

# A Narrative Review of Plastic Surgery and Climate Change: Context and Considerations

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**Summary:** Climate change poses significant threats to human health and society. Although healthcare will bear a large burden of the downstream effects of climate change, the healthcare industry is simultaneously a major contributor to climate change. Within hospitals, surgery is one of the most energy-intensive practices. There is a growing body of literature describing ways to mitigate and adapt to climate change in surgery. However, there is a need to better understand the unique implications for each surgical subspecialty. This review contextualizes plastic and reconstructive surgery within the climate change discussion. In particular, this review highlights the specific ways in which plastic surgery may affect climate change and how climate change may affect plastic surgery. In light of growing public demand for change and greater alignment between industries and nations with regard to climate change solutions, we also offer a conceptual framework to guide further work in this burgeoning field of research. (*Plast Reconstr Surg Glob Open* 2022; 10:e4703; doi: [10.1097/GOX.0000000000004703](https://doi.org/10.1097/GOX.0000000000004703); Published online 16 December 2022.)

## INTRODUCTION

The negative effects of climate change on health and society are well-documented and far-reaching.<sup>1</sup> Some examples include increasing heat-related morbidity and mortality, worsening food scarcity, growing infectious disease transmission, relocation of populations, and drastic tolls on economic output and productivity (estimated as 302 billion hours of labor capacity lost in 2019).<sup>1</sup> Moreover, the effects of climate change disproportionately affect vulnerable populations, such as those living in low-income nations or low-income individuals living in high-income nations, which threatens to further destabilize health equity.<sup>2</sup> Given the sweeping negative effects of climate change, increasing attention and efforts have been directed toward mitigating and adapting to climate change by various nations, industries, and individuals.

The healthcare industry, in particular, plays a unique role in climate change. While healthcare will undoubtedly bear a significant burden of climate change as extreme

weather events threaten infrastructure<sup>3</sup> and patients with climate-related health concerns swell,<sup>4</sup> the healthcare industry is a major contributor to climate change as well. The healthcare industry comprises 4.4% of the global climate footprint, meaning healthcare would rank fifth in global emissions if it were a country.<sup>5</sup> The United States, specifically, ranks first in healthcare-associated emissions,<sup>5</sup> estimated to be approximately 10% of the national total in 2013.<sup>6</sup>

Surgery is among the most energy-intensive<sup>7</sup> and waste-producing<sup>8</sup> practices within the hospital. Although all surgical disciplines warrant discussion within the broader context of climate change, there is a need to understand the unique concerns and implications for each surgical subspecialty. In light of increasing trends for both reconstructive and cosmetic surgical procedures in the past 20 years in the United States,<sup>9</sup> growing demands for globalization efforts,<sup>10</sup> and preliminary work on surgical mitigation measures,<sup>8,11,12</sup> plastic and reconstructive surgery is one unique lens from which to examine the relationship between surgery and climate change.

Using a previously developed framework for contextualizing surgical, obstetric, and anesthesia care,<sup>13</sup> the intersection of plastic surgery and climate change can be thought of in two ways: how plastic surgery impacts climate change and how climate change impacts plastic surgery. This study aimed to provide greater context and considerations, specifically, for plastic and reconstructive surgery in light of the growing challenges of climate change, and

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to highlight future directions and opportunities in this burgeoning field of research.

## METHODS

PubMed was queried January 2022 using the terms “plastic surgery AND climate change.” Three potentially relevant articles were identified.<sup>12,14,15</sup> The paucity of literature in this area would not have supported a systematic or scoping review on the topic. A narrative review aiming to contextualize plastic and reconstructive surgery in climate change was therefore pursued.

PubMed was subsequently queried using the terms “plastic surgery AND climate change,” “surgery AND climate change,” and “climate change” in January 2022. Reference lists in relevant articles were reviewed for other potentially relevant literature. A narrative review of sources was conducted.

Beyond a literature review, an estimate of the carbon emissions burden of cosmetic procedures was pursued. Carbon emission estimates from three procedures (rhinoplasty, abdominoplasty, and breast augmentation) were obtained from a study conducted by Berner et al.<sup>16</sup> Conversion of these estimates to comparable vehicular miles was conducted using emission factors published by the United States Environmental Protection Agency for standard passenger vehicles.<sup>17</sup> Google Maps was used to determine the mileage of traveling cross-country in a passenger vehicle between Los Angeles, California, and Boston, Massachusetts (2983 miles), and was approximated to 3000 miles. The total number of procedures performed was obtained from publicly available reports for the United States<sup>9</sup> and internationally.<sup>18</sup>

## THE EFFECTS OF PLASTIC SURGERY ON CLIMATE CHANGE

Reconstructive and cosmetic plastic surgery procedures have increased drastically over the past 20 years in the United States.<sup>9</sup> Overall cosmetic procedures have increased 22% from 2000 to 2020, with procedures such as lower body lifts increasing by 3974% in that same timeframe.<sup>9</sup> These trends are not unique to the United States. Cosmetic surgery procedure rates have increased in other high-income nations, such as the United Kingdom.<sup>19</sup> Increasing rates of medical tourism, whereby patients seek surgery abroad, are also driving the global demand for cosmetic and reconstructive surgery.<sup>10,20,21</sup>

At present, data are limited regarding the environmental impacts of plastic surgery procedures. One study conducted in Chile provides carbon footprint estimates (kgCO<sub>2</sub>-eq) for three common plastic surgery procedures: rhinoplasty, abdominoplasty, and bilateral breast augmentation using silicone implants.<sup>16</sup> Although there are certain limitations to this country- and hospital-specific data, reasonable extrapolations can be made to estimate environmental impact more broadly. Carbon footprint estimates from Chile are likely conservative relative to the United States, where surgery has been noted to generate

## Takeaways

**Question:** How does plastic surgery affect climate change and how can climate change be expected to affect plastic surgery?

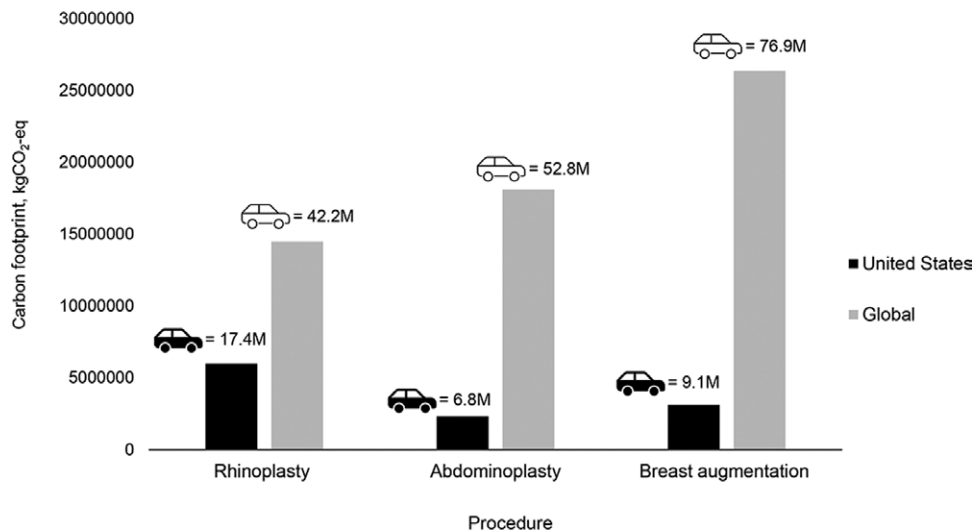
**Findings:** Although plastic surgery has a major impact on climate change, there are many ways in which plastic surgery can be expected to be impacted by the downstream effects of climate change.

**Meaning:** Future research is needed regarding the overlap between plastic surgery and climate change to mitigate the effects of surgery on climate change and to build resilient surgical systems.

excessive waste.<sup>22</sup> For context, the United States ranks eleventh worldwide in terms of per capita carbon dioxide emissions (15.2 metric tons), whereas Chile ranks seventeenth (4.6 metric tons).<sup>23</sup>

The total number of procedures performed in 2020 in the United States and globally, respectively, were 352,555 and 852,554 rhinoplasties; 97,988 and 765,248 abdominoplasties; and 193,073 and 1,624,281 breast augmentations.<sup>9,18</sup> The corresponding carbon footprint estimates for total procedures performed in 2020 in the United States are  $6.0 \times 10^6$  kgCO<sub>2</sub>,  $2.3 \times 10^6$  kgCO<sub>2</sub>, and  $3.1 \times 10^6$  kgCO<sub>2</sub> for rhinoplasty, abdominoplasty, and bilateral breast augmentation, respectively. To put this into context, the carbon footprint estimate of total rhinoplasties performed in 2020 in the United States ( $6.0 \times 10^6$  kgCO<sub>2</sub>) would be equivalent to driving over 17 million miles in a standard passenger vehicle, or just shy of 6000 cross-country trips between Los Angeles and Boston. Like many of the compounding effects of climate change, this carbon footprint amplifies further when considering global procedure totals, where the carbon footprint estimates are  $1.4 \times 10^7$  kgCO<sub>2</sub>,  $1.8 \times 10^7$  kgCO<sub>2</sub>, and  $2.6 \times 10^7$  kgCO<sub>2</sub> for rhinoplasty, abdominoplasty, and bilateral breast augmentation, respectively (Fig. 1).

Although it will be important to elucidate the ways in which plastic surgery procedures uniquely contribute to climate change, it is important to note that many of the climate-impacting elements of plastic surgery are shared by all surgical disciplines, and have been previously described more generally for surgical, obstetric, and anesthesia care.<sup>11,13</sup> For example, elements such as anesthesia and overall energy usage of operating rooms (ie, temperature control and ventilation) are some of the largest contributors to greenhouse gas emissions in surgery.<sup>7</sup> Operating rooms produce up to 30% of hospital waste, including materials that could be recycled (such as the widely used “blue wrap” of instruments),<sup>24</sup> as well as inadequate sorting of waste, such that nonbiohazardous waste inappropriately undergoes more energy-intensive processing intended for biohazardous waste.<sup>11,25</sup> As such, it will be important to investigate the particular climate impacts of plastic surgery alongside the ubiquitously shared concerns across surgical disciplines.



**Fig. 1.** Carbon footprint estimates of total rhinoplasty, abdominoplasty, and breast augmentation procedures performed in 2020 in the United States and globally. Procedures represented on the x-axis. Carbon footprint represented on the y-axis in kgCO<sub>2</sub>-eq. Icons representing cars denote equivalent carbon footprint in terms of vehicular miles, where M indicates million miles.

### THE EFFECTS OF CLIMATE CHANGE ON PLASTIC SURGERY

Climate change affects all aspects of human society, ranging from food, air, water, to shelter, all of which may have downstream impacts on plastic surgery.<sup>1</sup> These impacts, although inter-dependent, can be viewed at the patient-, surgeon-, hospital-, and systems-level.

#### Patient-level Impacts

Climate change will likely exacerbate the disease burden requiring plastic surgery interventions (Table 1). Increasing natural disasters and extreme weather events from climate change have both direct and indirect effects on patients. Larger and more long-lasting wildfires will likely increase the number of patients experiencing

severe burns,<sup>26</sup> and the need for plastic surgery interventions, especially because wildfire burns, in particular, have been associated with greater mortality and wound complications.<sup>27</sup> The increase in traumatic injuries associated with natural disasters like hurricanes, tropical storms, and tornadoes<sup>28</sup> may also necessitate plastic surgery interventions.<sup>29</sup> Hurricanes in the United States, for example, have led to complex lower extremity injuries,<sup>30</sup> laceration and hand trauma associated with tree removal,<sup>31</sup> and surges in hand trauma associated with animal bites from displaced domestic animals.<sup>32</sup> Indirectly, climate change may also be associated with worsening collective violence,<sup>33</sup> such as armed conflict and violent crime, similarly necessitating plastic surgery interventions for traumatic injuries.

Climate change has also been linked to the rising incidence of many different cancers that warrant plastic surgeons' attention<sup>34</sup> For example, climate change exacerbates air pollution,<sup>44</sup> which may be associated with the rising incidence of breast cancer<sup>44</sup> and subsequent need for reconstruction.

Climate change may also directly impact preoperative and postoperative risk factors. Through the disruption of global food supply, climate change has been linked to poor nutritional status—both obesity and malnutrition,<sup>36,37</sup> which have been shown to worsen wound healing and plastic surgery outcomes.<sup>38,39</sup> Wound infections may also become more prevalent, especially in lower-income nations, as water scarcity threatens irrigation capabilities<sup>38</sup> and flooding threatens the sanitation of water supply.<sup>41</sup> In addition, warm weather itself has been associated with a higher incidence of surgical site infections.<sup>42</sup>

#### Surgeon-level Impacts

Patient-level impacts largely drive the impacts on surgeons, as the types and volume of cases may change in

**Table 1. Potential Impact of Climate Change on Plastic Surgery Procedures**

Climate Change Factor	Potential Impact on Plastic Surgery
Larger and longer-lasting wildfires <sup>26</sup>	Increasing demand for complex wound and burn care <sup>27</sup>
Worsening natural disasters <sup>28</sup>	Increasing traumatic injury burden <sup>28</sup> and demand for extremity and hand reconstruction <sup>29-32</sup>
Worsening collective violence <sup>33</sup>	Increasing demand for complex reconstruction following violent trauma
Rising cancer incidence (eg, breast cancer) <sup>34,35</sup>	Increasing demand for cancer reconstruction
Strain on global food supply with resulting obesity and malnutrition <sup>36,37</sup>	Increased risk for poor wound healing <sup>38,39</sup>
Strain on global water supply, irrigation, and sanitation <sup>40,41</sup>	Increased risk for postsurgical infection <sup>41</sup>
Increasing warm weather <sup>1</sup>	Increased risk for surgical site infections <sup>42</sup>

order to cater to shifting demands and patient populations. In addition, natural disasters and extreme weather have significantly disrupted hospital operations around the globe,<sup>43,46–48</sup> which may lead to more frequent case cancellations, particularly for elective cases. Demands for sustainable surgery in light of pressure from climate change will also very likely alter surgical training and practice, of which there is a growing body of literature describing recommendations specifically for plastic surgeons.<sup>12,49</sup> Increasing regulatory pressures that require hospitals to cut carbon emissions in the coming years<sup>50</sup> may also require greater transparency and practice changes among surgeons.

**Hospital- and Systems-level Impacts**

The increasing frequency of natural disasters and extreme weather phenomena will undoubtedly disrupt hospital infrastructure and practice as described above.<sup>43,46–48</sup> There may be subsequent delays in resuming elective and cosmetic procedures as emergent surgery is prioritized during hospital recovery—negatively impacting patients, surgeons, and hospital revenue flows.<sup>51</sup>

And not all hospitals should be expected to recover. Nearly 150 rural hospitals have closed since 2010, largely driven by insurmountable financial challenges.<sup>52</sup> Natural disasters can cause costly physical damages and simultaneously interrupts elective surgical care that reduces hospital income. Because rural hospitals are already more financially vulnerable, climate change-driven natural disasters could exacerbate existing urban/rural disparities in access to plastic surgery.<sup>53</sup>

Climate change also poses equity issues at the global level. As climate events force massive relocations of populations and disrupt infrastructure,<sup>1</sup> it will be increasingly difficult to scale-up surgical care for the 4.8 billion people who already lack access to surgery as of 2015.<sup>54</sup> This is particularly relevant for plastic surgery, where there is already a great demonstrated global need without an adequate supply of plastic surgeons.<sup>10</sup>

In addition, climate change and environmental concerns have moved many systems toward more transparent reporting and sustainability standards. This may be due in part to the strong association between environmental impact and financial performance in a number of businesses.<sup>55</sup> Plastic surgery may similarly reap value gains through environmental investments, as has been seen in the pharmaceutical industry.<sup>56</sup>

The literature to date largely lacks attribution of climate change, specifically, to downstream effects on procedures. As a result, this is likely not an exhaustive list for the ways in which climate change may impact plastic surgery and will be an area of much needed future research.

**A WINDOW OF OPPORTUNITY**

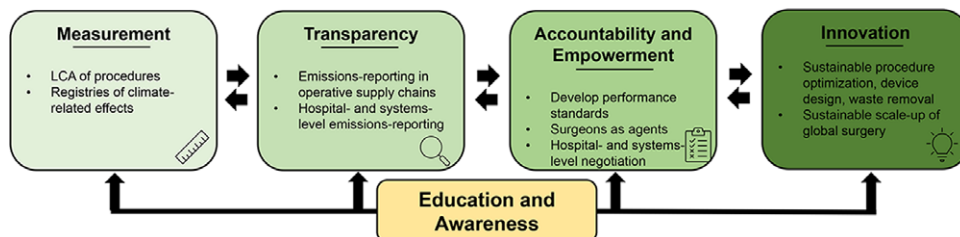
Despite the seemingly insurmountable challenges of climate change, momentum is growing for better preparedness. This may be due in part to greater alignment among the general public, industries, and governments across the globe. The majority of Americans, for example, believe global warming is happening and that corporations should do more to address it.<sup>57</sup> Recent work from our group shows that some members of the general public believe healthcare, specifically, has a role in climate change and would be willing to adapt their healthcare choices and pay more out-of-pocket to mitigate it (forthcoming data). Increasingly, hospitals are engaging in environmental stewardship<sup>58</sup> and international leaders are committing to climate change adaptation and mitigation in healthcare.<sup>1,59</sup> Now, more than ever, action is not only due, but also possible.

**FUTURE DIRECTIONS**

There is an urgent need to mitigate the effects of plastic surgery on climate change and adapt plastic surgery to the existing and imminent threats of climate change. Several authors have suggested key mitigation and adaptation strategies that are applicable to plastic surgery.<sup>11–13,24,49,60,61</sup> Here, we provide a conceptual framework for gaps, opportunities, and future directions in order to guide further work in this area. Although intended for plastic surgery, we believe this would be transferrable to other surgical disciplines as well (Fig. 2).

**Measurement**

Making advances in this area will require understanding the environmental impacts and consequences of plastic surgery. To date, this data are limited. Routine and systematic measurements of surgical procedures will therefore be key. Life-cycle assessment is a rigorous measurement process that can be used to determine the carbon footprint of products, surgeries, and systems,<sup>62,63</sup> and could be conducted across systems for plastic surgery, where there are numerous different devices, technologies, and unique materials (ie, biologic mesh and implants).



**Fig. 2.** Conceptual framework for future directions and opportunities. LCA, life cycle assessment.

### Transparency

Once measurements are made, there is a need for greater transparency. Previous life-cycle assessments have identified that surgeon-level changes such as recycling, although important, have minimal environmental impacts relative to other components of the surgical system.<sup>63</sup> Accordingly, systems-level changes, such as identifying carbon-heavy processes in device supply chains, are needed for greater impact and environmental effectiveness. This will be made easier with transparent reporting of emissions for the various components of plastic surgery procedures. Given the recent increase in regulatory and governmental pressure for reducing carbon emissions in hospitals, this is likely also more possible.<sup>50</sup>

### Accountability and Empowerment

Understanding the environmental impact of procedures will allow surgeons, hospitals, and even patients to hold the healthcare industry accountable for environmental effectiveness. Armed with measurements from transparent reporting combined with their clinical experience, plastic surgeons can act as active agents within the hospital and healthcare system to advocate for sustainable choices and negotiate for more climate-effective solutions that do not compromise quality of care. Through this process, environmental standards can be set and used for evaluation of new devices and technologies as they emerge. Relaying specific outcomes to surgeons as “report cards” has been identified as a key component in driving quality improvement.<sup>64</sup> With clearer environmental impact data, plastic surgeons can exercise their agency as major revenue generators for US hospitals to advocate for hospital-level environmental standards in the OR that align with high quality, efficient patient care. In addition, institutions, alongside individually acting surgeons, may be able to make informed recommendations regarding waste and recycling guidelines that not only optimize for cost-savings but also sustainability.

### Innovation

Better understanding the environmental impact of surgery, together with the downward pressures of accountability and demand for sustainability from the general public will likely drive an explosion of innovation in this area. There is great potential to optimize procedures, surgical device design, waste removal solutions, and strategies to scale-up plastic surgery on the global level in creative and sustainable ways. At the same time, innovative solutions will be needed to create systems and practices that are resilient to the downstream effects of climate change.<sup>11,13</sup> Notably, although up-front costs will certainly be needed to enact and drive innovation, downstream returns and cost-savings are both likely and possible in this field.<sup>24,56,66</sup>

### Education and Awareness

Throughout this process, greater education and awareness will be critical.<sup>67</sup> This could involve

interventions designed to educate and empower medical students, plastic surgery residents, attendings, and hospital systems. In addition, there is a great need to educate and empower patients. Plastic surgery is particularly well-poised to lead in this area, as elective and cosmetic settings could more easily facilitate sustainably-minded discussions and procedural choices. Building education and awareness in this area will also foster collaboration and innovation, and likely ease the adoption of effective solutions in the future.

## CONCLUSIONS

This review highlights the important overlap between plastic surgery and climate change. At first, one may believe that this overlap only concerns the consumption of goods and energy associated with plastic surgical care that contribute to climate change. However, the relationship between plastic surgery and climate change is a two-way street. Not only will the physical maladies associated with increasing wildfires and major storms necessitate a larger plastic surgery workforce, but the challenges to food security and pollution exposure could complicate the surgical recovery process. Delivering climate-smart plastic surgery care will be crucial to combatting the ill effects of climate change. Building out sustainable plastic surgery infrastructure globally will expand access to the tremendous value, positive health outcomes, and improvements in quality of life gained through plastic surgery.

Costs and benefits exist for all medical and surgical procedures. Although certain risks that factor into the cost-benefit calculus are more developed, such as mortality, side-effects, and even financial toxicity, there is both an opportunity and need to better understand environmental risk. This article contextualizes plastic surgery within the climate change discussion and highlights several key future directions in this area. Through this, we can continue optimizing the health of both our patients and the planet.

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