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Reassessing the operative threshold for abdominal aortic aneurysm repair in the context of COVID-19

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ABSTRACT

Objective: The worldwide pandemic involving the novel respiratory syndrome (COVID-19) has forced health care systems to delay elective operations, including abdominal aortic aneurysm (AAA) repair, to conserve resources. This study provides a structured analysis of the decision to delay AAA repair and quantify the potential for harm.

Methods: A decision tree was constructed modeling immediate repair of AAA relative to an initial nonoperative (delayed repair) approach. Risks of COVID-19 contraction and mortality, aneurysm rupture, and operative mortality were considered. A deterministic sensitivity analysis for a range of patient ages (50 to >80), probability of COVID-19 infection (0.01%-30%), aneurysm size (5.5 to >7 cm), and time horizons (3-9 months) was performed. Probabilistic sensitivity analyses were conducted for three representative ages (60, 70, and 80). Analyses were conducted for endovascular aortic aneurysm repair (EVAR) and open surgical repair (OSR).

Results: Patients with aneurysms 7 cm or greater demonstrated a higher probability of survival when treated with immediate EVAR or OSR, compared with delayed repair, for patients under 80 years of age. When considering EVAR for aneurysms 5.5 to 6.9 cm, immediate repair had a higher probability of survival except in settings with a high probability of COVID-19 infection (10%-30%) and advanced age (70-85+ years). A nonoperative strategy maximized the probability of survival as patient age or operative risk increased. Probabilistic sensitivity analyses demonstrated that patients with large aneurysms (>7 cm) faced a 5.4% to 7.7% absolute increase in the probability of mortality with a delay of repair of 3 months. Young patients (60-70 years) with aneurysms 6 to 6.9 cm demonstrated an elevated risk of mortality (1.5%-1.9%) with a delay of 3 months. Those with aneurysms 5 to 5.9 cm demonstrated an increased survival with immediate repair in young patients (60); however, this was small in magnitude (0.2%-0.8%). The potential for harm increased as the length of surgical delay increased. For elderly patients requiring OSR, in the context of endemic COVID-19, delay of repair improves the probability of survival.

Conclusions: The decision to delay operative repair of AAA should consider both patient age and local COVID-19 prevalence in addition to aneurysm size. EVAR should be considered when possible due to a reduced risk of harm and lower resource utilization. (J Vasc Surg 2021;73:780-8.)

Keywords: Severe acute respiratory syndrome coronavirus 2; SARS-COV-2; Vascular surgical procedures; Decision analysis

In December 2019 in Wuhan, China, a new respiratory syndrome (COVID-19) caused by the novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV2) emerged.[1] It has now progressed to a pandemic.[2,3] Health systems have been forced to reassess the delivery of elective care in the context of this new reality.[4,5]

The COVID-19 pandemic presents a challenge for medical conditions that are treated electively but pose a substantial risk to life when definitive treatment is delayed. The American College of Surgeons has released guidelines for the triage of surgical patients.[6] These guidelines and those produced by the Society of Vascular Surgery recommend postponing repair of abdominal aortic aneurysms (AAA) <6.5 cm in size and those >6.5 cm in size if possible.[6,7] These guidelines do not account for the age of the patient or local prevalence of COVID-19. COVID-19-related mortality and operative mortality are known to vary significantly with age.[1,8]

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To date no study has performed a structured analysis of the decision to postpone the management of AAA. The conservation of personal protective equipment (PPE) and risk of exposing patients to COVID-19 in hospital must be balanced against the risk of aneurysm rupture. The objective of this study was to perform a decision analysis, using the most up-to-date metrics, for deciding when to delay AAA repair while mitigating patient risk.

ARTICLE HIGHLIGHTS

- **Type of Research:** Decision analysis
- **Key Findings:** Patients who are young with large aneurysms can face a clinically relevant increased risk of mortality with delay of operative repair (1.5%-7.7%). As patients become older, COVID-19 prevalence increases, or open surgical repair is required; then a delay of operative repair becomes the dominant strategy.
- **Take Home Message:** The decision to delay repair of abdominal aortic aneurysms during the COVID-19 pandemic should consider patient age, method of repair, and local prevalence in addition to aneurysm size.

METHODS

Model and assumptions. A decision tree was constructed to model the choice between management strategies of immediate operative vs initial nonoperative (delayed operative) repair of AAA (Fig 1). Analysis was performed using Amua version 0.2.2.[9] Survival and death were the final outcomes in the model, and the objective was to maximize the probability of patient survival. The model assumes all individuals to be acceptable candidates for open or endovascular AAA repair. The method of repair (endovascular aortic aneurysm repair [EVAR] vs open surgical repair [OSR]) is assumed to be based on patient characteristics and aneurysm morphology, as they would have been before the COVID-19 pandemic. Patients are assumed to be COVID negative at initial presentation and still at risk for contraction of the virus. This model focuses only on the time interval in which care may be delayed due to the pandemic.

Baseline mortality was included in both decision arms based on life tables from the National Vital Statistics Reports 2016.[10] In the immediate operative (OR) decision arm, patients are at risk of mortality during elective repair. The base model includes probabilities associated with EVAR and in sensitivity analysis applies probabilities associated with OSR. EVAR was selected as the base model as more than 80% of elective aneurysm repairs in the United States are performed endovascularly.[11] Patients surviving operative repair are then considered at risk of in-hospital contraction of SARS-CoV2 and subsequent mortality.

In the nonoperative arm, patients were considered to be at risk for rupture. Those without rupture were susceptible to community-acquired COVID-19 with subsequent mortality. Those who ruptured were first at risk of rupture-related mortality (either out-of-hospital or operative mortality). Those surviving were again at risk of hospital contraction of SARS-CoV2 and subsequent mortality.

The model was developed with 3-month intervals (cycle length). Probabilities for contraction of COVID-19 and rupture were scaled appropriately based the total duration of repair deferral. Time horizons of 3 months, 6 months, and 9 months for deferral of operative care were considered.

Model parameters. There is significant heterogeneity on geographic, racial, and socioeconomic lines of an individual's risk of contracting COVID-19 in the community.[3,8,12] Even within any particular group, there is uncertainty as to the true risk of infection, not least because of underreporting of COVID-19 cases.[3,8] Because of these factors, a number of situations for the 3-month probability (ie, 3-month cumulative incidence) of COVID-19 infection in a geographic area were considered. These included a risk of contraction from 0.01% to 30% over the initial 3-month interval (which is then scaled based on the time horizon). Contraction of COVID-19 is believed to be greater in those admitted to hospital with a reported incidence two times greater than in the community.[13] The probability of COVID-19 contraction for those admitted to hospital is therefore increased by a factor of 2. After infection, individuals are considered to no longer be at risk of virus contraction.

Model parameters are presented in Table I. The model includes reported age-stratified infection fatality rates for COVID-19, based on infection fatality rates adjusted for underascertainment due to the prevalence of asymptomatic cases.[8] The probability of rupture was based on previously reported data in those treated nonoperatively with AAA.[14] Operative mortality after elective repair was based on population level data, on mortality in elective endovascular aortic repair (EVAR).[15] The majority (approaching 80%) of elective AAA repairs are performed endovascularly in the United States.[11] A subsequent analysis was performed separately for open repair with corresponding operative mortality.[15] Death secondary to rupture was based on population level data and included pre-hospital and intraoperative mortality.[16] Case fatality rates were only available in dichotomous format (less than or greater than 75 years old). The lower threshold (<75 years: 61% mortality) was used for those under 65, the overall mortality (74%) for those 65 to 79 years old, and the upper threshold (>75 years: 82% mortality) for those 80 and over.

Initially a deterministic analysis was conducted to allow for a broad summary of unique patient characteristics and the 3-month probability of infection with COVID-19.

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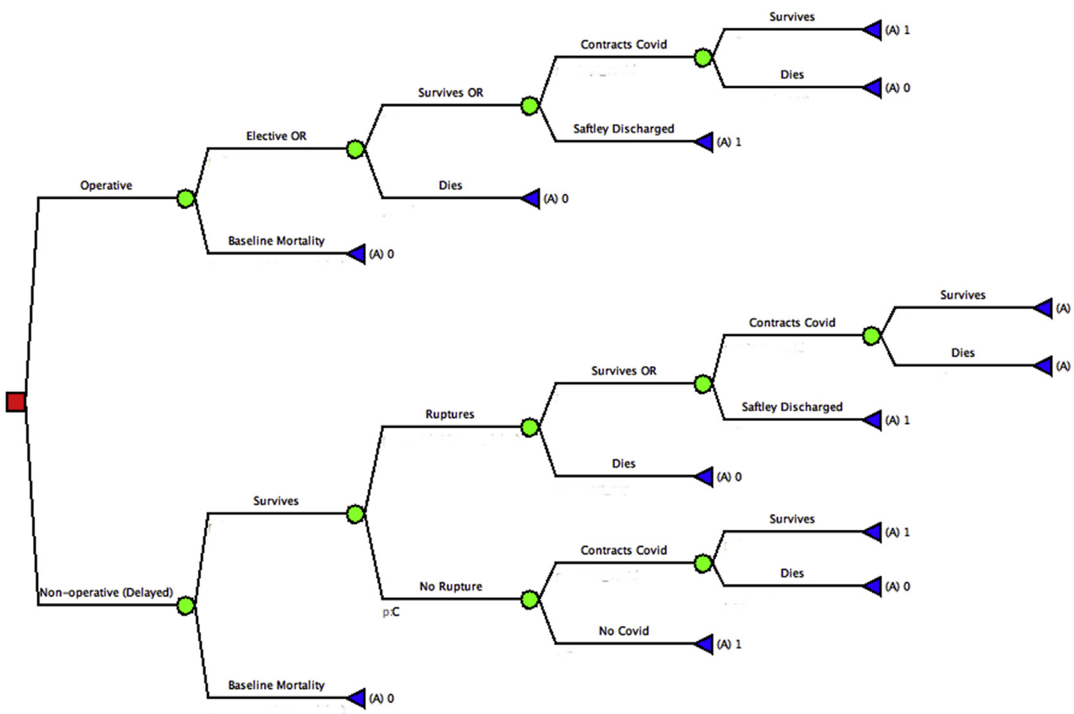

Fig 1. Decision tree modeling the choice between immediate operative repair (operative) and delay of operative repair (non-operative) in the context of the COVID 19 pandemic. Operative repair is either endovascular or open surgical repair (OSR) depending on the analysis. The overall framework of the tree remains unchanged, but input parameters are included based on the respective method of repair.

A probabilistic sensitivity analysis (PSA) at three representative ages, 60, 70, and 80 years, was then performed. A probabilistic sensitivity analysis samples values for the input parameters (eg, probability of mortality) from a distribution that reflects the uncertainty of the reported data (Table II). Distributions were estimated based on variability of central tendency and dispersion reported in the literature.[8,14-18] The model was run with 1000 iterations for each of the three PSAs, at each probability of COVID-19 infection considered. The mean probability of survival and 95% credibility intervals for each scenario were calculated. Statistical analyses were conducted using Amua version 0.2.2[9] and Microsoft Excel for Mac Version 16.15 (2018).

RESULTS

This study demonstrates that the optimal decision for deferral of operative repair of AAA varies with patient age and aneurysm size when attempting to minimize mortality. In line with current guidelines, aneurysms over 7 cm benefit from timely operative repair (Figs 2 and 3). In low-resource utilization scenarios and low 3-month probability of COVID-19 infection (0.1%-1%), delay of aneurysm repair comes with an elevated risk of patient mortality. As the probability of infection increases (10%-30%), small aneurysms (5.5-6.9 cm) should be delayed in older individuals (Fig 1). In those under the age of 70 years, even patients with small aneurysms have a greater probability of survival if aneurysm repair is not delayed. This is in contrast to when OSR is required (Fig 3). With OSR there is a general shift toward the nonoperative strategy initially. In this case, for patients with aneurysms <7 cm, a nonoperative strategy maximized the probability of survival in those over 60 to 75 years of age, depending on the probability of COVID-19 infection, and duration of delay. Those with aneurysms >7 cm still benefit from early surgical repair, except for those who are over 85 years old.

The PSA demonstrates that within each set of scenarios (age, aneurysm size, probability of infection), the magnitude of the difference in probability of survival differs (Fig 4). Fig 4 shows the density plot for the probability of survival with either immediate EVAR or a delayed strategy over a thousand iterations for each scenario. Perfect survival lies on the right end of the *x*-axis. The mean and 95% credibility interval for each curve are given at the bottom, along with the mean difference in probability of survival. With large aneurysms (>7 cm) there is minimal overlap between the density plots for survival. Survival benefit with an immediate operative strategy ranges from 5.8% to 7.7% in 7 cm AAAs depending on the probability of infection with COVID-19 and patient age. As the probability of infection increases, the magnitude of difference between strategies decreases,

Table I. Parameters used in model construction for deterministic analysis

Aneurysm size[14]	Yearly risk of rupture
5.5-5.9	9.4%/y
6-6.9	10.2%/y
>7	32.5%/y
Age-related mortality COVID[8]	
Age	**Mortality**
50-59	0.595%
60-69	1.93%
70-79	4.28%
>80	7.8%
Age-related mortality rupture[16]	
Age	**Mortality**
50-64	61%
65-80	74%
80+	82%
Age-related elective operative mortality (EVAR)[15]	
Age	**Mortality**
50-64	0.3%
65-74	0.8%
75-79	1%
80-84	1.25%
>80	1.5%
Age-related elective operative mortality (OSR)[15]	
Age	**Mortality**
50-64	1.2%
65-74	2.5%
75-80	5.6%
80-94	7.6%
>80	9.5%
Considered community risk of COVID-19 infection[8]	
Probability that a patient will contract COVID-19 over the initial 3-month interval[a]	
0.01%	
1%	
10%	
30%	

EVAR, Endovascular aortic aneurysm repair; *OSR*; open surgical repair.
[a]For intervals over 3 months, probabilities are scaled to reflect that a proportion of the population is no longer at risk.

illustrated by an increased overlap of the two density curves. In 60- and 70-year-old patients, there is still a 1.5% to 1.9% increased probability of survival if repair is not delayed for aneurysms 6 to 6.9 cm. Although immediate repair still offers a benefit, this is reduced in aneurysms between 5.5 and 5.9 cm.

A similar PSA was performed with a 6-month delay for EVAR (Table III). There is an increased risk of harm with increased time of delay for elective repair. Those with aneurysms 6 to 6.9 cm face a 2.4% to 4.5% increased risk of mortality with delay depending on the local prevalence of COVID-19 and patient age. Although the risk is still lower for those with aneurysms 5.5 to 5.9 cm, there can be as high as a 1.9% increased risk of mortality in younger patients, when COVID-19 prevalence is low.

The results for OSR in the PSA are consistent with the deterministic analysis. There is an overall shift toward the nonoperative (delay of OR) strategy, compared with the results for EVAR. In those with small aneurysms and the elderly, there can be a significant risk of harm if operative repair is not delayed. This was especially pronounced in those 80 years of age or older. Only those with aneurysms >7 cm and under 80 years of age demonstrated a relevant improvement in the probability of survival with OSR, when the probability of infection with COVID-19 was 1% or greater in a 3-month time horizon.

DISCUSSION

This decision analysis demonstrates that the potential to cause harm by postponing AAA repair is affected by both the age of the patient and the local prevalence of COVID-19. This is in contrast to current guidelines that focus primarily on aneurysm size only. This study acts as a framework to aid physicians and hospital planning committees in policy regarding elective aneurysm surgery. Although no model will perfectly capture real-world events, we believe that this analysis provides insight into how practitioners should approach this difficult dilemma.

The major trade-off in the analysis is the risk of aneurysm rupture relative to the risk of contracting the virus in hospital. COVID-19-related mortality is known to be substantially higher in the elderly. Infection fatality rates for patients less than 60 years of age are believed to be <0.6%, whereas for those 80 years and older are estimated to be greater than 7%.[8] The baseline COVID-19 mortality risk of a patient should be an important factor physicians consider when deciding to delay elective surgery. Contraction of COVID-19 is greater in hospital than in the community, and elderly patients admitted for surgery therefore take on greater risk with elective repair.[13] Perioperative risk is also greater for elderly patients. As the incremental net survival benefit of elective AAA surgery decreases, delaying surgery has a lower risk of harm. The model does not include baseline medical comorbidities; however, these would impact outcomes in a similar manner. Patients who are more comorbid will also face greater COVID-19 mortality and perioperative risk; therefore, delaying surgery in this population is more likely to prevent harm.[1,15] Practitioners can be guided by the Vascular Quality Initiative perioperative mortality risk score, per the Society of Vascular Surgery guidelines, on the care of patient with an abdominal

Table II. Parameters used for probabilistic sensitivity analysis (PSA)[a]

Age	Parameter	Distribution	Values
60	COVID mortality[8]	Normal	Mean: 0.0193 SD: 0.00695
	Rupture mortality[16]	Beta	a: 34, b: 56
	Elective mortality EVAR[15]	Normal	Mean 0.003 SD: 0.001
	Elective mortality OSR[15]	Normal	Mean: 0.012 SD: 0.01
70	COVID mortality[8]	Normal	Mean: 0.0428 SD: 0.0150
	Rupture mortality[16]	Beta	a: 104, b: 141
	Elective mortality EVAR[15]	Normal	Mean: 0.008 SD: 0.0015
	Elective mortality OSR[15]	Normal	Mean: 0.025 SD: 0.015
80	COVID mortality[8]	Normal	Mean: 0.078 SD: 0.0238
	Rupture mortality[16]	Beta	a: 70, b: 85
	Elective mortality EVAR[15]	Normal	Mean: 0.0125 SD: 0.01
	Elective mortality OSR[15]	Normal	Mean: 0.0755 SD: 0.02
Aneurysm rupture risk			
Size	**Parameter**	**Distribution**	**Values**
5.5-5.9 cm	Rupture risk[14,17]	Triangular	Center: 0.094 Lower bound: 0.01 Upper bound: 0.11
6-6.9 cm	Rupture risk[14,17]	Triangular	Center: 0.102 Lower bound: 0.10 Upper bound: 0.22
>7 cm	Rupture risk[14,17]	Triangular	Center: 0.325 Lower bound: 0.30 Upper bound: 0.50
Ratio of inpatient to outpatient COVID contraction			
Parameter		**Distribution**	**Values**
Ratio inpatient:outpatient contraction[13]		Normal	Mean: 2 SD: 1

EVAR, Endovascular aortic aneurysm repair; *OSR*, open surgical repair; *SD*, standard deviation.
[a]PSA samples from within a given distribution of parameters and is repeated for numerous iterations (n = 1000). The type of distribution used and the parameters used to define the shape are provided.

aortic aneurysm, which should be used in conjuncture with these findings.[11]

In contrast, the model demonstrates that delaying elective surgery in young patients, especially with larger aneurysms, is likely to lead to increased risk of death. A 60-year-old patient with even a relatively small (5.5-5.9 cm) aneurysm may suffer harm from delay of elective surgery (0.8% increased risk of death at 3 months, 1.9% at 6 months). This is especially true if repair is postponed for a prolonged period. Younger patients have a lower COVID-19 infection fatality rate than elderly patients, and they have a low perioperative risk. Elective repairs of small and asymptomatic aneurysms have already been suspended frequently due to the pandemic, and therefore it is important to understand this risk.[4] As long as hospital infrastructure and hospital resources are adequate, consideration should be made to repair aneurysms in young individuals.

An important consideration is that the model focuses on patient-specific outcomes. It is not inclusive of hospital resources and use of PPE. A widely used decision analytic approach is cost-effectiveness analysis, which typically compares cost per quality adjusted life year gained to a willingness to pay threshold. In the context of the pandemic, however, conservation of PPE and intensive care unit (ICU) beds is the foremost concern.

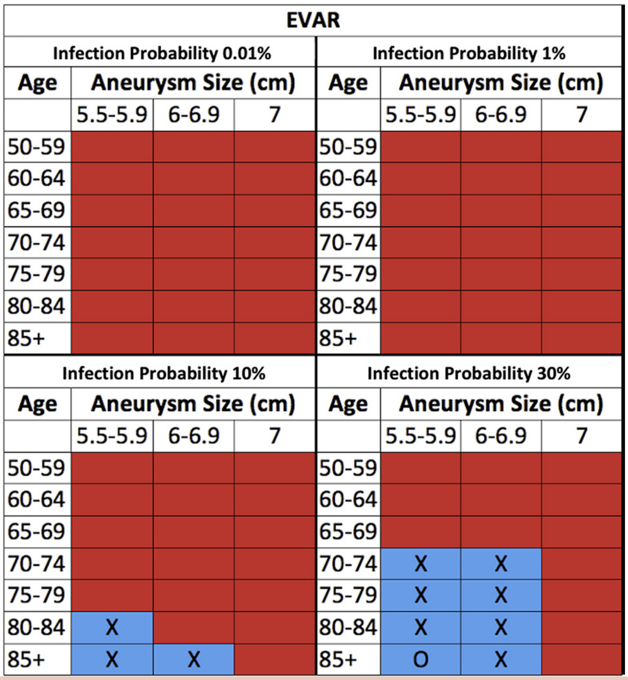

Fig 2. Comparison between an immediate and initial nonoperative (delayed) strategy involving endovascular abdominal aortic aneurysm repair (*EVAR*) at different community COVID-19 3-month infection probabilities. The color gives the dominant strategy considering a delay of repair of 3 months. Dominant strategy is additionally shown for alternate time horizons (time of delay) of 6 and 9 months. *Red*: operative strategy dominant. *Blue*: nonoperative strategy dominant. X: changes to operative strategy at 6 months of deferral. O: changes to operative strategy at 9 months of deferral.

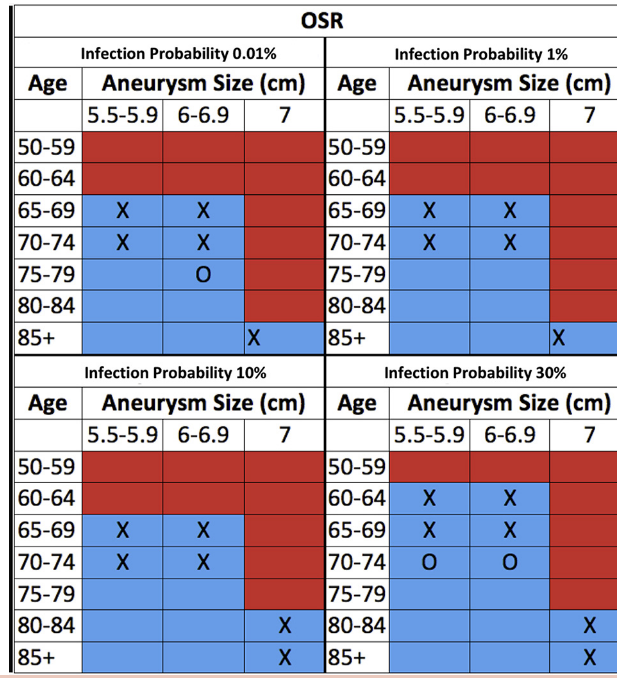

Fig 3. Comparison between an immediate and initial nonoperative (delayed) strategy involving open abdominal aortic aneurysm repair (*OSR*) at different community COVID-19 3-month infection probabilities. The color gives the dominant strategy considering a delay of repair of 3 months. Dominant strategy is additionally shown for alternate time horizons (time of delay) of 6 and 9 months. *Red*: operative strategy dominant. *Blue*: nonoperative strategy dominant. X: changes to operative strategy at 6 months of deferral. O: changes to operative strategy at 9 months of deferral.

Given the rapidity of the pandemic's onset, there has not yet been an effort to explicitly trade-off health gains against resource use in the COVID-19 setting. Based on these results, however, this trade-off can be contextualized.

As resources become more constrained, a greater risk to patient survival may be tolerated. For example, at a 30% probability of COVID-19 infection in a 3-month interval, a 1.4% elevated chance of patient mortality, caused by deferring OR by 3 months, may be tolerated (60-year-old with an AAA 6.5 cm). At 10% probability of infection, when resources are less constrained, this patient may be operated on electively (increased probability of survival 1.8%). These decisions will depend on the resource constraints of each hospital and health system. We therefore do not propose concrete cutoffs as the choice will vary based on each unique situation. In the case of elective EVAR, ICU utilization can be as low as 1%, and procedures can be performed with minimal loss of mask and gowns.[19] We estimate that 7 sets of PPE (mask, gown, gloves) would be used for a case. In many instances, we believe that this "expenditure" would be justified to reduce a patient's probability of mortality by 0.5% (which is close to the mortality faced by a person in his or her 50s or 60s who has contracted COVID).

Exposure of health care providers to COVID-19 is not considered in the model; however, this should be considered depending on regional circumstances. In scenarios where resource constraints do not allow for adequate protection of health care providers, operative repair should be delayed. Workers over 50 years of age who contract COVID face a 0.5% chance or greater of mortality, which is greater than the net survival benefit in a 3-month time horizon for aneurysms <7 cm. Treatment of AAA requires the involvement and possible exposure of many health care providers.

As operative risk increases, such as with open instead of endovascular repair, there is less risk associated with postponing repair. This is especially true in the elderly. As operative risk increases, patients must survive for a longer period of time to offset perioperative mortality risk. Mortality benefit of open vs endovascular repair favors EVAR in the immediate postoperative period but is equivalent at 1 to 2 years postoperatively.[18,20] During a COVID-19 outbreak, the elderly will have a greater risk of overall mortality than they would in pre-COVID times.

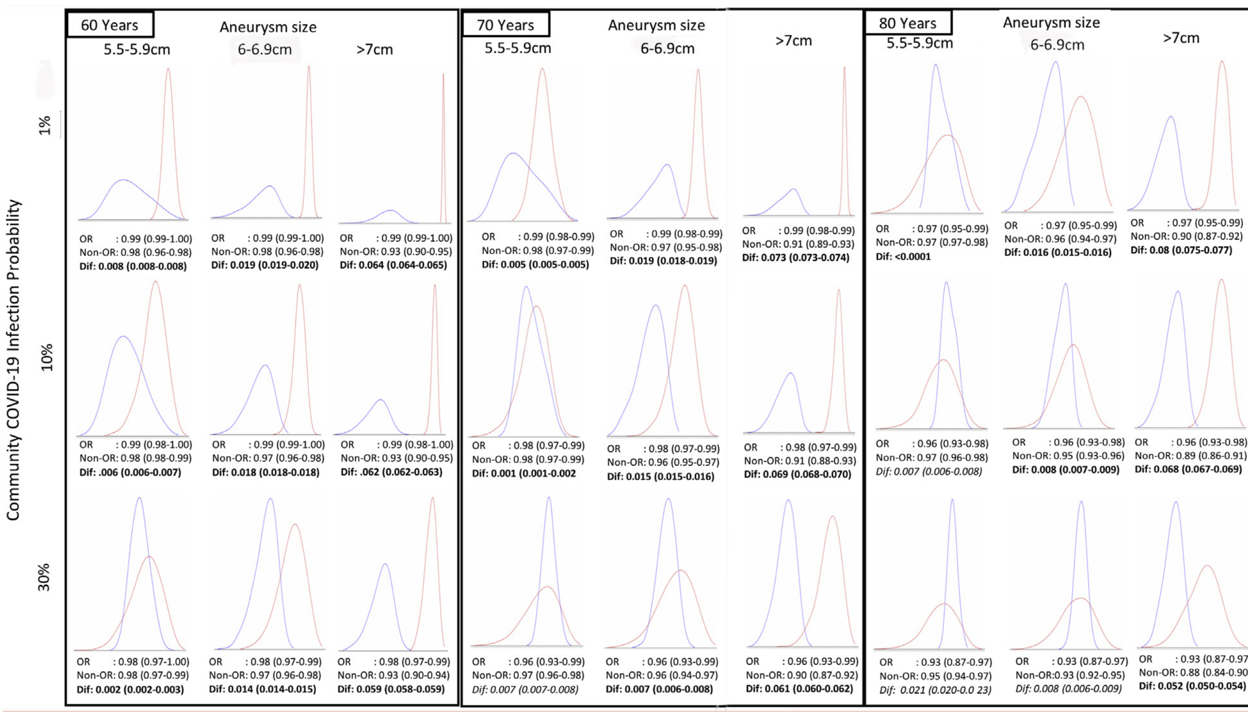

Fig 4. Probabilistic sensitivity analysis for endovascular aortic aneurysm repair (EVAR) assuming different community COVID-19 3-month probabilities of infection, patient age, and aneurysm size. The density distribution for the probability of survival demonstrates the uncertainty around this outcome and is shown in each case for the operative (*OR—red*) and nonoperative (delayed repair) strategy (*non-OR—blue*). The far-right of the *x*-axis is 100% survival probability. The mean of each distribution is given below each plot, with 95% credibility interval in parentheses. The mean absolute differences in probability of survival for the two strategies (*Dif*) are given, with 95% credibility intervals in parentheses. This difference is bolded when the operative strategy is dominant and italicized when the nonoperative approach is dominant.

If resource constraints require operative repair to be delayed, providers should first delay elderly patients who require open repair, as they are the least likely to suffer harm. Open repair is additionally more resource intensive with greater utilization of the ICU.[18,21-23] The use of the ICU and increased length of the case generally would require greater use of hospital resources.[18,19,21-23]

In the model, one limitation is that the probability of inpatient contraction of COVID-19 is dependent only on admission to hospital. It does not account for the possibility of increased risk of virus contraction with increased length of stay. As OSR requires a longer length of stay than EVAR, the model likely underestimates the benefit of EVAR relative to OSR.

In the context of the COVID-19 pandemic, these results suggest that endovascular repair should be considered as the preferred option in anatomically suitable patients. We would recommend that in times of high COVID-19 prevalence, only young patients, or those with a contraindication to endovascular repair (no neck or connective tissue disorders), should be treated with open repair. Elderly patients who are not amenable to endovascular repair should be deferred until COVID-19 infection risk decreases, and resource constraints are alleviated. The PSA on OSR demonstrated that elderly patients can face a substantially elevated risk of mortality (1.7%-7.9%) if repair is not delayed when COVID-19 prevalence is high.

There are limitations to the model. As discussed, it fails to capture all societal consequences of elective repair including overall resource utilization. There continues to be uncertainty in the parameters used in the analysis. The impact of this is minimized by including probabilistic sensitivity analyses that sample from a distribution representing the uncertainty in the underlying metrics. This model does not aim to replace clinical decision-making but instead provides a framework to aid practitioners and policy makers who will need to individualize this information for a more complex individual decision. Patient preference, aneurysm anatomic complexity, and unique hospital situations may all affect the final decision. On a patient-specific level, risk of rupture will vary with history of smoking, comorbidities, and aneurysm morphology.[11] Providers should consider the above points as well as how robust the results of this analysis were for a given patient profile (demonstrated in the PSA) when interpreting these data.

This model does not consider patients who are presenting to care with COVID-19. In the case of asymptomatic aneurysm, delay of repair until the patient is clinically improved is advisable. In the case of ruptured or

Table III. Probabilistic sensitivity analyses for endovascular aortic aneurysm repair (EVAR) considering a 6-month time horizon (*top*) and open surgical repair with a 3-month time horizon (*bottom*)

Age	Community risk of COVID-19 infection	Aneurysm size, cm		
		5.5-5.9	6-6.9	>7
Endovascular repair (6 months)				
60	1%	0.019 (0.018-0.019)	0.040 (0.040-0.041)	0.121 (0.119-0.122)
	10%	0.016 (0.015-0.016)	0.038 (0.037-0.039)	0.119 (0.118-0.121)
	30%	0.014 (0.014-0.015)	0.036 (0.035-0.036)	0.117 (0.116-0.119)
70	1%	0.017 (0.017-0.017)	0.045 (0.044-0.046)	0.014 (0.014-0.015)
	10%	0.013 (0.011-0.013)	0.038 (0.037-0.039)	0.137 (0.136-0.139)
	30%	0.008 (0.007-0.009)	0.034 (0.033-0.035)	0.133 (0.131-0.134)
80	1%	0.015 (0.014-0.015)	0.044 (0.043-0.045)	0.152 (0.151-0.154)
	10%	0.002 (0.001-0.003)	0.032 (0.030-0.033)	0.140 (0.138-0.142)
	30%	*0.003 (0.005-0.002)*	0.024 (0.023-0.026)	0.130 (0.128-0.132)
Open surgical repair (3 months)				
60	1%	*0.003 (0.002-0.004)*	0.009 (0.008-0.009)	0.053 (0.052-0.054)
	10%	*0.005 (0.004-0.005)*	0.007 (0.006-0.007)	0.051 (0.050-0.052)
	30%	*0.009 (0.008-0.009)*	0.003 (0.002-0.004)	0.048 (0.047-0.049)
70	1%	*0.012 (0.011-0.013)*	<Difference 0.001	0.055 (0.054-0.056)
	10%	*0.017 (0.018-0.016)*	*0.003 (0.002-0.004)*	0.051 (0.050-0.052)
	30%	*0.024 (0.023-0.026)*	*0.011 (0.010-0.012)*	0.044 (0.042-0.045)
80	1%	*0.060 (0.059-0.062)*	*0.044 (0.043-0.046)*	0.014 (0.012-0.015)
	10%	*0.066 (0.065-0.067)*	*0.051 (0.049-0.052)*	0.009 (0.007-0.11)
	30%	*0.079 (0.078-0.081)*	*0.064 (0.062-0.066)*	*0.003 (0.001-0.005)*

The mean absolute difference in probability of survival between the operative and delayed repair strategies is given with 95% credibility intervals. Values are italicized when delayed repair was the dominant strategy.

symptomatic aneurysms, decisions will depend on a case-by-case basis. The patient's age-specific risk of mortality due to COVID-19, irrespective of surgical outcome, should be considered before undertaking heroic surgical measures.

The COVID-19 pandemic is constantly evolving, and the length of time these recommendations are applicable to practice is hard to predict. In the absence of an active outbreak, health care providers will have to evaluate their available resources, including inpatient bed space, relative to the risk of an outbreak. This will be impacted by that geographic region's history of COVID-19 infection, local public health precautions, and country or world-wide prevalence. These findings should be used in conjuncture with the Society of Vascular Surgery guidelines on the management of AAA.[11] In the absence of new COVID-19 cases and a low likelihood of COVID-19 outbreak, practitioners should fully resume their normal practice.

CONCLUSIONS

The decision to delay operative repair of an abdominal aortic aneurysm should consider patient age, aneurysm size, and the probability of COVID-19 infection, which can be informed by local incidence of COVID-19 infection. Deferral should be considered in cases where open repair is required or when patients are elderly with small aneurysms. Those most likely to benefit from immediate repair are young patients due to a low risk of both COVID-19 and perioperative mortality. The risk of harm caused by delay of repair varies with patient age, aneurysm size, and COVID-19 prevalence. This must be weighed against available hospital resources when making individual or system-wide decisions.

AUTHOR CONTRIBUTIONS

Conception and design: BM, VI
Analysis and interpretation: BM, MT, LJ, SB, VI
Data collection: BM
Writing the article: BM
Critical revision of the article: MT, LJ, SB, VI
Final approval of the article: BM, MT, LJ, SB, VI
Statistical analysis: BM
Obtained funding: Not applicable
Overall responsibility: BM

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