Innovation in surgery: appropriateness and economic/green sustainability
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Vanni Agnoletti,[1] Luca Ansaloni,[2] Gian Luca Baiocchi,[3] Stefano Bonilauri,[4] Paolo Carcoforo,[5] Tiziano Carradori,[6] Graziano Ceccarelli,[7] Francesco Cristini,[8] Franco De Cian,[9] Salomone Di Saverio,[10] Giorgio Ercolani,[11] Carlo Fabbri,[12] Emiliano Gamberini,[13] Costanza Martino,[14] Daniele Perrina,[15] Stefano Sanniti,[16] Massimo Sartelli,[17] Mario Testini,[18] Carlo Vallicelli,[15] Gabriele Vigutto[15]

[1]Anesthesia and Intensive Care Unit, Bufalini Hospital, AUSL Romagna, Cesena; [2]Surgery Unit, IRCCS San Matteo Hospital, Pavia; [3]General Surgery Unit, ASST Cremona; [4]Emergency General Surgery Unit, AUSL Reggio Emilia; [5]Surgery Unit, Hospital of Ferrara; [6]General Director, AUSL Romagna; [7]General Surgery Unit, San Giovanni Battista Hospital, Foligno (PG); [8]Infectious Diseases Unit, AUSL Romagna, Forlì; [9]Surgery Clinic, IRCCS San Martino Hospital, Genoa; [10]General Surgery Unit, Madonna del Soccorso Hospital, AST Marche, San Benedetto del Tronto (AP); [11]Surgery Unit, Morgagni Pierantoni Hospital, AUSL Romagna, Forlì; [12]Gastroenterology and Digestive Endoscopy Unit, AUSL Romagna, Forlì; [13]Anesthesia and Intensive Care Unit, Morgagni Pierantoni Hospital, AUSL Romagna, Forlì; [14]Anesthesia and Intensive Care Unit, AUSL Romagna, Lugo (RA); [15]General and Emergency Surgery Unit, Bufalini Hospital, AUSL Romagna, Cesena; [16]Medical Physics and Clinical Engineering Unit, AUSL Romagna; [17]General Surgery Unit, Provincial Hospital of Macerata, AST Marche; [18]Endocrine, Digestive and Emergency Surgery Unit, Hospital of Bari, Italy

Background

The "Innovation in surgery: appropriateness and economic/green sustainability" congress, held in Cesena, Italy, on December 13th, 2024, brought together leading researchers, clinicians, and professionals in the field of healthcare and surgery to share the latest developments, research findings, and clinical practices. Organized by *Società Italiana di Fisiopatologia Chirurgica* (SIFIPAC) and *Società Italiana di Chirurgia Geriatrica* (SICG), this conference served as a platform for interdisciplinary collaboration, innovative discussion, and the dissemination of critical advancements in medical science and healthcare delivery.

Correspondence: Gabriele Vigutto, General and Emergency Surgery Unit, Bufalini Hospital, AUSL Romagna, Cesena, Italy.
E-mail: gabrielevigutto@gmail.com

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Innovation in surgery has transformed patient care, improving outcomes, reducing recovery times, and enhancing overall efficiency.[1,2] However, as the field progresses, there is an increasing need to ensure that these innovations align with principles of appropriateness, economic feasibility, and environmental sustainability. The convergence of these priorities is essential in addressing the growing challenges of healthcare delivery in a resource-constrained world.

Appropriateness in surgery involves ensuring that innovative techniques and technologies are applied judiciously, tailored to individual patient needs, and supported by robust clinical evidence. Key aspects include:

- *Evidence-based practice*: innovations must undergo rigorous clinical trials to demonstrate their safety, efficacy, and superiority over existing methods.
- *Patient-centered care*: surgical advancements should focus on improving patient outcomes, reducing invasiveness, and enhancing quality of life.
- *Ethical considerations*: decisions regarding the adoption of new technologies must prioritize patient welfare over commercial interests.

Healthcare systems worldwide face financial pressures, making the cost-effectiveness of surgical innovations a critical factor. Strategies for ensuring economic sustainability include:

- *Cost-benefit analysis*: evaluating the long-term savings achieved through reduced hospital stays, lower complication rates, and faster recovery times.
- *Resource allocation*: prioritizing investments in technologies that deliver the greatest impact across diverse patient populations.
- *Training and scalability*: ensuring that new techniques can be adopted widely without excessive training costs or infrastructure requirements.

The environmental impact of surgical practices is increasingly under scrutiny. Operating rooms are resource-intensive, contribut-

ing significantly to hospital waste and carbon emissions. Sustainable practices include:

- *Reduction of waste*: implementing waste segregation, recycling programs, and reusable surgical instruments to minimize landfill contributions.
- *Energy efficiency*: upgrading to energy-efficient lighting, heating, ventilation, and air conditioning (HVAC) systems, and equipment to reduce the carbon footprint of surgical facilities.
- *Sustainable procurement*: sourcing surgical supplies and technologies from manufacturers with environmentally responsible practices.
- *Digital innovations*: leveraging telemedicine, virtual reality training, and simulation technologies to reduce travel and resource use.

Examples of sustainable innovations are:

1. *Minimally invasive surgery (MIS)*
   - Reduces hospital stays and associated resource consumption.
   - Lowers the need for large surgical instruments and disposable supplies.
2. *Biodegradable surgical materials*
   - Reduces environmental impact compared to traditional synthetic materials.
   - Ensures safe degradation without harmful residues.
3. *Energy-efficient surgical equipment*
   - Advanced tools with lower power requirements and longer lifespans.
4. *Digital operating rooms*
   - Integration of real-time data and AI to optimize surgical workflows and reduce waste.

Challenges and future directions

While progress is evident, barriers remain in aligning innovation with appropriateness and sustainability:

- *High initial costs*: advanced technologies often require significant upfront investments.
- *Resistance to change*: adoption of sustainable practices may face inertia within established surgical teams.
- *Global disparities*: ensuring equitable access to innovative yet sustainable surgical solutions in low-resource settings.

Future directions should focus on fostering collaborations between clinicians, industry, and policymakers to drive the development of cost-effective, patient-centered, and environmentally conscious surgical innovations.

Innovation in surgery must go hand in hand with appropriateness, economic viability, and green sustainability to ensure a future where advanced healthcare delivery does not compromise planetary health or financial accessibility. By adopting a holistic approach, the surgical community can continue to lead in shaping a sustainable and equitable healthcare landscape.

The National Health Service (NHS) is a highly advanced healthcare system with significant potential, but it is hindered by inadequate and inefficient funding. Improving the quality of our NHS is feasible with better funding, but also with effective resource management.

Appropriateness and sustainability walk together down the same path: focusing the right amount of financial and medical resources on selected cases would both offer the optimal service for the patient and reduce the wasting of public resources.

A typical example is given by antibiotic resistance: the inconsiderate use of antibiotics leads to an exponential surge of antibiotic resistance, increasing the resources required to treat a single patient and the amount needed for researching and developing new and efficient therapies. Implementing appropriate prevention strategies appears to be the most promising policy in the years to come.[3-5]

At the same time, the use of procalcitonin as a marker of bacterial infection and/or sepsis in guiding antibiotic therapy[6-8] and creating protocols using procalcitonin in different infectious diseases showed a cost-effectiveness ratio.[9,10]

Technological innovation is reshaping the world of surgery: the use of minimally invasive and robotic surgery, surgical navigation, and training with simulators is shown to be effective in reducing hospital stays and postoperative complications. Assessing the surgical patient properly with a multidisciplinary team is the key to reducing the ecological impact.

Healthcare systems are one of the biggest producers of CO_2, and acute care settings are second only to the food sector. Following the 6 R's (Reduce, Reuse, Recycle, Rethink, Refuse, and Repair) is suggested in technologically advanced fields such as intensive care and anesthesia to reduce both emissions and plastic waste.

Needing to integrate new technologies in standard operating rooms, more and more hospitals are now investing in hybrid operating rooms (ORs), where imaging and imaging-related tools are synergistic with standard surgical work.[11] The first hybrid OR was accomplished in cardiovascular surgery, but the hybrid concept is starting to expand to lots of different fields, such as trauma surgery, especially in hemorrhagic trauma.[12] Nevertheless, all surgical teams must be aware of the different costs per minute and, at the same time, the reduced risk of mortality in trauma patients. Cost-effectiveness, as seen before, remains the best policy: properly assessing a patient and avoiding the waste of resources is the key to future sustainability.

Another risk of wasting resources lies in surgical trays: most surgical trays happen to be filled with surgical tools that are never used but need to be sterilized before another operation. Optimizing inventory is key to achieving sustainability.[13,14] There are already some innovative systems where standardized inventories have shown a reduction in resources and time wasted, making the perspective of applying a set and tray for standardized procedures promising.[15]

As stated before, the last feature to achieve sustainability is the proper assessment of a patient. Creating specialized centers with multidisciplinary teams and fast tracks for every kind of disease would focus the right resources on the right patient.

Several experts brought their knowledge in their specific fields. For example, improving outcomes for pancreatic cancer patients mainly depends on assessing the patient.[16-18] A radical resection offers the best chance of treating this neoplasia, but the outcomes are better with adjuvant chemotherapy and adequate lymphadenectomy in borderline resectable or locally advanced tumors.[19,20] Adding minimally invasive approaches and referring all the patients to a specialized center will reduce postoperative mortality and morbidity, limiting the overall cost as well.[21,22]

One of the most important innovations in surgery that has arisen in recent years is the use of indocyanine green to achieve fluorescence-guided surgery. In particular, two fields showed a clear improvement: visualizing the vascularization of the bowel after resection or in intestinal ischemia and the biliary tree during cholecystectomy.[23-27] Indocyanine green (ICG) is a low-cost vital dye and can be easily detected by most of the laparoscopic or robotic tools in present ORs, thus having a cost-effectiveness ratio particularly interesting for future applications.

Another perspective involves bariatric surgery, which addresses both the emerging need in our society due to the rising obesity crisis and the ethical and environmental sustainability challenges. Also, in this situation, assessment of the patient from a multidisciplinary team ranging from surgeons to psychologists and personal trainers can improve the quality of the service, avoid wasting resources, and reduce additional strain on the national health system.[28-30]

Key issues are present on the sensitive topic of breast surgery: using techniques such as video-assisted nipple-skin-sparing mastectomy or cryoablation on selected patients is a new approach to treating benign and malignant mammary neoplasia. These minimally invasive approaches offer both an aesthetic improvement and a significant cost reduction, considering the short or nonexistent postoperative stay and the fewer resources needed to perform them.[31,32]

Finally, many articles report how the use of biological and biosynthetic prostheses is even more efficient than typical mesh, and their production has a lower carbon footprint. This creates the perfect combination between innovation and sustainability in one of the most common types of operations in general surgery (hernia surgery), making it a perfect occasion to achieve widespread sustainable surgery.

Conclusions

As the main topic of this paper, innovation must rise with sustainability. Healthcare may be one of the most impactful fields in wasting resources and polluting the planet, and it is our duty as physicians to make the right choices for our future.

Different perspectives emerged as possible problems in the actual management; however, several solutions are on the table to mitigate the environmental impact of hospitals.

The future will be characterized by increasing innovations to improve our daily jobs as doctors and offer better service for our patients. Nevertheless, we should never forget about the rest of society, which is comprised of healthy individuals who can be harmed by a progressive accumulation of pollution resulting from our inappropriate choices.

Sustainability should be the guiding light of the future of healthcare, and all medical research must consider the environment when proposing new and more performing innovations.

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