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BRIEF COMMUNICATION

Modeling the Impact of Delaying Bariatric Surgery due to COVID-19: a Decision Analysis

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Abstract

We developed a decision analysis model to evaluate risks and benefits of delaying scheduled bariatric surgery during the novel coronavirus disease (COVID-19) pandemic. Our base case was a 45-year-old female with diabetes and a body mass index of 45 kg/m^2. We compared immediate with delayed surgery after 6 months to allow for COVID-19 prevalence to decrease. We found that immediate and delayed bariatric surgeries after 6 months resulted in similar 20-year overall survival. When the probability of COVID-19 infection exceeded 4%, then delayed surgery improved survival. If future COVID-19 infection rates were at least half those in the immediate scenario, then immediate surgery was favored and local infection rates had to exceed 9% before surgical delay improved survival. Surgeons should consider local disease prevalence and patient comorbidities associated with increased mortality before resuming bariatric surgery programs.

Keywords Decision analysis · Coronavirus · COVID-19 · Bariatric surgery · Sleeve gastrectomy · Risk modeling

Introduction

The novel coronavirus disease (COVID-19) pandemic resulted in the suspension of routine healthcare in the USA to prevent viral transmission and conserve valuable resources. As the country eases restrictions, the risks of resuming procedures must be balanced with the harms arising from delayed health care. Furthermore, expected future waves of COVID-19 or a new, highly transmissible respiratory disease necessitates understanding how the infection, possible disease progression during delays, and patient-specific risk factors impact non-emergent surgeries.

Bariatric surgery is the most effective treatment for severe obesity and results in improved long-term overall survival, but these benefits may be tempered if delay occurs [1, 2]. The survival benefit from immediate surgery must be weighed against the potential harm from infection with COVID-19, as reports indicate obesity-related comorbidities increase the likelihood of intensive care admission and dying from COVID-19 [3–6]. The purpose of this study was to use a decision-analytic model to compare immediate with delayed bariatric surgery during the COVID-19 pandemic and estimating that decision's impact on 20-year overall survival.

Methods

Decision Model Design

We developed a decision analysis model to evaluate two treatment strategies for a patient approved and scheduled for bariatric surgery during the COVID-19 pandemic (Fig. 1a). The decision tree details the initial choice (the decision node) of immediate or 6 months of delayed surgery and follows branch points to the ultimate outcomes of death or 20-year overall survival (terminal nodes). If immediate surgery is chosen,

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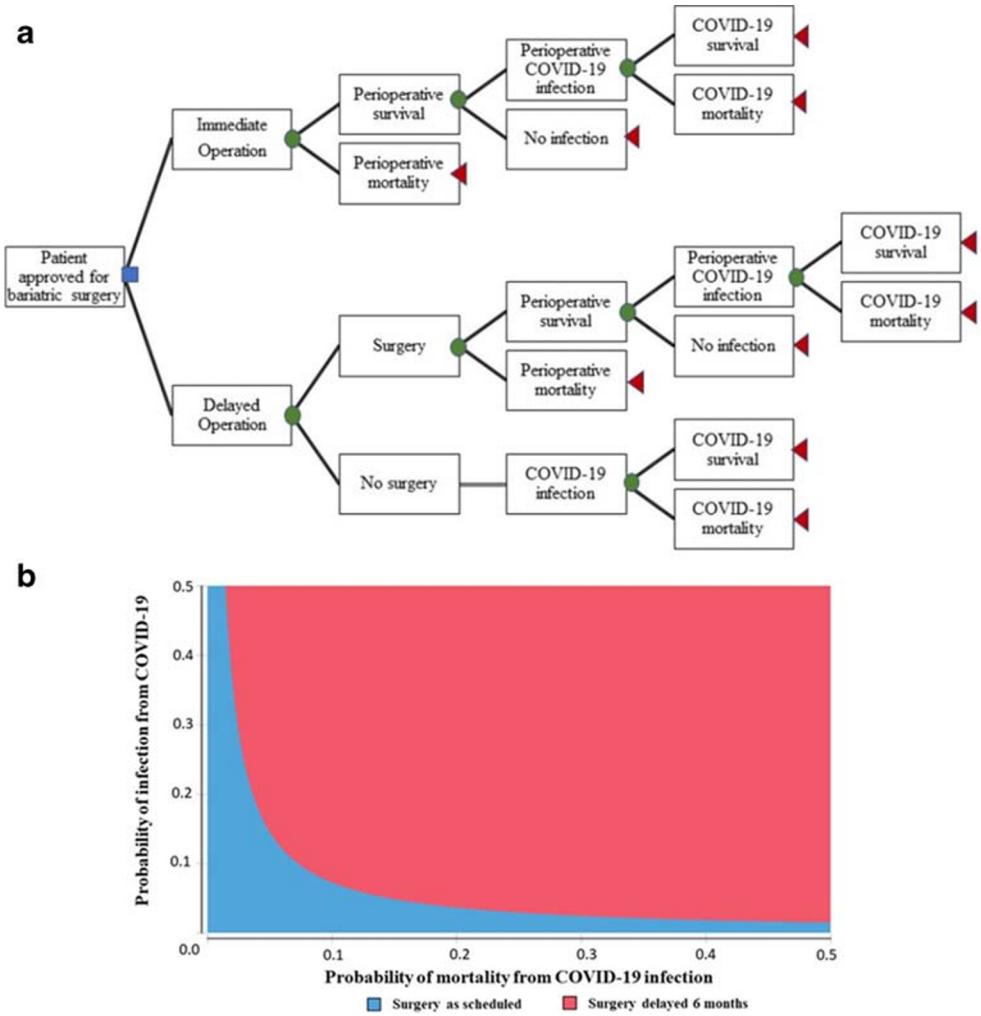

Fig. 1 **a** Decision analysis tree for resuming bariatric surgery during COVID-19 pandemic. Blue square: decision node, whether to choose immediate or delayed surgery. Green circles: chance nodes. Red triangles: terminal nodes. **b** Two-way sensitivity analysis for probability of infection and mortality from COVID-19. Graph displays the favored strategy (immediate or delayed surgery) across a range of possible hospital-acquired COVID-19 infection and COVID-19-related mortality probabilities while holding all other model variables constant at baseline values

the subtree has branch points with chance nodes for operative mortality, COVID-19 infection, and COVID-19-related mortality. If delayed surgery is chosen, the same operative pathway is possible, or the patient has the chance of not undergoing surgery due to events that occurred during the delay.

The model was constructed using TreeAge Pro v2018 (TreeAge Software, Inc., Williamson, MA). Literature review and expert opinion (when published data was not available) defined model parameters and applicable ranges for sensitivity analysis.

Patients

Our base clinical case was a 45-year-old Caucasian female with morbid obesity (BMI 45 kg/m^2), Type 2 diabetes mellitus who was an average-risk operative candidate. The patient was initially scheduled for surgery when the local community entered an acute phase of the COVID-19 pandemic. This assumes the presence of COVID-19 patients in the community and hospital, but not to a degree that all hospital resources have been diverted to caring for COVID-19 patients. She had negative preoperative COVID-19 testing.

Model Variables

For both immediate and delayed surgeries, the patient underwent minimally invasive laparoscopic vertical sleeve gastrectomy (Table 1) [1, 7]. Operative delay was 6 months, allowing for community COVID-19 prevalence to decrease to near zero a separate scenario that assumed future infection rate equal to half of the current rates (0.7%). There was a small probability that the patient will no longer qualify for surgery after the delay, either due to a change in insurance status or progression of comorbidities such that she was no longer a safe surgical candidate [1, 8].

COVID-19 parameters were derived from the limited published reports available as of July 10, 2020. COVID-19 infection probability was modeled with a single parameter, incorporating both hospital- and community-acquired COVID-19 risks during the perioperative period. Probabilities of COVID-19 infection reflected local prevalence at the time of modeling

Table 1 Model parameters

	Probability	Values for sensitivity analysis	Reference(s)
Operative mortality	0.0058	0.00001–0.011	[1, 7]
COVID-19 mortality	0.25	0.1–0.5	[3–5]
Immediate surgery			
Perioperative COVID-19	0.014	0–0.05	*
Delayed surgery			
Undergoes surgery	0.99	-	-
No surgery	0.01	0.00001–0.05	[1, 8]
Perioperative COVID-19	0.00001	0.001–0.009	*
20-year overall survival			
Immediate surgery	0.847	0.8–0.95	[2]
Delayed surgery	0.842	0.78–0.93	[2]
No surgery	0.725	0.65–0.85	[2]

COVID-19 novel coronavirus disease discovered in 2019

*Parameters set by research team based on local data

(1.4%). The probability of COVID-19-related mortality was estimated from reports demonstrating higher disease acuity and mortality among patients with morbid obesity and diabetes [3, 5, 6]. This rate is significantly higher than for those in the community aged 40–49 [9], which we felt was appropriate for this model as bariatric patients have a higher burden of comorbidities than the average population.

Survival Estimates

We estimated survival from a study by Cohen et al. that utilized Markov modeling to estimate the impact of delaying bariatric surgery on long-term survival [2]. We used a 20-year survival improvement estimate of 12% percent to calculate the survival improvement for immediate surgery, the potential survival loss for a 6-month delay, and the lack of survival improvement for no surgery (Table 1). As COVID-19 is a new disease, there is no long-term follow-up of patients available for reference. Such modeling is outside the scope of this limited analysis. However, if the patient survives the acute phase of the illness, we assumed no impact on long-term survival.

Sensitivity Analyses

One-way sensitivity analyses were performed by varying one parameter at a time while holding all other parameters constant at their baseline values to assess the impact of uncertainty in baseline values on model results and to represent different possible patient- or community-level characteristics. We varied the likelihood of surgical mortality, of not qualifying for surgery after the delay, of perioperative COVID-19 and COVID-19-related mortality. Two-way sensitivity analysis was performed by simultaneously varying the probability of perioperative COVID-19 infection and COVID-19-related mortality. Expanding to 1 year's delay did not change the baseline risk but did increase the exposure time to the higher progression risk.

Results

For our base case scenario, proceeding with bariatric surgery as scheduled during the COVID-19 pandemic did not decrease 20-year overall survival compared with delaying surgery for 6 months to allow for COVID-19 prevalence to decrease, 0.84 for both immediate and delayed surgeries. When future infection rates were expected to be at least half those at the time of immediate surgery decision, then immediate surgery had a slightly higher survival likelihood (0.84) compared with delayed (0.83) surgery. Increasing delay to 1 year decreased survival to a similar amount making immediate surgery the preferred strategy at baseline infection rates.

Sensitivity Analyses

Varying the probability of surgical mortality did not impact the outcome of our model. If the probability perioperative infection exceeded 4% or mortality due to COVID-19 exceeded 61%, then delayed surgery was increasingly favored. When the future COVID-19 infection rate increased to above zero, immediate surgery was the preferred strategy when the future infection rate was at least half of that observed in the immediate surgery setting. In the same future infection prevalence scenario, the preferred choice to delay occurred only when the perioperative infection rate exceeded 9%. If the probability of not undergoing surgery after a 6-month delay exceeded 2%, then immediate surgery was preferred.

When becoming disqualified for surgery due to delay was increased to 5% or when surgery was delayed for a year, then delaying surgery was favored if the likelihood of COVID-19 infection exceeded 8%. Generally, delayed resection was increasingly preferred as the probability of either perioperative infection or mortality from COVID-19 increased (Fig. 1b) and was not preferred as future infection rates increased above zero. For example, if the probability of infection was greater than 10% or mortality was greater than 10%, then delaying surgery resulted in improved long-term survival.

Conclusion

Resuming non-emergent operations such as bariatric surgery during the ongoing COVID-19 pandemic presents a new challenge to surgeons who must weigh the potential risks to patients with minimal data available to guide decision-making. Hospitals must balance the consumption of resources potentially needed to treat COVID-19 patients with potential harm to patients if procedures are delayed. To assist surgeons and hospitals, we created a simple and informative model to estimate the potential harm to a patient scheduled for weight-loss surgery if her procedure was delayed by 6 months.

Our decision analysis model found that proceeding with bariatric surgery when the prevalence of COVID-19 was low (1.4% for our base scenario) had equivalent 20-year overall survival as delaying surgery for 6 months but not if delay extends to beyond a year or if infection rates after a period of delay remain above zero. However, if the perioperative risk of COVID-19 infection was above 4% in the no future infection setting or above 9% when future COVID-19 is expected, a patient undergoing bariatric surgery may have worse survival than a patient with a delayed operation. As infection rates fluctuate, our model presents the possible benefits and harms of non-emergent surgeries and informs clinicians and hospital leadership when they should be paused or resumed.

While this simple model is designed to reflect only the outcome in our base case patient, the two-way sensitivity analysis can be used to estimate the outcomes across varying patient populations. For example, older patients with multiple comorbidities would be at higher risk for infection and mortality [10], thus when the mortality rate is set to 35%, delayed surgery is preferred once the local infection risk exceeds 2.5%. Alternatively, for a younger patient with no comorbidities and a potential mortality risk of 5%, immediate surgery is preferred until the local infection risk exceeds 15%.

In our model, if the length of surgical delay or the proportion of individuals unable to undergo surgery was increased, the model favored proceeding with surgery immediately despite the risk of infection. For example, we found that, if the likelihood of a patient not undergoing surgery after the delay exceeds 2%, then immediate operation is preferred. This illustrates that patients may have a "window of opportunity" to obtain this operation, and, if they do not receive it, that harm could occur.

This study had several limitations. First, the paucity of literature available on COVID-19 resulted in needing to estimate several model parameters; we addressed this by analyzing a wide range of possible values in our sensitivity analyses. Secondly, long-term survival data used in the model was obtained from a published Markov model and does not reflect actual survival statistics. Further, the impact of weight-loss surgery on improving obesity-related comorbidities such as diabetes during the COVID-19 pandemic is unknown but could potentially improve both short-term and long-term survival and was not accounted for in our model. Generally, these surgery-related benefits, like reducing perioperative COVID mortality risk from strong surgery responders, increased the benefit of immediate surgery. Despite these limitations, we believe that our decision analysis model still provides a useful framework to inform non-emergent surgical decision-making during the COVID-19 pandemic.

For an average-risk patient approved for bariatric surgery, proceeding with surgery during the COVID-19 pandemic resulted in similar 20-year overall survival as compared with a 6-month delay in this decision analysis model. However, as the risk of perioperative COVID-19 infection increased above 4%, then delaying bariatric surgery for 6 months improved long-term survival. Surgeons should consider local rates of infection and patient factors such as age, race, and BMI that could lead to increased mortality before resuming bariatric surgery programs.

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