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Evaluating the potential impact of spinal anesthesia use in lumbar surgery on global healthcare cost and climate change

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ABSTRACT

Introduction: Despite recent evidence demonstrating its safety and efficacy, spinal anesthesia remains a seldom-utilized anesthetic modality in lumbar surgical procedures. In addition, numerous clinical advantages, such as reduced cost, blood loss, operative time, and inpatient length of stay have been consistently demonstrated with spinal anesthesia over general anesthesia.
Research question: In this report we aim to examine the differences between spinal anesthesia and general anesthesia with regard to accessibility and climate impact and determine whether wider adoption of spinal anesthesia would have a meaningful impact on the global population. ***Materials and Methods***: The climate impact of spinal fusions performed under spinal and general anesthesia were obtained from recent studies published in the literature. Cost of spinal fusions was obtained from an unpublished study performed at our institution. Volume of spinal fusions performed in several countries were ascertained from published reports. Data on cost and carbon emissions were extrapolated based on volume of spinal fusions in each of the nations.
Results: In the U.S., use of spinal anesthesia for lumbar fusions would have resulted in savings of 343 million dollars in 2015. A similar reduction in cost was seen with each country studied. Additionally, spinal anesthesia was associated with 12,352 kg carbon dioxide equivalents (CO_2e) while general anesthesia produced 942,872 kg CO_2e. Similar reduction in carbon emissions was seen with each country studied.
Discussion and conclusion: Spinal anesthesia is safe and effective for both simple and complex spine surgeries, it reduces carbon emissions, permits lower operative times, and decreases cost.

1. Introduction

Spinal procedures such as discectomy, laminectomy, foraminotomy, and fusion may be performed under general or spinal anesthesia. Historically, concerns about intraoperative movement and anxiety, along with previously reported risks associated with prone positioning, anesthetic failure, intraoperative complications, and increased medical complexity have impeded the adoption of spinal anesthesia (Meng et al., 2017). Recently, multiple studies have reported the efficacy and safety of spinal anesthesia, leading to growing interest in the anesthetic modality across the United States. The reported benefits of spinal anesthesia are abundant, including reduced intraoperative time, cost, urinary retention, post-operative cognitive dysfunction (POCD), and intraoperative blood loss (Ehsani et al., 2020; Lessing et al., 2017; Yilmaz et al., 2010; Wang et al., 2022; Perez-Roman et al., 2021). Additionally, spinal anesthesia confers the ability to reposition a patient's chest, arms, and legs, thereby preventing pressure necrosis and nerve damage (McLain et al., 2005; Scott and Kehlet, 1988).

Lumbar surgery is extremely prevalent in the U.S. with cases of instrumented fusions increasing from 122,679 in 2004 to 199,140 in 2015 (Martin et al., 2019). The largest increase in fusion procedures was seen within the elderly population with cases rising from 98.3 per 100, 000 patients in 2004 to 170.3 in 2015 (Martin et al., 2019). Although elderly patients are known to have more comorbidities when compared to non-elderly patients, studies have shown that elderly patients experience equal and significant health benefits in all health domains after receiving lumbar fusion (McGirt et al., 2015). In all age categories, spinal fusions significantly improved pain, quality of life, and disability (McGirt et al., 2015). Despite the benefits of spinal fusion, developing nations have yet to perform this procedure at equivalent rates when compared to other countries. The U.S. performs, at a minimum, 40% more spine surgeries than any other nation (Cherkin et al., 1994). Studies investigating the cause for decreased rates of spinal surgery in Latin America and Nigeria have reported increased cost as a barrier[12,13]. Thus, reports

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suggesting cost-effective ways to perform spinal fusions without compromising safety and efficacy are valuable additions.

Lumbar spinal surgery, like many neurosurgical procedures, is a resource-intensive intervention contributing to healthcare carbon emissions. The U.S. health care sector contributes approximately 8.5% of the total national greenhouse gas emissions (Eckelman et al., 2020). This amounted to 553 million metric tons of carbon dioxide equivalents (CO_2e) in 2018 alone (Eckelman et al., 2020). These greenhouse gas emissions contributed to a loss of approximately 388,000 disability-adjusted life years (Eckelman et al., 2020). The health impacts of climate change are not uniformly distributed. Instead, there exists an almost inverse relationship between distribution of greenhouse gas emissions and health burden. As reported in the literature, the poorest countries incur the most severe consequences of climate change, while wealthier, industrialized nations account for most of the greenhouse gas emissions (Chikani et al., 2019). In this report, we compare the impact of spinal and general anesthesia on climate change and cost of lumbar fusion procedures to elucidate the benefits of widespread adoption of spinal anesthesia on equitable access to neurosurgical care worldwide and climate impact.

2. Methods

The volume of spinal fusion procedures in the United States was obtained from a report of the National Inpatient sample in 2015 (Martin et al., 2019). The volume of fusion procedures in Latin America was ascertained based on a report by Guiron et al. (Guiroy et al., 2020) in 2020. The volume of fusion procedures in the European countries of Norway, Finland, and Italy were ascertained from several published reports (Grotle et al., 2019; Ponkilainen et al., 2021; Cortesi et al., 2017). Data on cost of procedure, operating room costs, and time savings was gathered from a single-institution analysis of lumbar fusions under general versus spinal anesthesia (Jacob et al., 2022). Aggregate cost of procedures and time savings were extrapolated based upon surgical volume and cost elements noted above.

The amount of carbon dioxide equivalents (CO_2e) was obtained from a single-institution analysis of transforaminal lumbar interbody fusions (TLIF) performed under spinal and general anesthesia (Wang et al., 2022). Wang et al. (2022) compared CO_2e produced by TLIF procedures under spinal and general anesthesia, while maintaining the same infrastructure factors and patient supportive measures in the operating room. The volume of spinal fusions performed in 2015 were obtained from a report of the National Inpatient Sample (Martin et al., 2019). Climate impact was extrapolated based upon U.S. surgical volume in 2015. Number of fusion procedures in Australia were obtained from a study conducted by Harris and Dao in 2015 (Harris and Dao, 2009). The CO_2e released from fusion procedures in the US, Norway, Finland, Italy, and Australia was extrapolated based upon fusion volume and CO_2e measurements from Wang et al. (2022) noted above.

3. Results

3.1. Cost

According to the National Inpatient Sample, in 2015 there were 199,140 fusions performed in the United States (Martin et al., 2019). The cost of a unilateral TLIF under spinal or general anesthesia was found to be $16,228.39 and $17,934.34, respectively (Jacob et al., 2022). Therefore, the cost of such procedures would equate to approximately $3.23 billion under spinal anesthesia, compared to $3.57 billion under general anesthesia. Spinal anesthesia is also associated with an operating room (OR) supplies reduction cost of $1795.25, which results in an additional savings of approximately $358 million per year (Jacob et al., 2022). Therefore, introducing spinal anesthesia as the standard anesthetic modality for unilateral spinal fusion results in an aggregate cost savings of approximately $698 million per year. The time savings for procedures under general and spinal anesthesia should also be considered as fusions under spinal anesthesia are, on average, 38 min shorter (Jacob et al., 2022). This equals 7 million minutes saved on procedures compared to those utilizing general anesthesia.

Additionally, in Latin America, 55,006 fusions were performed in 2015 (Guiroy et al., 2020). This volume would be associated with a cost of $8.93 billion under spinal anesthesia, versus $9.86 billion using general anesthesia. In addition, the OR supply cost difference equates to approximately $98 million in savings. Together, this results in aggregate $191 million in cost savings. This is separate from the 2 million minutes in time efficiency savings associated with a switch to spinal anesthesia. As shown in Fig. 1, the European nations of Norway, Finland, and Italy would also experience savings in the cost of lumbar fusion procedures if all procedures were performed under spinal anesthesia as compared to general anesthesia.

3.2. Climate

TLIF procedures performed under general anesthesia produced on average 22,707 g CO_2e (Wang et al., 2022). Given that 199,140 fusions were performed in 2015, this would equate to approximately 4.5 million kg CO_2e. In comparison, TLIF procedures performed under spinal anesthesia produce 62 g CO_2e (Wang et al., 2022). Thus, 199,140 fusion procedures under spinal anesthesia would produce 12,352 kg CO_2e. Desflurane, an inhaled anesthetic commonly used in general anesthesia was the largest contributor to CO_2e (Wang et al., 2022). To account for this, median CO_2e produced from general and spinal anesthesia were calculated. Median CO_2e produced when using general anesthesia was found to be 4725 g, equating to approximately 942,872 kg CO_2e (Wang et al., 2022). Median CO_2e produced when using spinal anesthesia was 70 g, yielding 13,940 kg CO_2e.

Analysis of CO_2e produced from fusions performed in developed nations in Europe and Australia should also be considered. According to several published studies, European countries like Norway performed 120 fusions per 100,000 in 2013, Finland performed 30 fusions per 100,000 people in 2018, and Italy performed 20 fusions per 100,000 people in 2018 (Grotle et al., 2019; Ponkilainen et al., 2021; Cortesi et al., 2017). In 2006, Australia performed 28.3 fusions per 100,000 people (Harris and Dao, 2009). Thus, a cumulative 198.3 instrumented fusions per 100,000 people were performed in the three European countries and Australia. The use of general anesthesia during these fusions would equate to a mean of 4502 kg CO_2e. Conversely, use of spinal anesthesia would yield 12 kg CO_2e per 100,000 people. As shown in Table 1, CO_2e

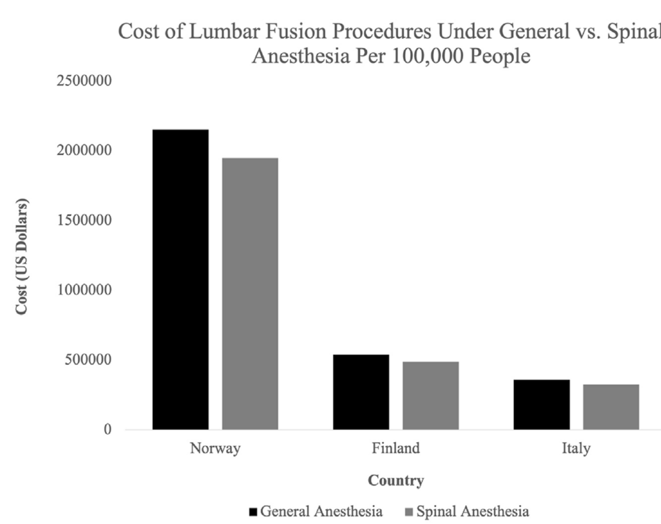

Fig. 1. Cost of lumbar fusions under general versus spinal anesthesia per 100,000 people in European countries.

Table 1
CO_2e produced by lumbar fusion procedures under general versus spinal anesthesia per 100,000 people.

Country	CO_2e Released Per 100,000 People For Fusions Under General Anesthesia	CO_2e Released Per 100,000 People For Fusions Under Spinal Anesthesia
Norway	2724.84 kg	7.44 kg
Finland	681.21 kg	1.86 kg
Italy	454.14 kg	1.24 kg
Australia	642.61 kg	1.75 kg

produced by lumbar fusions in Norway, Finland, Italy, and Australia is far reduced when procedures are performed under spinal anesthesia.

4. Discussion

This report presents one of the first analyses of the impact of two different anesthetic modalities on global climate change for lumbar fusions. We highlight how wider adoption of spinal anesthesia could ameliorate the environmental impact of neurosurgery, and how decreased cost associated with use of spinal anesthesia could aid in increasing the amount of fusions performed worldwide. Given the lower health care costs in Europe as compared to the United States, we acknowledge the reported estimates of cost savings in Norway, Finland, and Italy are likely an overestimate. Nonetheless, cost savings are still expected with the use of spinal anesthesia compared to general anesthesia in these countries.

Today, many industrialized countries such as the US, Germany, UK, Sweden, Denmark, and Norway report increasing numbers of lumbar surgeries (Grotle et al., 2019). For instance, from 2004 to 2015 the U.S. saw an increase in lumbar fusion procedures from 122,679 to 199,140 (Martin et al., 2019). Carbon emissions have an inequitable impact on health around the world. Poorer, developing countries bear the greatest consequences of climate change due to vulnerabilities such as coastal location, high population density, and poor sanitation (Campbell-Lendrum and Corvalán, 2007). Climate change drastically affects food security and the proliferation of arthropod vectors, leading to malnutrition and the spread of vector borne illness like malaria (Zhou et al., 2005; Khasnis and Nettleman, 2005; Rocklöv and Dubrow, 2020; Nakstad et al., 2022). Given the learning curve for lumbar spine surgery under spinal anesthesia is not as steep as previously thought, training spine neurosurgeons in developed countries may be feasible (West et al., 2022). Although this report focused on cost and climate impact of lumbar fusions, simple lumbar surgery may represent the most approachable target for the use of spinal anesthesia considering simple surgeries are more common than complex fusions. Thus, if our findings associated with lumbar fusions performed under spinal anesthesia were extrapolated to all lumbar surgery, there would likely be a similar proportion of cost savings and reduction in climate impact. Analysis for simple lumbar surgeries was not documented in this report due to differences between simple and instrumented cases, however, it is intuitive that carbon emissions would be proportional to procedure duration and OR hardware savings would likely be similar.

The increasing levels of spinal procedures warrant a closer examination of the increasing impact of anesthetic choice on climate change. Spinal anesthesia was shown to be drastically superior in reducing the carbon footprint of lumbar fusion surgeries in the U.S. According to EPA reports, $8.887e^{-3}$ metric tons of CO_2 are produced per gallon of gasoline ("Greenhouse Gases Equivalencies Calculator). Thus, use of spinal anesthesia in lumbar fusions would equate to burning 510,810 fewer gallons of gasoline. It is important to recognize this conservative approach used to estimate the burden of lumbar fusions on carbon emissions as the actual burden is likely much greater given only lumbar fusions were captured in our estimates. Spinal fusion procedures may increase in the future given the rising elderly population, and thus the impact on climate change and carbon emissions may increase. Widespread adoption of spinal anesthesia for lumbar fusions may mitigate the harm. Other surgical procedures such as discectomy, decompressive laminectomy, and foraminotomy can also be achieved under spinal anesthesia, collectively reducing the carbon footprint of lumbar spine surgery.

5. Conclusion

Increased global health equity will require a broad effort distributed across numerous spheres. In this report, we conclude that wider adoption of spinal anesthesia in lumbar fusion procedures would play a meaningful role in this improvement by both reducing cost and thereby increasing accessibility to beneficial procedures as well as reducing the global healthcare carbon emissions and thereby benefiting those living in areas most at risk.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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