

Calculating the Carbon Cost in Critical Care: A Global View from an Intensive Care Window

P Ramesh Menon

Received: 11 December 2012 Accepted: 5 January 2013 Published: 15 January 2013

Abstract

The "Global Climate Change and Children's Health" is a technical report and policy statement (1), that outlines the specific ways global climate change impacts child health, and calls on health practitioners to understand the threats, anticipate the impact on health, and advocate for strategies that will lessen the effects. A carbon footprint is defined as: The total amount of greenhouse gases produced to directly and indirectly support human activities, usually expressed in equivalent tons of carbon dioxide (CO₂). It is often understood as in the following examples: Other greenhouse gases which might be emitted as a result of human activities are methane and ozone. These greenhouse gases are normally also taken into account for the carbon footprint. They are converted into the amount of CO₂ that would cause the same effects on global warming. This is called equivalent CO₂ amount. Carbon footprint may also be expressed in kg carbon rather than kg carbon dioxide (By multiplying with a factor 0.27 i.e. 1'000 kg CO₂ equals 270 kg carbon).

Index terms—

1 Introduction

The "Global Climate Change and Children's Health" is a technical report and policy statement (1), that outlines the specific ways global climate change impacts child health, and calls on health practitioners to understand the threats, anticipate the impact on health, and advocate for strategies that will lessen the effects.

A carbon footprint is defined as: The total amount of greenhouse gases produced to directly and indirectly support human activities, usually expressed in equivalent tons of carbon dioxide (CO₂). It is often understood as in the following examples:

Other greenhouse gases which might be emitted as a result of human activities are methane and ozone. These greenhouse gases are normally also taken into account for the carbon footprint. They are converted into the amount of CO₂ that would cause the same effects on global warming. This is called equivalent CO₂ amount. Carbon footprint may also be expressed in kg carbon rather than kg carbon dioxide (By multiplying with a factor 0.27 i.e. 1'000 kg CO₂ equals 270 kg carbon).

The carbon footprint is a very powerful tool to understand the impact of personal behaviour (including healthcare) on global warming. Individual activities like, e.g. travelling by car, train, bus or air plane, fuel consumptions, electricity bills are called "carbon stamps" (individual contributions). In the medium-and long term, the carbon footprint must be reduced to less than 2'000 kg CO₂ per year and per person. (2)

Author: Registrar, PICU Royal Children's Hospital Melbourne Australia. e-mail: rpmpgi@gmail.com
Keywords: carbon footprint, ventilation, health.

Carbon footprint in the ICU: In the medical parlance, Carbon dioxide (CO₂) is produced by cell metabolism in the mitochondria. It depends on the rate of metabolism and the relative amounts of carbohydrate, fat and protein metabolized. The amount is about 200ml.min⁻¹ when at rest and eating a mixed diet; this utilizes 80% of the oxygen consumed, giving a respiratory quotient of 0.8 (RQ = rate of CO₂ production / rate of O₂ consumption). A carbohydrate diet, in a healthy human in a resting state, gives a quotient of 1 and a fat diet 0.7. (3) In a sick child as the metabolic processes are in a compensatory overdrive / decompensated mode, the CO₂ production

2 CARBON COST AND HEALTH CARE (A GLOBAL VIEW):

increases and the homeostatic processes go into overdrive with increasing Work of breathing (WoB) to eliminate the excess CO₂ generated and to get more O₂ available for gas exchange. (4) It is in this context of increased WoB that the intensivist manages the patient with Mechanical ventilation and sedation/analgesia and nutrition (enteral or parenteral) and supportive care (temperature / fluid etc).

Considerable changes in healthcare delivery practices have been suggested and adopted to improve efficient utilisation of energy.(5,6) However, no formal assessment of actual health care/delivery services in terms of their carbon footprint/ stamps have been done to date. (7) This would enable improvisations of the services which consume the energy rather than the technology available to the end user.(2) While the Hospital sector and health care organizations have made great efforts to improve hospital sustainability practices, the transition may be guided by Life Cycle Assessment (LCA),(8) a method being increasingly used to determine the entire "cradle to grave" economic and climatic effects (carbon cost) of processes and products. (9) Advanced computing methods have been used to look at the amount of CO₂ produced for energy consumed per unit of medical equipment (e.g.: cannulae, ventilator, operation theatre equipment, anesthetic gases etc) and other healthcare accessories including hospital buildings, biological waste disposal etc. (5, ??, ??0,11). However, computing carbon cost of actual processes of health care interventions (like cannulation, mechanical ventilation, parenteral nutrition) have not been considered, yet. It is only recently that an T Each of the following activities adds 1 kg of CO₂ to carbon footprint:-? Travel by public transportation (train or bus) a distance of 10 to 12 km

? Drive by car a distance of 6 km (assuming 7.3 litres petrol per 100 km)

? Fly with a plane a distance of 2.2 km ? Operate a computer for 32 hours (60 Watt consumption assumed)

? Production of 5 plastic bags/ 2 plastic bottles/ one third of an American cheeseburger (the production of each cheeseburger emits 3.1 kg of CO₂!) approach at estimating the carbon cost of "processes" in service of the end user have begun to be looked at.(6) Sustainable health care practices can be maintained into future by conserving an ecological balance. Its relative importance may be assessed by audits that found over 8% of US total carbon cost originating from health care system. (12) Here, we intend to look at the concept of carbon cost of the process of mechanical ventilation of a sick child, in the intensive care setting, to understand the perspective of accounting for the individual practices of health care intervention in terms of their ecological impact. Hypothesis: In a ventilated child, other supportive care remaining the same (e.g. sedation / analgesia / nutrition / temperature/ inotropic support), the PaCO₂ levels across time (x axis: time; y axis: PCO₂) would directly yield the carbon footprint of the process of mechanical ventilation (in their respective modes of ventilation) for the duration of ventilation.

Approximately 75% of carbon dioxide is transported in the red blood cell and 25% in the plasma. There is a difference between the percentage of the total carbon dioxide carried in different forms in blood and the percentage exhaled from them. For example, 5% of the total is in solution (in plasma) but 10% of exhaled carbon dioxide comes from this source; 10% is protein bound, particularly with Hb, but this supplies 30% of the exhaled amount. This corresponds to 0.5ml.kPa-1 carbon dioxide in 100 ml blood at 37oC. The partial pressure of carbon dioxide is 5.3pKa in arterial blood and 6.1kPa in mixed venous blood; therefore, arterial blood will contain about 2.5ml per 100ml of dissolved carbon dioxide and venous blood 3ml per 100ml. A cardiac output of 5l.min-1 will carry 150ml of dissolved carbon dioxide to the lung, of which 25ml will be exhaled. Because of this high solubility and diffusion capacity, the partial pressure of carbon dioxide in alveolar and pulmonary end-capillary blood are virtually the same.(3) Hence PA CO₂ (= PaCO₂) is a direct correlate of CO₂ produced in metabolically active tissues of the body and brought to the lungs for exhalation, via blood. PaCO₂ is the only blood gas measurement that provides information on VA. Furthermore, PaCO₂ states directly, with one number, the relationship of VA to carbon dioxide production, at least at the time the sample is taken. (4) The production of CO₂ (and thereby PaCO₂) in a steady state is dependent on the metabolic state of the tissues and the work done by the mechanical ventilator (which offloads the work of breathing in a sick child). After the initial stabilization of a sick child, the metabolic state of the tissues attains a new equilibrium, including the work shouldered by the mechanical ventilator. (4) Other factors and interventions like sedatives/ analgesics / inotropes/ parenteral nutrition etc are significant factors in the attainment of the equilibrium. Once attained, the metabolic equilibrium is a function of the underlying disease process and the compensatory work demand performed by the mechanical ventilator. Given that the body's homeostatic mechanisms in overdrive / distress become less efficient (generating more CO₂ in disease / decompensated state), mechanical ventilation may actually have benefits in terms of saving the carbon cost due to the disease or death. There has to be a method of quantifying the carbon cost of the process of health care intervention.

This concept of saving carbon cost with health care intervention (like heart surgery) (13, 14) finds an echo in the similar concept of carbon cost saved in the process of E-news. (15) Technical improvements in any specific sector (e.g. communication, transportation) may not generate per capita reductions in energy use or GHG emissions as large as reductions possible through changing the means by which people achieve the ends currently provided in those sectors (e.g. E-news, social interaction). However, reductions are constrained by how well the alternative (e.g., e-readers, vehicle sharing) substitutes for the existing means of providing the service. (??5)

2 Carbon cost and health care (a Global view):

This reminds people in health care that we're not a trivial part of the issue. The primary focus is on issues surrounding patient safety, health care quality, and cost containment at this current point in time. The health

care sector, in general, may be a bit slower than other sectors to put this [emissions] on their radar screen. But given the focus on health care policy and environmental policy, it might be interesting if not wise to start accounting for environmental externalities in health care.

According to a WHO report (16)

? Climate change affects the fundamentals for health -clean air, safe drinking water, sufficient food and secure shelter. ? Many of the major killers such as diarrhoeal diseases, malnutrition, malaria and dengue are highly climate-sensitive and worsen as the climate changes. ? Areas with weak health infrastructure -mostly in developing countries (12). -will be the least able to cope without assistance to prepare and respond.

Treating climate-related ills will require preparation, and early-warning systems. Climate change can contribute to such diseases as diarrhea, malaria and infectious illnesses in a number of ways. (17,18) In warmer temperatures, for example, the parasite that spreads malaria via mosquitoes develops more quickly.(??) A 2000 study conducted in Peru (19) found that when the periodic El Nino phenomenon boosted temperatures there, hospital admissions of children with diarrhea increased exponentially.

Pediatric perspective: For children, this can mean post-traumatic stress, loss of caregivers, disrupted education and displacement. Increased climate-sensitive infectious diseases, air pollution-related illness, and heat-related illness and fatalities also are expected. (20) Disruptions in the availability of food and water and the displacement of coastal populations can cause malnutrition, vitamin deficiencies and waterborne illness. Direct health impacts from global warming include injury and death from more frequent extreme weather events, such as hurricanes and tornados. India, like most other developing countries with high growth indices can grow differently, because "it is in an early stage of development". In other words, it can leapfrog to a low carbon economy, using high-end and emerging technologies and by being different. As doctors, our field of care must broaden to ensure that today's children who would inherit the burden of our actions today and bequeath it to tomorrow's children, are well prepared. The new paradigm of an abruptly changing climate system has been well established by research over the last decade, but this new thinking is little known and scarcely appreciated by the wider community of natural and social scientists and policy makers-National Academy of Sciences/National Research Council 2002. (??)II.

Hospital Perspective 1) Use point of contact for health care delivery to discuss with parents regarding potential impact on health of climate change. Antenatal clinics, Immunisation clinics, well baby clinics; School health services .Doctors can effectively create awareness about "future" effects of climate change; make sure that patients understand the air quality index, pollen counts and UV measures used in most metropolitan areas. These may be opportunities to introduce the broader issue of climate change and the importance of reducing CO2 emissions.

5) Emulate other hospital sectors and organisations that have made great efforts to improve hospital sustainability practices e.g.: using less volatile anesthetics like desflurane. (??) Some measures that hospitals can use to improve energy efficiency include creating recycling programs and purchasing goods and services from environmentally friendly suppliers. At the University of Chicago Medical Centre, the Sustainability program has implemented a plastic recycling program that diverts more than 500 pounds of waste each day from landfills to recycling plants and ensured that 90 percent of cleaning supplies used by the hospital have Green Seal certification. Such efforts have reduced waste costs from \$55,000 per month to \$35,000 per month, suggesting that reducing environmental impact can go hand in hand with reducing costs in a hospital setting. An audit of Hospital care, scientific research and the production and distribution of pharmaceutical drugs, found that they produce 3-8% of the total carbon dioxide output. (5, ??) The audit used 2007 health care spending and a model of environmental impact, called the environmental input-output life cycle assessment (EIO-LCA) model, developed by the Green Design Institute at Carnegie-Mellon University. The analysis found that hospitals were by far the largest contributor of carbon emissions in the health care sector, and were attributable to the high energy demands needed for temperature control, ventilation and lighting in large hospital buildings. The second largest health care contributor to the overall carbon footprint was the pharmaceutical industry, where carbon emissions were attributable to manufacturing combined with transportation costs associated with distribution.

3 5) Policy advocacy:

To advocate and support policies that strengthens public transportation, expand green spaces and reward energy efficiency. It's also crucial that children are given specific attention in emergency and disaster response planning.

According to the Intergovernmental Panel on Climate Change (21,22) global mean temperatures could increase by 1.5 to 5.8 °C by the end of the next century in response to this additional radiative forcing. While this may appear to be a minor warming when compared to diurnal or seasonal amplitudes of the temperature cycle, it should be emphasised that this is a warming unprecedented in the last 10000 years. It is time for a motivated implementation of on-the ground adaptation strategies and policy initiatives immediately. ^{1 2}

¹© 2013 Global Journals Inc. (US) © 2013 Global Journals Inc. (US)

²()

162 [Epstein et al. ()] ‘Biological and physical signs of climate change: focus on mosquito-borne diseases’. P R Epstein
163 , H F Diaz , S Elias . *Bull Am Meteorol Soc* 1998. 78 p. .

164 [Menon] *Carbon Cost of Health Care: New Thoughts*, P R Menon . [http://healthsciences.ac.in/
165 julysep12/Contents.html](http://healthsciences.ac.in/julysep12/Contents.html)

166 [Houghton et al. ()] *Climate change 2001: the scientific basis: contribution of the Working Group I to the third
167 assessment report of the Intergovernmental Panel on Climate Change*, J T Houghton , Y Ding , D J Griggs .
168 2001. Cambridge, England: Cambridge University Press.

169 [Paul ()] ‘Climate Change and Human Health’. R E Paul . *N Engl J Med* 2005. 353 p. .

170 [Beniston ()] ‘Climate change: possible impacts on human health’. Martin Beniston . *Swiss Med Wkly* 2002. 132
171 p. .

172 [Checkley et al. ()] ‘Effect of El Niño and ambient temperature on hospital admissions for diarrhoeal diseases in
173 Peruvian children’. W Checkley , L D Epstein , R H Gilman , D Figueroa , R I Cama , J A Patz , R E Black
174 . *Lancet* 2000. 355 p. .

175 [Crane et al. ()] *Energy Services Analysis: An Alternative Approach for Identifying Opportunities to Reduce
176 Emissions of Greenhouse Gases*, Keith Crane , Liisa Ecola , Scott Hassell , Shanthi Nataraj . 2012. Santa
177 Monica, CA: RAND Corporation.

178 [Chung and Meltzer (2009)] ‘Estimate of the carbon footprint of the US health care sector’. J W Chung , D O
179 Meltzer . *JAMA* 2009 Nov 11. 302 p. .

180 [Shea ()] ‘Global climate change and children’s health’. K M Shea . *Pediatrics* 2007. 120 p. .

181 [Berners-Lee ()] *How bad are bananas?: the carbon footprint of everything*, M Berners-Lee . 2011. Vancouver,
182 Greystone Books.

183 [Mills ()] ‘Insurance in a climate of change’. E Mills . *Science* 2005. 309 p. .

184 [Ipcc. Climate and Change ()] Ipcc. Climate , Change . *Volumes. I (Science) II (Impacts) and III (Socio-
185 economic implications*, (New York) 1996. Cambridge University Press. (The IPCC Second Assessment Report
186 Cambridge and)

187 [Life cycle assessment: From the beginning to the current state Klöpffer W. Environ Sci Pollut Res Int ()] ‘Life
188 cycle assessment: From the beginning to the current state’. Klöpffer W. *Environ Sci Pollut Res Int* 1997. 4
189 (4) p. .

190 [Leaf ()] ‘Potential health effects of global climatic and environmental changes’. A Leaf . *N Engl J Med* 1989.
191 321 p. .

192 [Mcgain et al. (2012)] ‘Workplace sustainability: the ”cradle to grave” view of what we do’. F Mcgain , D Story
193 , E Kayak , Y Kashima , S Mcalister . *Anesth Analg* 2012 May. 114 p. .