be discarded in specific collectors complying with the NF EN ISO 23907-1 standard [119].
- Blood products for therapeutic use that have not been fully used or that have expired.
- Human anatomical waste, including fragments of human tissue that are not easily identifiable.

In its June 2023 Opinion, the HCSP provides [120] a definition that characterizes the infectious risk of HCW: "Infectious risk waste (biological hazard) encompasses waste generated by healthcare activities that originates from a source of active proliferation of pathogenic biological agents (groups 2 to 4) (infectious source or microbial colonization). Infectious risk waste also encompasses healthcare waste that is heavily impregnated with blood, secretions, or excretions with a risk of leakage". However, the HCSP points out in its rationale that the prevention of biological risks is based on a sound knowledge of work situations and the transmission chain, including its different links (reservoir, exit, transmission route, entry point, and potential host). In addition, the HCSP reiterates that household and similar waste mainly contains non-pathogenic micro-organisms (group 1 classification), and occasionally group 2 pathogenic agents that are widespread in communal environments (staphylococci, streptococci, and *pseudomonas*).

It also highlights the need to align the procedures with the general framework for defining IHW proposed in this opinion, the specific requirements of the activities of health professionals, and the local organization of household waste disposal pathways.

Lastly, in its October 2024 opinion, the HCSP recommends the following: training healthcare staff in how to identify IHW based on the context and clinical condition of the patient; introducing training programs for logistics and waste collection staff; and overseeing the organization of recycling and repurposing channels.

Converting IHW into NHHW

NHHW can follow the standard waste system.

Disposing of MDs and MD packaging after use forms part of the overall approach to the disposal of HCW. The latter, at the end of their lifecycle, can fall under both IHW and NHHW depending on their composition, nature, and context of use.

Biological liquids and other effluents may be solidified using gelling powder and converted into NHHW, provided they do not contain any potentially pathogenic microorganisms and that there is no risk that they will penetrate the body of individuals exposed to the waste [121].

Discussion:

The recommendations presented here highlight a strong commitment to integrating environmental responsibility into healthcare practices, without compromising the quality or safety of patient care. This systemic approach, encompassing prescription, utilization, logistics, and waste management, reflects the growing awareness within the healthcare sector of its environmental footprint. Table 1 aims to improve readability and to help clinicians, administrators, and decision-makers prioritize actions according to their local resources and strategic objectives.

These recommendations were developed using the GRADE® framework; however, their interpretation must take into account the limited availability of high-level evidence in the field of environmental sustainability in perioperative care. For most topics addressed, robust comparative studies and standardized life cycle assessment (LCA) methodologies remain scarce, heterogeneous, or highly context-dependent. As a result, the majority of recommendations could only be formulated as expert opinions based on the best available data combined with multidisciplinary clinical expertise.

Accordingly, these recommendations should be viewed as a structured decision-support framework rather than as prescriptive or universally applicable rules. Their implementation should be adapted to local clinical practices, organizational constraints, and regulatory environments. In particular, eco-responsible strategies should not be systematically promoted but rather applied selectively to medical devices and practices for which the available evidence is consistent, reproducible, and compatible with patient safety requirements.

Future research is essential to strengthen the evidence base supporting sustainable perioperative practices. Priority areas include the development of standardized and transparent LCAs for reusable and single-use medical devices, long-term evaluations of device durability and performance after repeated reprocessing, and integrated cost–benefit analyses that account for environmental, economic, and organizational outcomes. Such data will be critical to moving from expert consensus toward more robust, data-driven recommendations and to ensuring that sustainability initiatives remain aligned with clinical effectiveness and patient safety.

The recommendations concerning injectable drugs, oral forms, and reusable medical devices emphasize the possibility of combining clinical effectiveness with reduced environmental impact. Extemporaneous preparation, the avoidance of advance desterilization, and the rationalization of surgical trays emerge as concrete levers to decrease waste generation while maintaining patient safety. These measures are consistent with recent studies showing that the use phase of healthcare products contributes significantly to hospitals' carbon footprints.

The reassessment of packaging and sterilization practices constitutes a major area for improvement. Revising sterility requirements, extending the use-by date after sterilization, and prioritizing single-barrier systems illustrate a pragmatic balance between microbiological safety and material sobriety. These recommendations also encourage closer collaboration between hospitals and manufacturers to redesign packaging and devices according to measurable environmental indicators (weight, recyclability, logistics optimization). The introduction of electronic instructions for use *via* QR codes contributes to the digital and sustainable transformation of healthcare while reducing paper consumption. Nevertheless, these developments require strong scientific validation, regulatory approval, and user acceptability.

Incorporating environmental indicators into procurement strategies and actively involving healthcare professionals in the eco-responsible care represent a major organizational shift. Healthcare institutions are becoming active agents in the ecological transition, promoting collective responsibility and professional training. Streamlined logistics, reduced emergency orders, and increased local or grouped purchasing are examples of efficient and sustainable practices that also reduce costs. This systemic approach aligns with the United Nations Sustainable Development Goals (12 and 13) and the principles of a circular economy applied to health systems.

The practical implementation of these recommendations requires local adaptation and adequate institutional resources (Figure 2). Regulatory constraints, heterogeneous infrastructure, and the availability of reprocessing and recycling channels remain significant challenges. Moreover, quantitative data on the actual environmental impact of the proposed measures are still scarce. Multicenter studies assessing ecologic and economic savings associated with each strategy are needed to strengthen the evidence base and guide policy decisions.

These recommendations are part of a comprehensive effort to embed eco-responsible principles within healthcare systems, balancing clinical excellence with environmental sustainability. They mark a decisive step toward structural transformation based on shared responsibility, organizational innovation, and interprofessional collaboration. By considering environmental impact as a core dimension of healthcare quality, this framework paves the way for "sustainable health" — ensuring harmony between human health and planetary health.

Coordinator of experts: Delphine CABELGUENNE (SFPC),

Organizers: El-Mahdi HAFIANI (SFAR) and Patrick PESSAUX (AFC)

Group of experts (alphabetical order):
H BELOEIL (SFAR), A BROS (SFPC), D CABELGUENNE (SFPC), P CASSIER (SF2H), C CHAPUIS (SFPC), B CHAUVEAU (SFR), A DAIKH (SFPC), C DANANCHE (SF2H), L DURAND (SFPC), M DUPUY (SFCR), F LALLEMANT (SFAR), C LAMBERT (SF2S), A PETIT (EURO-PHARMAT-SPFDM), M PIOCHE (SFED)

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References

[1] Armoiry X, Carry P, Lehot J, Michel C, Aulagner G, Piriou V. Estimated economic impact of pre-filled ephedrine syringes in the operating room. Acta Anaesthesiol Scand 2016;60:917–24.
[2] Atcheson CLH, Spivack J, Williams R, Bryson EO. Preventable drug waste among anesthesia providers: opportunities for efficiency. J Clin Anesth 2016;30:24–32. https://doi.org/10.1016/j.jclinane.2015.12.005.
[3] Barbariol F, Deana C, Lucchese F, Cataldi G, Bassi F, Bove T, et al. Evaluation of Drug Wastage in the Operating Rooms and Intensive Care Units of a Regional Health Service. Anesth Analg 2021;132:1450–6. https://doi.org/10.1213/ANE.0000000000005457.
[4] Chaudhary K, Garg R, Bhalotra A, Anand R, Girdhar K. Anesthetic drug wastage in the operation room: A cause for concern. J Anaesthesiol Clin Pharmacol 2012;28:56–61.
[5] Crégut-Corbaton J, Malbranche C, Guignard M-H, Fagnoni P. [Economic impact of strategies using ephedrine prefilled syringes]. Ann Fr Anesth Reanim 2013;32:760–5. https://doi.org/10.1016/j.annfar.2013.06.019.
[6] Lejus C, Blanloeil Y, Oudot M, Le Teurnier Y, Lepage J, Loutrel O, et al. Atropine and ephedrine: a significant waste in the operating theatre. Anaesthesia 2012;67:300–1.
[7] Mankes RF. Propofol wastage in anesthesia. Anesth Analg 2012;114:1091–2. https://doi.org/10.1213/ANE.0b013e31824ea491.
[8] Peker K. The wastage and economic effects of anaesthetic drugs and consumables in the operating room. Turk J Anaesthesiol Reanim 2020;48:321–7.
[9] Weinger M. Drug wastage contributes significantly to the cost of routine anesthesia care. J Clin Anesth 2001;13:491–7.
[10] Amster E. Mitigating pharmaceutical waste exposures: policy and program considerations. Isr J Health Policy Res 2016;5:58.
[11] Brighton & Sussex Medical School, Centre for Sustainable Healthcare, and UK Health Alliance on Climate Change. Green surgery: reducing the environmental impact of surgical care (v1.1). UK Health Alliance on Climate Change; 2024. Available from: . 2025.
[12] Rinehardt EK, Sivarajan M. Costs and wastes in anesthesia care. Curr Opin Anaesthesiol 2012;25:221–5. https://doi.org/10.1097/ACO.0b013e32834f00ec.
[13] Driver RP, Snyder IS, North FP, Fife TJ. Sterility of anesthetic and resuscitative drug syringes used in the obstetric operating room. Anesth Analg 1998;86:994–7. https://doi.org/10.1097/00000539-199805000-00015.
[14] Van Norman GA, Jackson S. The anesthesiologist and global climate change: an ethical obligation to act. Curr Opin Anaesthesiol 2020;33:577–83. https://doi.org/10.1097/ACO.0000000000000887.
[15] Perry H, Reeves N, Ansell J, Cornish J, Torkington J, Morris DS, et al. Innovations towards achieving environmentally sustainable operating theatres: A systematic review. Surgeon 2023;21:141–51. https://doi.org/10.1016/j.surge.2022.04.012.
[16] Rueangchira-Urai R, Rujirojindakul P, Geater AF, McNeil E. Bacterial Contamination

of Anaesthetic and Vasopressor Drugs in the Operating Theatres: Ameliyathanelerde Anestetik ve Vazopressör İlaçların Bakteriyel Kontaminasyonu. Turk J Anaesthesiol Reanim 2017;45:47–52. https://doi.org/10.5152/TJAR.2017.21703.
[17] Soong WA. Bacterial contamination of propofol in the operating theatre. Anaesth Intensive Care 1999;27:493–6. https://doi.org/10.1177/0310057X9902700510.
[18] Segal S, Gunawan A, McLaughlin DH, Palavecino E. Microbial stability of syringes of anesthetic drugs prepared in the operating room. J Clin Anesth 2019;55:20–3. https://doi.org/10.1016/j.jclinane.2018.12.029.
[19] Gordon D. Sustainability in the Operating Room: Reducing Our Impact on the Planet. Anesthesiol Clin 2020;38:679–92. https://doi.org/10.1016/j.anclin.2020.06.006.
[20] McGain F, Muret J, Lawson C, Sherman JD. Environmental sustainability in anaesthesia and critical care. Br J Anaesth 2020;125:680–92. https://doi.org/10.1016/j.bja.2020.06.055.
[21]Taconet C, Hafiani EM, Daigne D, Camus F, Didier M, Paubel P et al. Potential cost savings and environmental benefits of prefilled syringes of suxamethonium in anaesthesia practice. Br J Anaesth. 2024 Dec;133(6):1501-1503.
[22] Franchina MP, Charpiat B. [Unfractionned heparin wastage at a French university hospital]. Ann Pharm Fr 2024;82:575–83. https://doi.org/10.1016/j.pharma.2024.02.002.
[23] Petre M-A, Malherbe S. Environmentally sustainable perioperative medicine: simple strategies for anesthetic practice. Can J Anaesth 2020;67:1044–63. https://doi.org/10.1007/s12630-020-01726-0.
[24] Davies JF, McAlister S, Eckelman MJ, McGain F, Seglenieks R, Gutman EN, et al. Environmental and financial impacts of perioperative paracetamol use: a multicentre international life-cycle assessment. Br J Anaesth 2024;133:1439–48. https://doi.org/10.1016/j.bja.2023.11.053.
[25] Bouvet L, Juif-Clément M, Bréant V, Zieleskiewicz L, Lê M-Q, Cottinet P-J. Environmental impact of intravenous versus oral administration materials for acetaminophen and ketoprofen in a French university hospital: an eco-audit study using a life cycle analysis. Can J Anaesth 2024;71:1457–65. https://doi.org/10.1007/s12630-024-02852-9.
[26] SFCR. Check list « Green Bloc » en chirurgie du rachis. Société Française de Chirurgie du Rachis. 2023. Available from: . 2025.
[27] Pauchard J-C, Hafiani E-M, Bonnet L, Cabelguenne D, Carenco P, Cassier P, et al. Guidelines for reducing the environmental impact of general anaesthesia. Anaesth Crit Care Pain Med 2023;42:101291. https://doi.org/10.1016/j.accpm.2023.101291.
[28] Guide de bonnes pratiques de traitement des dispositifs médicaux réutilisables n.d. https://www.sf2h.net/publications/guide-de-bonnes-pratiques-de-traitement-des-dispositifs-medicaux-reutilisables.html (accessed January 20, 2025).
[29] Article R6111-21 - Code de la santé publique - Légifrance n.d. https://www.legifrance.gouv.fr/codes/article_lc/LEGIARTI000022806405 (accessed January 20, 2025).
[30]McGain F, McAlister S. Reusable versus single-use ICU equipment: what's the environmental footprint? Intensive Care Med. 2023 Dec;49(12):1523-1525.
[31]Eussen MMM, Moossdorff M, Wellens LM, de Reuver PR, Stobernack T, Bijlmakers L et al. Beyond single-use: a systematic review of environmental, economic, and clinical impacts of endoscopic surgical instrumentation. Int J Surg. 2024 Dec 1;110(12):8136-8150.
[32] Babu MA, Dalenberg AK, Goodsell G, Holloway AB, Belau MM, Link MJ. Greening the Operating Room: Results of a Scalable Initiative to Reduce Waste and Recover Supply Costs. Neurosurgery 2019;85:432–7. https://doi.org/10.1093/neuros/nyy275.
[33] Laurut T, Duran C, Pages A, Morin M-C, Cavaignac E. What is the cost burden of surgical implant waste? An analysis of surgical implant waste in an orthopedics and trauma

surgery department of a French university hospital in 2016. Orthop Traumatol Surg Res 2019;105:1205–9. https://doi.org/10.1016/j.otsr.2019.06.010.
[34] Bravo D, Thiel C, Bello R, Moses A, Paksima N, Melamed E. What a Waste! The Impact of Unused Surgical Supplies in Hand Surgery and How We Can Improve. Hand (N Y) 2023;18:1215–21. https://doi.org/10.1177/15589447221084011.
[35] Holland H, Kong A, Buchanan E, Patten C. Breast Surgery Cost Savings Through Surgical Tray Instrument Reduction. J Surg Res 2022;280:495–500. https://doi.org/10.1016/j.jss.2022.07.033.
[36] Rizan C, Lillywhite R, Reed M, Bhutta MF. Minimising carbon and financial costs of steam sterilisation and packaging of reusable surgical instruments. Br J Surg 2022;109:200–10. https://doi.org/10.1093/bjs/znab406.
[37] Toor J, Bhangu A, Wolfstadt J, Bassi G, Chung S, Rampersaud R, et al. Optimizing the surgical instrument tray to immediately increase efficiency and lower costs in the operating room. Can J Surg 2022;65:E275–81. https://doi.org/10.1503/cjs.022720.
[38] Desbos N. Démarche d'écoresponsabilité en santé : exemple du set de pose d'anesthésie péridurale à l'hôpital Lyon Sud, HCL. Hospices Civils de Lyon. 2024. Available from: . 2025.
[39] Bouvet L, Chassard D. Fighting global warming: it's time to reduce waste! Int J Obstet Anesth. 2019 Aug:39:150-151.
[40] Goldfield NM, Malapati P, Chafitz T, Saravanapavan Y, Alamgir N, Gander J, et al. Sterile surgical supply waste identification using asynchronous analysis: Pediatric surgery QI pilot. Surg Open Sci 2023;15:32–7. https://doi.org/10.1016/j.sopen.2023.07.025.
[41] Peltoniemi T, Suomi R. Eliminating medicine waste in a Finnish university hospital: a qualitative study. J Pharm Policy Pract. 2019;12:27. doi:10.1186/s40545-019-0188-8. 2025.
[42] Henniger D, Lux T, Windsheimer M, Brand M, Weich A, Kudlich T, et al. Reducing scope 3 carbon emissions in gastrointestinal endoscopy: results of the prospective study of the "Green Endoscopy Project Würzburg." Gut 2024;73:442–7. https://doi.org/10.1136/gutjnl-2023-331024.
[43] Guide pratique écolo-endoscopie - fiche n°7. SFED n.d. https://www.sfed.org/media/guide-pratique-ecolo-endoscopie-fiche-n7/ (accessed January 9, 2025).
[44] Rouvière N, Pitard M, Boutry E, Prudhomme M, Bertrand M, Leguelinel-Blache G, et al. How a hospital pharmacist can contribute to a more sustainable operating theater. J Visc Surg 2024;161:37–45. https://doi.org/10.1016/j.jviscsurg.2023.11.004.
[45] Sherman JD, Raibley LA, Eckelman MJ. Life Cycle Assessment and Costing Methods for Device Procurement: Comparing Reusable and Single-Use Disposable Laryngoscopes. Anesth Analg 2018;127:434–43. https://doi.org/10.1213/ANE.0000000000002683.
[46] - SFAR GREEN 2020 SFAR Fiche 15 Lames de laryngoscopes réutilisables 2020 https://sfar.org/comites/developpement-durable/fiches-pratiques/sfar-green/ 2025.
[47] INSTRUCTION N° DGS/RI3/2011/449 du 1er décembre 2011 relative à l'actualisation des recommandations visant à réduire les risques de transmission d'agents transmissibles non conventionnels lors des actes invasifs. - Légifrance n.d. https://www.legifrance.gouv.fr/circulaire/id/34277 (accessed January 21, 2025).
[48] HCSP. Avis relatif à la conduite à tenir face aux accidents d'exposition aux prions et au propagons et dans le cadre des soins comportant des actes invasifs. Paris: Haut Conseil de la Santé Publique; 2023.
[49] Rouvière N, Chkair S, Auger F, Alovisetti C, Bernard MJ, Cuvillon P, et al. Ecoresponsible actions in operating rooms: A health ecological and economic evaluation. International Journal of Surgery 2022;101:106637. https://doi.org/10.1016/j.ijsu.2022.106637.
[50] Rouvière N, Chkair S, Auger F, Cuvillon P, Leguelinel-Blache G, Chasseigne V.

Reusable laryngoscope blades: a more eco-responsible and cost-effective alternative. Anaesth Crit Care Pain Med 2023;42:101276. https://doi.org/10.1016/j.accpm.2023.101276.
[51] Bhutta M, Rizan C. The Green Surgery report: a guide to reducing the environmental impact of surgical care, but will it be implemented? Annals of the Royal College of Surgeons of England 2024;106. https://doi.org/10.1308/rcsann.2024.0005.
[52] FD S98-135. Afnor EDITIONS n.d. https://www.boutique.afnor.org/fr-fr/norme/fd-s98135/sterilisation-des-dispositifs-medicaux-guide-pour-la-maitrise-des-traitemen/fa136818/25149 (accessed January 21, 2025).
[53] NF EN ISO 11607-1. Afnor EDITIONS n.d. https://www.boutique.afnor.org/fr-fr/norme/nf-en-iso-116071/emballages-des-dispositifs-medicaux-sterilises-au-stade-terminal-partie-1-e/fa189062/84850 (accessed January 21, 2025).
[54] NF EN ISO 11607-2. Afnor EDITIONS n.d. https://www.boutique.afnor.org/fr-fr/norme/nf-en-iso-116072/emballages-des-dispositifs-medicaux-sterilises-au-stade-terminal-partie-2-e/fa189063/84845 (accessed January 21, 2025).
[55] NF EN 868-2. Afnor EDITIONS n.d. https://www.boutique.afnor.org/fr-fr/norme/nf-en-8682/emballages-des-dispositifs-medicaux-sterilises-au-stade-terminal-partie-2-e/fa059829/58891 (accessed January 21, 2025).
[56] NF EN 868-3. Afnor EDITIONS n.d. https://www.boutique.afnor.org/fr-fr/norme/nf-en-8683/emballages-des-dispositifs-medicaux-sterilises-au-stade-terminal-partie-3-p/fa059845/58922 (accessed January 21, 2025).
[57] NF EN 868-4. Afnor EDITIONS n.d. https://www.boutique.afnor.org/fr-fr/norme/nf-en-8684/emballages-des-dispositifs-medicaux-sterilises-au-stade-terminal-partie-4-s/fa059843/58848 (accessed January 21, 2025).
[58] NF EN 868-5. Afnor EDITIONS n.d. https://www.boutique.afnor.org/fr-fr/norme/nf-en-8685/emballages-des-dispositifs-medicaux-sterilises-au-stade-terminal-partie-5-s/fa190088/82265 (accessed January 21, 2025).
[59] NF EN 868-6. Afnor EDITIONS n.d. https://www.boutique.afnor.org/fr-fr/norme/nf-en-8686/emballages-des-dispositifs-medicaux-sterilises-au-stade-terminal-partie-6-p/fa059841/58847 (accessed January 21, 2025).
[60] NF EN 868-7. Afnor EDITIONS n.d. https://www.boutique.afnor.org/fr-fr/norme/nf-en-8687/emballages-des-dispositifs-medicaux-sterilises-au-stade-terminal-partie-7-p/fa059844/58762 (accessed January 21, 2025).
[61] NF EN 868-8. Afnor EDITIONS n.d. https://www.boutique.afnor.org/fr-fr/norme/nf-en-8688/emballages-des-dispositifs-medicaux-sterilises-au-stade-terminal-partie-8-c/fa190089/1783 (accessed January 21, 2025).
[62] NF EN 868-9. Afnor EDITIONS n.d. https://www.boutique.afnor.org/fr-fr/norme/nf-en-8689/materiaux-et-systemes-demballage-pour-les-dispositifs-medicaux-sterilises-a/fa190067/82204 (accessed January 21, 2025).
[63] NF EN 868-10. Afnor EDITIONS n.d. https://www.boutique.afnor.org/fr-fr/norme/nf-en-86810/materiaux-et-systemes-demballage-pour-les-dispositifs-medicaux-sterilises-a/fa190087/83017 (accessed January 21, 2025).
[64] 16. Comment établir la date de péremption des dispositifs médicaux réutilisables stériles? sssh n.d. https://www.sssh.ch/fr/documentation/16-comment-etablir-la-date-de-peremption-des-dispositifs-medicaux-reutilisables-steriles/ (accessed January 21, 2025).
[65] Leguay Z, Figueiredo E, Evrillus L, Jacques-Terracol V, Le Verger M. [Study of the deadlines for the use after sterilization of hot-sealable bags and sheaths]. Ann Pharm Fr 2018;76:321–33. https://doi.org/10.1016/j.pharma.2018.01.003.
[66] ISO 11737-1:2018. ISO n.d. https://www.iso.org/fr/standard/66451.html (accessed February 24, 2025).
[67] Vidor M, Raguenes C, Astier H, Gbaguidi G, Le Tohic S. [Optimizing the use-by date

of reusable medical devices. Experience in a healthcare establishment]. Ann Pharm Fr 2024;82:292–305. https://doi.org/10.1016/j.pharma.2023.12.007.
[68] Webster J, Lloyd W, Ho P, Burridge C, George N. Rethinking Sterilization Practices: Evidence for Event-Related Outdating. Infection Control & Hospital Epidemiology 2003;24:622–4. https://doi.org/10.1086/502264.
[69] Bonnes Pratiques de Stérilisation des Dispositifs Médicaux Réutilisables. Académie de Paris n.d. https://pia.ac-paris.fr/portail/jcms/p2_2523771/bonnes-pratiques-de-sterilisation-des-dispositifs-medicaux-reutilisables (accessed January 21, 2025).
[70] 2022 - Renouvellement - Pharmacopée Européenne (Ph. Eur.) 11e Édition.pdf. Direction européenne de la qualité du médicament & soins de santé n.d. https://www.edqm.eu/en/d/503869 (accessed January 21, 2025).
[71] 15/30 Simple ou double emballage pour le "non tissé" au bloc opératoire. Euro-Pharmat.com n.d. https://www.euro-pharmat.com/communications-affichees/2007-15-30-simple-ou-double-emballage-pour-le-non-tisse-au-bloc-operatoire (accessed January 21, 2025).
[72] Webster J, Radke E, George N, Faoagali J, Harris M. Barrier properties and cost implications of a single versus a double wrap for storing sterile instrument packs. Am J Infect Control 2005;33:348–52. https://doi.org/10.1016/j.ajic.2004.11.010.
[73] Environmental Protection Agency (EPA). Reusable Totes, Blue Wrap Recycling, and Composting 2002.
[74] Pioche M, Cunha Neves JA, Pohl H, Lê M-Q, Grau R, Dray X, et al. The environmental impact of small-bowel capsule endoscopy. Endoscopy 2024;56:737–46. https://doi.org/10.1055/a-2313-5142.
[75] Keyser A, Chang DF, Thiel C, Hovanesian J. Analysis of intraocular lens packaging weight and waste. J Cataract Refract Surg 2024;50:1270–4. https://doi.org/10.1097/j.jcrs.0000000000001514.
[76] Règlement d'exécution - 2021/2226 - FR - EUR-Lex n.d. https://eur-lex.europa.eu/eli/reg_impl/2021/2226/oj/fra (accessed March 1, 2025).
[77] Stern B, Rampat R, Shahnazaryan D, Gatinel D. Paper waste from instructions for use brochures in cataract surgery implant packaging in Europe and the United States. J Cataract Refract Surg 2024;50:72–7. https://doi.org/10.1097/j.jcrs.0000000000001310.
[78] Desbos N. Démarche d'écoresponsabilité en santé : exemple du set de pose d'anesthésie péridurale à l'hôpital Lyon Sud, HCL. Hospices Civils de Lyon. 2024. n.d.
[79] de'Angelis N, Conso C, Bianchi G, Barría Rodríguez AG, Marchegiani F, Carra MC, et al. Revue systématique du bilan carbone des interventions chirurgicales. Journal de Chirurgie Viscérale 2024;161:7–15. https://doi.org/10.1016/j.jchirv.2023.02.002.
[80] Campion N, Thiel CL, Woods NC, Swanzy L, Landis AE, Bilec MM. Sustainable healthcare and environmental life-cycle impacts of disposable supplies: A focus on disposable custom packs. Journal of Cleaner Production 2015;94:46–55. https://doi.org/10.1016/j.jclepro.2015.01.076.
[81] Décarboner la santé pour soigner durablement : édition 2023 du rapport du Shift Project – The Shift Project n.d. https://theshiftproject.org/article/decarboner-sante-rapport-2023/ (accessed January 21, 2025).
[82] Giraud J-S, Hamidou F, Hassani Y, Borel C, Le Gonidec P. [French national overview of the inclusion of environmental criteria in the public purchasing of health products (drugs and sterile medical devices)]. Ann Pharm Fr 2022;80:216–26. https://doi.org/10.1016/j.pharma.2021.06.005.
[83] ISO/TR 14062:2002(fr), Management environnemental — Intégration des aspects environnementaux dans la conception et le développement de produit n.d. https://www.iso.org/obp/ui/#iso:std:iso:tr:14062:ed-1:v1:fr (accessed January 21, 2025).

[84] Piffoux M, Le Tellier A, Taillemite Z, Ducrot C, Taillemite S. Carbon footprint of oral medicines using hybrid life cycle assessment. Journal of Cleaner Production 2024;475:143576. https://doi.org/10.1016/j.jclepro.2024.143576.
[85] School B& SM, Change UHA on C. Green surgery: reducing the environmental impact of surgical care (v1.1). UK Health Alliance on Climate Change 2024.
[86] Pattnaik S, Dixit SK, Bishnoi V, Pattnaik S, Dixit S, Bishnoi V. The Burden of Surgical Cancellations: A Quality Improvement Study on the Importance of Preoperative Assessment. Cureus 2022;14. https://doi.org/10.7759/cureus.21731.
[87] Hafiani E-M, Cassier P, Aho S, Albaladejo P, Beloeil H, Boudot E, et al. Guidelines for clothing in the operating theatre, 2021. Anaesth Crit Care Pain Med 2022;41:101084. https://doi.org/10.1016/j.accpm.2022.101084.
[88] Chambrin C, de Souza S, Gariel C, Chassard D, Bouvet L. Association Between Anesthesia Provider Education and Carbon Footprint Related to the Use of Inhaled Halogenated Anesthetics. Anesth Analg. 2023 Jan 1;136(1):101-110.
[89] Environmental impact and life cycle financial cost of hybrid (reusable/single-use) instruments versus single-use equivalents in laparoscopic cholecystectomy - PubMed n.d. https://pubmed.ncbi.nlm.nih.gov/34559257/ (accessed February 24, 2025).
[90] Toia GV, Rose SD, Brown Z, Dovalis D, Bartels CM, Bladorn RM, et al. Consumable Material Waste and Workflow Efficiency Comparison Between Multi-use Syringeless and Single-use Syringe-Based Injectors in Computed Tomography. Acad Radiol 2023;30:2340–9. https://doi.org/10.1016/j.acra.2023.05.038.
[91] Lindsey JS, Frederick-Dyer K, Carr JJ, Cooke E, Allen LM, Omary RA. Modeling the Environmental and Financial Impact of Multi-dose vs. Single-dose Iodinated Contrast Media Packaging and Delivery Systems. Acad Radiol 2023;30:1017–23. https://doi.org/10.1016/j.acra.2022.12.029.
[92] Routhier J, Piazzo K, Sodickson A. Contrast and cost savings by implementation of a multidose bulk IV contrast delivery system. J Am Coll Radiol 2011;8:265–70. https://doi.org/10.1016/j.jacr.2010.08.031.
[93] Huo B, Eussen MMM, Marconi S, Johnson SM, Francis N, Oslock WM, et al. Scoping review for the SAGES EAES joint collaborative on sustainability in surgical practice. Surg Endosc 2024;38:5483–504. https://doi.org/10.1007/s00464-024-11141-x.
[94] Jehle K, Jarrett N, Matthews S. Clean and Green: Saving Water in the Operating Theatre. Ann R Coll Surg Engl 2008;90:22–4. https://doi.org/10.1308/003588408X242277.
[95] SFED. Guide pratique écoresponsable. Société Française d'Endoscopie Digestive. Available from: . 2025.
[96] Hygiène des mains n.d. https://www.sf2h.net/publications/hygiene-des-mains.html (accessed February 24, 2025).
[97] [SFCR] SFCR Check list « Green Bloc » en chirurgie du rachis » 2023 https://www.sfcr.fr/actualite/check-list-green-bloc-en-chirurgie-du-rachis 2025.
[98] Marchal R, Nicolau E, Ballaguet J-P, Bertoncini F. Biodegradability of polyethylene glycol 400 by complex microfloras. International Biodeterioration & Biodegradation 2008;62:384–90. https://doi.org/10.1016/j.ibiod.2008.03.013.
[99] Ueda T, Li JW, Ho S-H, Singh R, Uedo N. Precision endoscopy in the era of climate change and sustainability. J Gastroenterol Hepatol 2024;39:18–27. https://doi.org/10.1111/jgh.16383.
[100] Gordon IO, Sherman JD, Leapman M, Overcash M, Thiel CL. Life Cycle Greenhouse Gas Emissions of Gastrointestinal Biopsies in a Surgical Pathology Laboratory. Am J Clin Pathol 2021;156:540–9. https://doi.org/10.1093/ajcp/aqab021.
[101] Beloeil H, Ruchard D, Drewniak N, Molliex S. Overuse of preoperative laboratory coagulation testing and ABO blood typing: a French national study. Br J Anaesth

2017;119:1186–93. https://doi.org/10.1093/bja/aex268.
[102] Rodríguez de Santiago E, Dinis-Ribeiro M, Pohl H, Agrawal D, Arvanitakis M, Baddeley R, et al. Reducing the environmental footprint of gastrointestinal endoscopy: European Society of Gastrointestinal Endoscopy (ESGE) and European Society of Gastroenterology and Endoscopy Nurses and Associates (ESGENA) Position Statement. Endoscopy 2022;54:797–826. https://doi.org/10.1055/a-1859-3726.
[103] Pessaux P, Cherkaoui Z, Collectif d'écoresponsabilité en santé (CERES). A new healthcare paradigm: Integration of the environment in value-based health care. EROMs: Environment-related outcome measures. J Visc Surg 2024:S1878-7886(24)00157-7. https://doi.org/10.1016/j.jviscsurg.2024.11.001.
[104] Spoyalo K, Lalande A, Rizan C, Park S, Simons J, Dawe P, et al. Patient, hospital and environmental costs of unnecessary bloodwork: capturing the triple bottom line of inappropriate care in general surgery patients. BMJ Open Qual 2023;12. https://doi.org/10.1136/bmjoq-2023-002316.
[105] Rodríguez de Santiago E, Dinis-Ribeiro M, Pohl H, Agrawal D, Arvanitakis M, Baddeley R, et al. Reducing the environmental footprint of gastrointestinal endoscopy: European Society of Gastrointestinal Endoscopy (ESGE) and European Society of Gastroenterology and Endoscopy Nurses and Associates (ESGENA) Position Statement. Endoscopy 2022;54:797–826. https://doi.org/10.1055/a-1859-3726.
[106] Kothari S, Kalinowski M, Kobeszko M, Almouradi T. Computed tomography scan imaging in diagnosing acute uncomplicated pancreatitis: Usefulness vs cost. World J Gastroenterol 2019;25:1080–7. https://doi.org/10.3748/wjg.v25.i9.1080.
[107] Alshqaqeeq F, McGuire C, Overcash M, Ali K, Twomey J. Choosing radiology imaging modalities to meet patient needs with lower environmental impact. Resources, Conservation and Recycling 2020;155:104657. https://doi.org/10.1016/j.resconrec.2019.104657.
[108] Société Française de Radiologie et d'Imagerie Médicale Radiologie et Ecoresponsabilité Sur la voie d'une "Green Radiology" ? https://www.radiologie.fr/sites/www.radiologie.fr/files/medias/documents/Livret%20blanc%20-%20version%20web%2010%20dec%202021_.pdf n.d.
[109] Emballages et déchets d'emballages : amendements du Parlement Européen, adoptés le 22 novembre 2023, modifiant le règlement (UE) 2019/1020 et la directive (UE) 2019/904, et abrogeant la directive 94/62/CE https://eur-lex.europa.eu/legal-content/FR/TXT/PDF/?uri=OJ:C_202404250 2025.
[110] Décret n° 2016-288 du 10 mars 2016 portant diverses dispositions d'adaptation et de simplification dans le domaine de la prévention et de la gestion des déchets. 2016.
[111] McGain F, Jarosz KM, Nguyen MNHH, Bates S, O'Shea CJ. Auditing Operating Room Recycling: A Management Case Report. A A Case Rep 2015;5:47–50. https://doi.org/10.1213/XAA.0000000000000097.
[112] Friedericy HJ, van Egmond CW, Vogtländer JG, van der Eijk AC, Jansen FW. Reducing the Environmental Impact of Sterilization Packaging for Surgical Instruments in the Operating Room: A Comparative Life Cycle Assessment of Disposable versus Reusable Systems. Sustainability 2022;14:430. https://doi.org/10.3390/su14010430.
[113] Pangilinan K, Pamulapati LG, Caldas LM. A call for sustainability: Why unused drugs should be redistributed to pharmacy schools for simulated pharmacy practice learning activities. Curr Pharm Teach Learn 2023;15:849–53. https://doi.org/10.1016/j.cptl.2023.08.001.
[114] Loi anti-gaspillage économie circulaire n.d. https://www.ecologie.gouv.fr/loi-anti-gaspillage-economie-circulaire (accessed February 25, 2025).
[115] SFAR DECHETS DE SOINS Tri des déchets de soins au bloc opératoire et en

réanimation https://sfar.org/comites/developpement-durable/fiches-pratiques/sfar-green/ 2025.
[116] Directive 2012/19/UE du Parlement européen et du Conseil du 4 juillet 2012 relative aux déchets d'équipements électriques et électroniques (DEEE). n.d.
[117] Guide technique Déchets d'activités de Soins d'activités à Risque, comment les éliminer ? 2009 n.d.
[118] Sanusi IO, Olutona GO, Wawata IG, Onohuean H. Occurrence, environmental impact and fate of pharmaceuticals in groundwater and surface water: a critical review. Environ Sci Pollut Res 2023;30:90595–614. https://doi.org/10.1007/s11356-023-28802-4.
[119] NF EN ISO 23907-1. Afnor EDITIONS n.d. https://www.boutique.afnor.org/fr-fr/norme/nf-en-iso-239071/protection-contre-les-blessures-par-perforants-exigences-et-methodes-dessai/fa188837/82447 (accessed February 25, 2025).
[120] HCSP. Révision du guide national sur l'élimination des déchets d'activités de soins à risques infectieux et assimilés (DASRIA). Paris: Haut Conseil de la Santé Publique; 2024.
[121] Guide régional pour Ets Santé et méd-soc : Cpias-ARS « Déchets d'activités de soins et risque infectieux : mise au point » 02/21 (pdf, 952.62 Ko) . https://www.occitanie.ars.sante.fr/media/75151/download?inline n.d.

Table 1: Prioritize actions according to their local resources and strategic objectives.

Domain	Recommendation type	Expected environmental impact	Resource / organizational requirements	Implementation priority
Care practices	Avoid advance preparation of injectable drugs when not required	High	Low (change in practice, staff awareness)	**High**
	Prefer oral administration when clinically appropriate	High	Low (clinical decision-making)	**High**
	Reduce contents of surgical trays with optional add-on trays	High	Moderate (multidisciplinary review)	**High**
	Avoid advance desterilization of MDs	Moderate to high	Low to moderate (planning, briefing)	**High**
	Use reusable MDs when evidence and reprocessing capacity are adequate	Moderate to high	High (sterilization capacity, monitoring)	**Moderate**
Packaging	Reduce unnecessary double packaging	Moderate	Low to moderate (practice reassessment)	**Moderate**
	Extend use-by dates based on risk analysis and data	Moderate	Moderate (pharmacy oversight, validation)	**Moderate**
	Tailor packaging to frequency of use	Moderate	Moderate (manufacturer dialogue)	**Moderate**
	Use electronic instructions for use (eIFU)	Low to moderate	Low (regulatory compliance)	**Low–Moderate**
Organization of care	Integrate environmental criteria into purchasing decisions	High	High (institutional strategy)	**High**
	Engage healthcare professionals in eco-design	High	Moderate (training, governance)	**High**
	Optimize logistics and reduce urgent orders	Moderate	Moderate (logistics systems)	**Moderate**
Waste management	Improve waste sorting and reduce infectious waste misclassification	Very high	Moderate (training, signage)	**High**
	Promote recycling and repurposing pathways	Moderate	High (external partners, regulation)	**Moderate**

<u>Figure 1:</u> Reusable Laryngoscope Blades: A Relevant and Sensible Choice

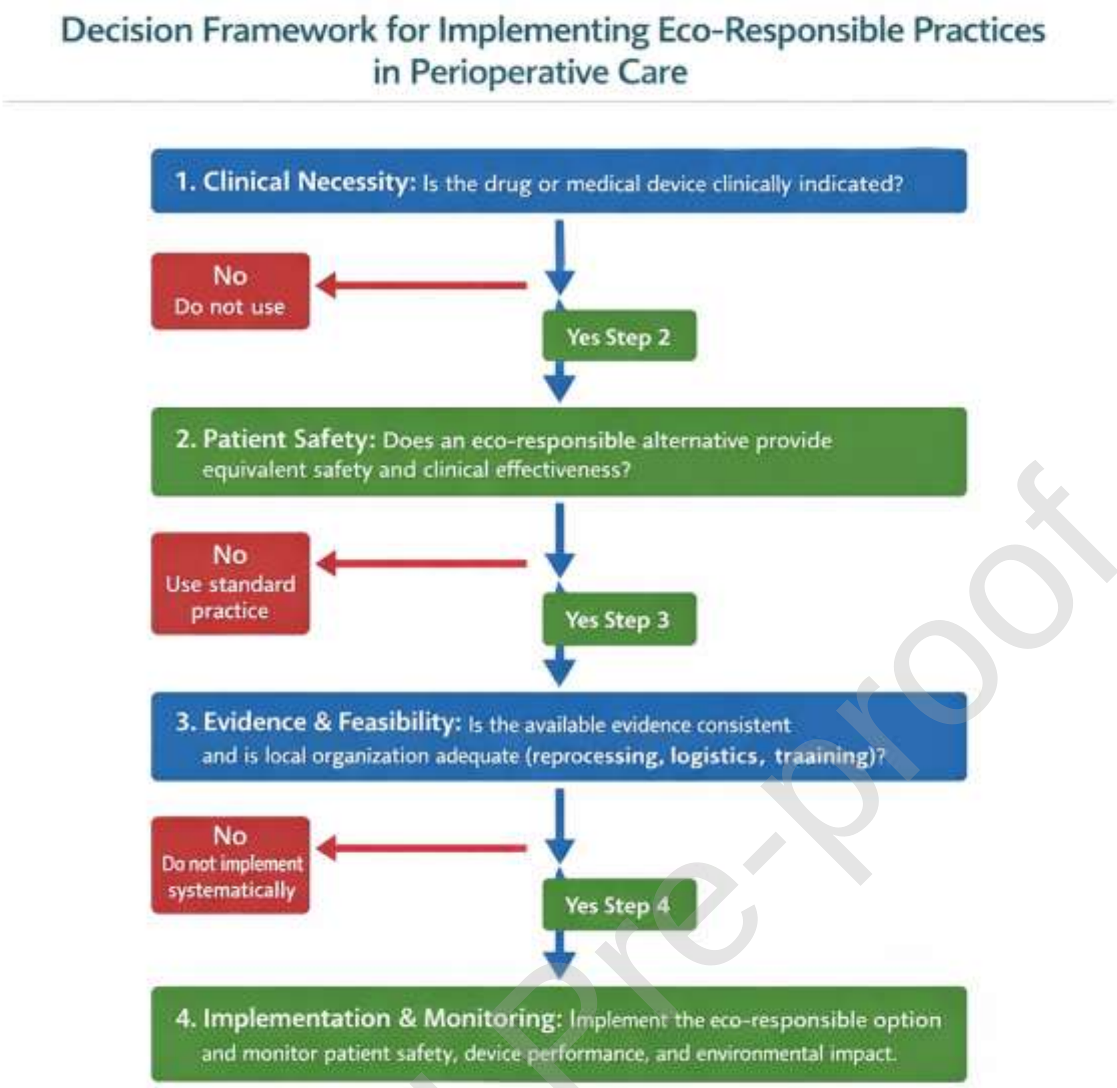

Figure 2: Decision framework for implementing eco-responsible practices in perioperative care