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Themed Section: COVID-19

Brief Cost Analysis of Surgical Personal Protective Equipment During the COVID-19 Pandemic

Kandice A. Kapinos, PhD, Jordan R. Salley, BS, Andrew Day, MD, MPH

ABSTRACT

Objectives: This study aimed to compare the costs incurred and saved from universal use of N95 respirators with surgical masks for operating room providers in the United States during the COVID-19 pandemic.

Methods: We built a decision analytic model to compare direct medical costs of healthcare workers (HCWs) infected with COVID-19 during operating room procedures from expected transmission when using an N95 respirator relative to a surgical mask. We also examined quarantine costs.

Results: Results varied depending upon prevalence and false-negative rates of tests, but if N95 respirators reduce transmission by 2.8%, prevalence is at 1%, and testing yields 20% false negatives, providers should be willing to pay an additional $0.64 per HCW for the additional protection. Under this scenario, approximately 11 COVID-19 cases would be averted among HCWs per day.

Conclusions: Potential savings depend on disease prevalence, rate of asymptomatic patients with COVID-19, accuracy of testing, the marginal cost of respirators, and the quarantine period. We provide a range of calculations to show under which conditions N95 respirators are cost saving.

Keywords: healthcare worker, personal protective equipment, surgery, decision analysis.

Introduction

The Joint Commission, an independent accreditation body, and other governing bodies responded to the COVID-19 pandemic by endorsing universal airborne precautions for operating room (OR) healthcare workers (HCWs) involved in aerosol-generating procedures (AGPs) in the spring of 2020—even for asymptomatic patients with negative preoperative testing.1 The effectiveness of this widely adopted position has not yet been evaluated. In this perspective, we built a decision analytic model to estimate the health economic impact.

Methods

We conducted a cost analysis comparing the expected healthcare sector–based costs of using N95 respirators with surgical masks for all inpatient and outpatient surgeries performed each day in the United States. Surgeries were presumed to involve an AGP (eg, endotracheal intubation or monitored anesthesia care [oxygen supplementation via nasal cannula or facemask]). We approximated the following costs to the healthcare system from HCW exposure to severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2): (1) direct medical costs from treating HCWs and (2) costs associated with quarantining HCWs for 8 days2 because of wages paid to stay home.

Model Structure and Input Parameters

We built a decision analytic model assuming 59,001 surgeries are performed each day in the United States (21,535,490 million annual cases/365 days = 59,001 cases per day).3 Our modeling parameters are presented in Table 14-18 where we report the base case assumptions and the range of alternative assumptions we examined in sensitivity analyses (see Supplemental Materials found at https://dx.doi.org/10.1016/j.jval.2022.03.015). In our base case, we assumed a population daily prevalence of 1%, but also present results ranging from 0.01% to 3%.4,5 We assumed that 60% of preoperative patients with COVID-19 were symptomatic6 and their surgeries would be postponed. The remaining 40% would undergo preoperative testing, where patients with positive test results would have surgery postponed and patients with false-negative test results would have surgery and expose HCWs. The base case false-negative testing rate was 20%, but we report results varying this from 3% to 70%.7 In particular, because rapid antigen tests are much less sensitive among asymptomatic patients (who would not be tested in our model), this rate may be much higher than 20%.8
Table 1. Input parameters.

| Parameter                                      | Base case | Source/notes |
|------------------------------------------------|-----------|--------------|
| COVID-19 prevalence                           | 1%        | 4,5          |
| % symptomatic (surgery postponed)             | 60%       | 6,15,16      |
| Test false-negative rate                      | 20%       | 7,8,17       |
| Transmissibility difference of N95 vs surgical mask | 2.8% | 9,14,18 |
| HCW assumptions                               |           |              |
| Number on OR team                             | 8         | 12           |
| Caseload per day                              | 3         |              |
| Prob(outpatient care)                         | 0.60      | 6,15,16      |
| Prob(hospitalization | infected) | 0.066      | 10           |
| Prob(ICU | infected) | 0.003      | 10           |
| Healthcare sector cost assumptions            |           |              |
| Direct medical costs for treated HCW          |           |              |
| Outpatient costs                              | $3045     | 10,11        |
| Inpatient cost (not including ICU)            | $21,936   | 10,11        |
| ICU cost                                      | $38,755   | 10,11        |
| Quarantine labor costs                        |           |              |
| Weighted daily wage                           | $771      | 13           |
| Average quarantine length (work days)         | 8         |              |

Note. See Supplemental Materials found at https://dx.doi.org/10.1016/j.jval.2022.03.015 for additional sensitivity analyses. HCW indicates healthcare worker; ICU, intensive care unit; OR, operating room; Prob, probability.

Evidence evaluating the transmissibility of SARS-CoV-2 during AGPs to HCWs using standard surgical masks versus N95 respirators is sparse so we used a range of estimates from a meta-analysis evaluating SARS-CoV-2 transmission in “healthcare settings.” In our base case, we assumed N95 respirators prevent 99.3% of SARS-CoV-2 transmission and surgical masks prevent 96.5%.

We assumed an average of 8 HCWs were present for each case and each HCW would participate in an average of 3 cases daily. This translates to 157,336 HCWs requiring personal protective equipment (PPE) daily in the United States.

The estimated cost for treatment of each HCW infected with COVID-19 was $3388 assuming 40% would not have symptoms or seek care, 60% would receive outpatient care (with an average treatment cost of $3045), 6.6% would require hospital floor admission (with an average treatment cost of $21,936), and 0.3% would require intensive care (with an average treatment cost of $38,755). These costs would be savings to the healthcare sector if avoided from reduced HCW exposure and infection. We did not include the value of statistical lives here from HCW mortality but discuss this below.

To calculate quarantine labor costs, we assumed all infected HCWs would quarantine. To estimate the average daily wage cost, we assumed 8 HCWs were involved in each case (1 anesthesiologist, 1 nurse anesthetist, 1 surgeon, 2 surgical technicians, 2 nurses). We used the following total daily wages from the US Bureau and Labor Statistics plus fringe costs to calculate an average weighted daily quarantine cost: 1 anesthesiologist ($1712), 1 nurse anesthetist ($1195), 1 surgeon/proceduralist ($1640), 2 surgical technicians ($321 each), and 2 nurses ($491 each). This gives us a daily team cost of $6172 or $771 per HCW on average. We note that not all OR teams will be composed of the same team members, but this gives us an average cost that incorporates varying wage levels.

Because of the uncertainty and variation of the price of N95 respirators, we calculated a breakeven price for healthcare systems. That is, we calculated the price of N95 respirators at which healthcare systems should be indifferent between providing HCWs with an N95 and a surgical mask.

Results

The base case scenario assumed 1% COVID-19 prevalence, 20% testing false-negative rate, and a difference in transmissibility risk of 2.8% from using N95 respirators over surgical masks. We calculated reduced exposure to HCWs would result in 10.57 fewer COVID-19 cases among HCWs per day. We show that this value ranges from 0.02 to 111.02 in panel A of Table 2 reflecting significant variation in cases averted depending on prevalence and test sensitivity.

In panel B of Table 2, we report the total medical and quarantine costs that would be avoided per day with fewer COVID-19 cases among HCWs. These also varied and depended on the prevalence, false-negative test rates, and reduction in transmissibility from higher-level PPE (see Supplemental Materials found at https://dx.doi.org/10.1016/j.jval.2022.03.015 for more results). Under our base case assumptions, the total costs avoided are estimated at $101,075 per day—$35,834 in reduced medical treatment and $65,252 from reduced quarantine costs. Dividing these expected savings by the number of N95 respirators needed (157,336) gives us the breakeven price. At this price, healthcare systems would be indifferent between paying additional costs to obtain more protective PPE (eg, N95 respirators) and surgical masks. The breakeven price under the base case is $0.64 per HCW suggesting systems should be willing to pay at least $0.64 more per HCW for an N95 over a surgical mask for OR procedures.

Under the base case scenario, if the fraction of surgical patients who were asymptomatic increased from 40% to 45% (meaning fewer surgical patients would undergo COVID-19 preoperative testing), the number of HCWs COVID-19 cases averted from N95 use per day would increase by 1.32, total savings from reduced HCW exposure would increase by almost $11,000 per day, and the breakeven price would increase to $0.71 per HCW (see Appendix Table 1 in Supplemental Materials found at https://dx.doi.org/10.1016/j.jval.2022.03.015).

Conclusions

These data capture the substantial uncertainty in estimating the costs or savings of observing universal airborne precautions for elective surgeries in 2020. Potential savings would be larger with higher disease prevalence, higher rates of asymptomatic patients with COVID-19, less accurate testing, a lower marginal cost of respirators, or a longer quarantine period.

In the interim, several novel SARS-CoV-2 variants have emerged and COVID-19 vaccine uptake continues to increase. Future cost analyses will require a more precise understanding of COVID-19 prevalence rates, false-negative testing rates in asymptomatic COVID-19 patients, and respirator versus surgical mask efficacy rates in the context of an evolving environment. Differences in PPE cost, identification of exposed HCWs needing to quarantine, length of quarantine, and HCW direct healthcare costs will also need to be considered.

Earlier in the pandemic, many healthcare systems faced PPE shortages and were unable to provide N95s because they were
Although the availability of N95s has increased significantly over the course of the pandemic, prices have also increased and uncertainty remains in how the COVID-19 pandemic will continue to evolve. Nevertheless, studies have increasingly suggested that N95s can be decontaminated and reused; taken together with our findings implies that healthcare systems could prioritize reuse, particularly for OR procedures.

Our study exhibits a number of limitations, including uncertainty of some parameters and modeling assumptions. Our analysis does not account for the significant increase in vaccination rates in 2021, which may reduce the likelihood of severe disease among HCWs who are vaccinated. We are also unable to include all factors, including the costs of cancelled surgeries or lost productivity for HCW quarantines, the cost of testing, long-term costs of HCW exposure including required rehabilitation or prolonged medical care in severe cases, disability, or the statistical values for the lives lost. Without accounting for labor shortages and how vaccines might change this dynamic, under our base case assumptions, we would expect N95 respirators to prevent 10 additional HCW deaths over the course of a year relative to surgical masks. Using the value of a statistical life of $11.4 million per life saved, this amounts to approximately $220 million. Thus, not including the cost benefit calculations to the healthcare sector as described in this study, a back of the envelope calculation suggests society should be willing to pay at least $10.21 per surgery ($220 million/21.5 million surgeries per year) for more protective PPE.

Developing this evidence will inform PPE selection in this new context of broad COVID-19 vaccine uptake. It will also facilitate preparation for new waves of disease because of SARS-CoV-2 variants and novel pandemics.

Supplemental Materials

Supplementary data associated with this article can be found in the online version at [https://dx.doi.org/10.1016/j.jval.2022.03.015](https://dx.doi.org/10.1016/j.jval.2022.03.015).

**Table 2.** Impact of implementation of universal airborne precautions during elective surgeries on daily COVID-19 cases and related costs averted.

| Panel A: HCW COVID-19 cases averted | False-negative rate |
|------------------------------------|---------------------|
|                                    | 3%                  | 10%                | 20%                | 70%                |
| Prevalence rate                    |                     |                    |                    |                    |
| 0.01%                              | 0.02                | 0.05               | 0.11               | 0.37               |
| 0.10%                              | 0.16                | 0.53               | 1.06               | 3.70               |
| 1%                                 | 1.59                | 5.29               | 10.57              | 37.01              |
| 3%                                 | 4.76                | 15.86              | 31.72              | 111.02             |

| Panel B: medical treatment and quarantine costs averted | False-negative rate |
|--------------------------------------------------------|---------------------|
|                                                        | 3%                  | 10%                | 20%                | 70%                |
|                                                        |                     |                    |                    |                    |
| Prevalence rate                                        |                     |                    |                    |                    |
| 0.01%                                                  | $758                | $505               | $1011              | $3538              |
| 0.10%                                                  | $1516               | $5054              | $10108             | $35376             |
| 1%                                                     | $15161              | $50538             | $101075            | $353764            |
| 3%                                                     | $45484              | $151613            | $303226            | $1061292           |

| Panel C: breakeven “willingness to pay” of N95 respirators per HCW per day | False-negative rate |
|---------------------------------------------------------------------------|---------------------|
|                                                                           | 3%                  | 10%                | 20%                | 70%                |
|                                                                           |                     |                    |                    |                    |
| Prevalence rate                                                          |                     |                    |                    |                    |
| 0.01%                                                                   | $0.005              | $0.003             | $0.01              | $0.02              |
| 0.10%                                                                   | $0.01               | $0.03              | $0.06              | $0.22              |
| 1%                                                                      | $0.10               | $0.32              | $0.64              | $2.25              |
| 3%                                                                      | $0.29               | $0.96              | $1.93              | $6.75              |

Note. Values in parentheses reflect costs to the healthcare sector. The breakeven analysis assumes one HCW uses the same respirator for up to 3 cases in a given day. HCW indicates healthcare worker.
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