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Perspective

Greening the Neurosurgical Operating Room: The Environmental Impact of Spine Surgery

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Emerging studies have called attention to the rising environmental impact of healthcare delivery. In the United States, the healthcare sector has a carbon footprint exceeding 7-10% of total national carbon dioxide emissions annually [1,2]. Hospitals are the largest contributor, responsible for approximately 40% of total healthcare-related greenhouse gas (GHG) emissions.[1] US healthcare has been estimated to cause an annual loss of 614,000 disability-adjusted life-years due to the harmful effects of GHG emissions [3]. The relative contributions of various surgical specialties to the environmental footprint of healthcare remain unknown.

In the latest issue of *World Neurosurgery*, Wang and colleagues characterize the environmental impact of two widely used anesthetic strategies in a common orthopedic and neurosurgical lumbar spinal fusion procedure [4]. The authors find that changing from a general anesthetic protocol (based on inhalational gases) to a spinal anesthetic protocol for single level transforaminal lumbar interbody fusion procedures resulted in a significantly reduced carbon footprint. The authors calculated that the energy savings after 50 procedures were equivalent to burning over 560 kilograms of coal.

Importantly, the authors' energy savings calculations are specific to the anesthetic agents used intraoperatively. They astutely point out that many other factors can be considered, including medical supplies and energy usage. Notably, this is the first study to our knowledge to specifically quantify the environmental impact of spine surgery. There is thus a critical unmet need to understand and address the unique challenges that arise in spine surgeries.

One set of challenges relates to the significant quantity of supplies involved, particularly when surgical implants are used in spine fusion procedures. This frequently requires sterilizing and opening multiple instrument packs; although these are predominantly reusable instruments, only a small fraction of the instruments in each tray are used in the course of most fusion procedures. This represents an opportunity for surgeons to work with operating room supply centers and industry partners to streamline the instrument trays used in each procedure. Preparing fewer instrument trays per procedure could significantly lower utilization of energy-intensive sterilization, particularly in high-volume centers. These measures are broadly termed source reduction as well as management control procedures to guide product use.

Healthcare waste disposal may also be reduced by waste segregation before disposal and increasing product reuse or recycling. This is particularly important in resource-intensive operations such as spine procedures. In a recent study, Azouz and colleagues at the Mayo Clinic found that the greatest barrier to recycling in the operating room was a lack of staff awareness of what could be recycled [5]. They thus implemented a recycling improvement program in a three-operating-room facility; this included education for staff members as well as signs describing proper sharps disposal. The authors found that this translated to a decrease of more than

10 kilograms of sharps disposal per month, translating to cost savings of over 10% in sharps waste disposal expenditures. Other centers should consider adopting these protocols in order to promote recycling, reduce waste and achieve cost savings.

Given the frequent utilization of neurologic and musculoskeletal imaging in patients with spinal disease, we also encourage the exploration of imaging protocols that minimize energy use while maintaining clinical appropriateness [6]. This challenge extends to the use of intraoperative fluoroscopy and particularly the recent increase in use of computed tomography. Optimizing the use of these modalities may reduce both environmental impact and radiation exposure. Additional study is needed to quantify the environmental impact of these modalities as well as enabling technologies such as robotic assistance and navigation.

Many exciting frontiers lie ahead in the effort to make healthcare, and specifically spine surgery, more environmentally sustainable. Every aspect of surgical care delivery should be explored, from imaging to materials sourcing, operative protocols, and even the design of operating rooms and hospitals themselves [7]. We applaud efforts to characterize and address these challenges - particularly interdisciplinary efforts that involve other surgical specialists, anesthesiologists, operating room staff, hospital leaders and environmental and facilities experts.

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