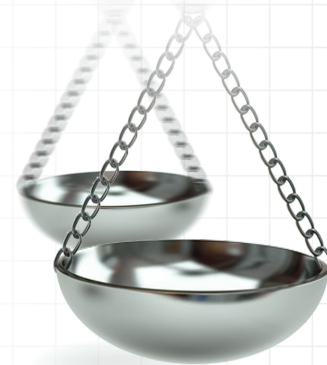




The economic cost of gender disparities in perioperative medicine

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Lauren Rosario¹, Rohan Jotwani¹ , Jaclynn Chen³, Robert S White^{*,2} & Jaime A Aaronson²

¹Department of Anesthesiology, Weill Cornell Medicine/NewYork-Presbyterian, New York, NY 10021, USA

²Department of Anesthesiology, Weill Cornell Medicine, New York, NY 10021, USA

³Department of Nursing, Weill Cornell Medicine/NewYork-Presbyterian Alexandra Cohen Hospital for Women & Newborns, New York, NY 10021, USA

*Author for correspondence: Tel.: +1 212 746 2941; rsw33@cornell.edu

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In 2018, USA healthcare spending accounted for 17.7% of gross domestic product, totaling US\$3.6 trillion [1]. This spending is continually under scrutiny as healthcare organizations work to minimize costs. Previously, our group has discussed the economic cost of racial disparity both in the perioperative and chronic pain settings as these discussions help to identify areas to improve care and equity in healthcare [2,3]. In this commentary, we aim to better characterize the cost related to gender-based discrepancy. Based on 2014 CMS data, females accounted for 56% of total personal healthcare spending [1]; per person spending for females was US\$8,811, 21% more than male spending (US\$7,272) [1]. Some portion of this difference has been ascribed to female utilization of gynecological and obstetrical care services [1]. Alternatively, other evidence looking at more specific perioperative outcomes has shown gender-based differences in length of stay (LOS) and mortality when isolating a single surgical event, such as coronary artery bypass graft (CABG) [4]. In this selective review, we seek to hypothesize the perioperative cost discrepancies that can be attributed to gender disparity. By utilizing ‘back of the envelope’ estimates that look at the rate of a specific disparity and the cost associated with that disparity, we aim to generate a hypothetical cost that can inform or provide scale for further studies looking to attribute cost in perioperative care. Specifically, we aim to discuss blood transfusions for CABG, unilateral total hip arthroplasty and total knee arthroplasty (TKA), surgical site infections (SSIs) across a range of surgical procedures, and LOS after TKA, as three case studies where sufficient cost data exists to postulate discrepancies [3]. By looking at these areas, we aim to identify areas of intervention, so we can better understand and therefore minimize future cost.

Blood transfusion

Patients undergoing CABG have increased morbidity and mortality associated with preoperative anemia, perioperative blood loss and the need for blood transfusion [4–6]. Available literature has shown that females have higher transfusion requirements compared with males during CABG and some orthopedic surgeries. In nonemergent CABG patients, Ad *et al.* showed that females were more likely to have a blood transfusion (26 vs 12%) and have major morbidities (12 vs 7%) compared with males [7]. Gombotz *et al.* showed that in patients undergoing CABG, unilateral total hip arthroplasty and primary unilateral knee arthroplasty (TKA), women had a higher transfusion rate (26.4 vs 20.8%) and received a higher blood product volume than men [8]. They attributed the higher transfusion rates, in part, to nongender specific transfusion thresholds, leading to over-transfusion occurring in women.

This has implications for the increased direct costs of the blood product transfusion itself as well as the increased indirect costs related to blood transfusion-associated morbidity and mortality [3].

Based upon an activity-based cost analysis by Shander *et al.* it is estimated that the mean direct and indirect costs per red blood cell (RBC) unit transfusion are US\$761 [9]. In nonemergent CABG, the difference between female and male transfusion is 14% or 0.14. The combined CABG/THA/TKA data by Gombotz shows a 5.6% or 0.056 difference in transfusion rate. By using these numbers, one can estimate a range of direct cost increase seen in transfusions that can be attributed to gender discrepancy: US\$42 for combined cost between CABG/THA/TKA with (US\$761 $\times$ 0.056) data to US\$106 per nonemergent CABG (US\$761 $\times$ 0.14).

Surgical site infections

The 2015 CDC healthcare-associated infection prevalence survey reported an estimated 110,800 SSIs [10]. In a large meta-analysis by Zimlichman *et al.* SSIs accounted for 33.7% of healthcare-associated infection, which equated to around US\$3.3 billion in costs [11]. SSIs also added over 1 million inpatient-days with greater than a billion dollars in extra cost [12]. Given this information, reducing SSIs has become a critical hospital outcome measurement, and there are a handful of studies looking at the differences in SSIs between males and females [13–15]. Cohen *et al.* report an odds ratio of 0.79 for females compared with males, and Langelotz *et al.* showed an overall rate of SSIs of 1.74/100 procedures (females) versus 2.26/100 procedures (males) [13,14]. When broken down by surgery, Langelotz *et al.* reported a lower rate of SSI in females undergoing abdominal surgery, 2.92 versus 4.37 (49% increase), but a higher risk of SSI in cardiac surgery, 5.50 versus 3.02 (82% increase) for females. There was no difference found in vascular or orthopedic surgery [14]. Between both studies, SSI rate differences were hypothesized to be due to variation in skin flora, anatomy and hormones [13,14].

Based on this data, cost estimates from de Lissovoy *et al.* can be used to determine how much gender impacts hospital costs associated with SSIs [12]. In abdominal surgery, they evaluated gastrointestinal (mean increased cost US\$20,829) and colorectal surgery (mean increased cost US\$17,955) separately; using the average of these two (US\$19,392), a ‘back-of-the envelope’ strategy to estimate cost of the total hospital course would suggest that gender disparity in total hospital cost due to higher rates of female SSI versus male would be US\$9,502 (US\$19,392 $\times$ 0.49). Lissovoy *et al.* also found that in cardiovascular patients with SSI there was a mean increased cost of US\$37,513 for the hospitalization compared with cardiac non-SSI hospitalizations. In cardiac surgery, the differential hospital cost due a female SSI versus male SSI would, therefore, be US\$30,760 (US\$37,513 $\times$ 0.82). While the utility of these calculations may be limited as they are based on a single study’s cost estimation, it nevertheless exemplifies that surgical infections based on gender have a significant impact on total hospital costs. Despite accounting for direct costs associated with longer LOS, these calculations are inclusive of indirect costs including the opportunity cost of reduced patient turnover [16]. Further research is needed to understand why SSI rates differ among gender so that specific preventative measures can be implemented.

LOS after TKA

Total joint arthroplasty (TKA and THA) accounts for the largest procedural expenditure paid by Medicare annually [17]. According to the 2014 National Inpatient Sample, 680,150 TKAs were performed, and this number is projected to reach around 1 million by 2030 [18]. With the aging population, increased procedural demand and decreases in reimbursement, it may be prudent for providers to better understand cost relating to this procedure. Specifically, if decreasing LOS correlates to lower cost, understanding the association of gender and LOS may play a role in both clinical and policy developments.

Based on a selective literature review, there is no clear consensus on whether gender is a significant predictor for increased LOS. Shah *et al.* performed a 68-study meta-analysis that found a positive correlation between female gender and LOS [19]. However, they also found that it was the combination of demographic variables (increased age, female gender, BMI $\geq$ 30, non White race, ASA $>$ 2, CCI $>$ 0 and low pre-operative hemoglobin) that correlates to increased LOS [19]. Females were also found to have longer LOS in the retrospective analysis done by Whitlock *et al.* [20]. They attributed this to females in the cohort being older, having worse baseline ability and reporting higher postoperative pain scores. Basques *et al.* found that male LOS is 0.2 days shorter than females, but they also found males are at significantly increased risk for multiple adverse events as well as increased risk of readmission [21]. This is important to note, as there would be additional costs associated with re-admission and treatment, despite initially noted shorter LOS [22]. Pugely *et al.* analyzed 516,745 TKA patients from the 2009 Nationwide Inpatient Sample dataset, and they estimated the effect of comorbidities on resource use and LOS. They found that the mean hospital

cost was US\$14,491 (derived using cost-to-charge conversions to estimate cost), and that females incurred slightly lower costs (US\$193) compared with males; however, there was no significant difference in LOS between males and females [23]. Multiple other studies also found that gender was not a significant predictor for LOS [24,25]. Based on this literature review, gender discrepancy and impact on LOS for TKA does not have a conclusive consensus. However, the findings continue to support the need for continued research into understanding the differences between males and females in regard to comorbidities and perioperative management.

In conclusion, here we look at three perioperative costs in relation to gender and found gender-based discrepancies exist for blood transfusions, SSIs and not for LOS after TKA. Just as with our previous analysis on racial disparity, these calculations are based off assumptions of universal costs and discrepancies, which will vary across different healthcare contexts [24,25]. These costs represent a highly generalizable context; further work needs to be done at the local and regional level to define costs specific to health systems. The goal, however, is to help highlight the presence of a discrepancy cost in relation to gender and hopefully generate continued interest in better understanding how gender discrepancy is present within perioperative medicine. Only then can we work as perioperative care providers to address these disparities.

Author contributions

L Rosario conducted the literature review and primary writing of the manuscript. R Jotwani conducted the literature review and edited the manuscript. J Chen conducted the literature review and edited the manuscript. RS White edited and provided guidance throughout the entirety of the writing process. JA Aaronson edited and provided guidance throughout the entirety of the writing process.

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