ORIGINAL ARTICLE

Impact of Severe Acute Respiratory Syndrome Coronavirus 2-Induced COVID-19 on Fixed Operating Room Times in Urologic Operations

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Abstract

Objective: To evaluate the impact of coronavirus disease 2019 (COVID-19), caused by severe acute respiratory syndrome coronavirus 2, on operating room (OR) efficiency for urologic procedures using the concept of fixed OR times.

Patients and Methods: Over a 24-month period, urology OR data were prospectively collected. Operations were divided into fixed and variable time points. The fixed OR times were in-roomw to anesthesia-release time, anesthesia-release to cut time, in-room to cut time, and close to wheels-out time. Data from January 1, 2019, to December 31, 2019, were pre-COVID-19 data, and data from April 1, 2020, to December 31, 2020, were post-COVID-19 data. Operations were grouped into endoscopic, implant, major open, and robotic-assisted cases. In the post-COVID-19 era, all patients had a negative polymerase chain reaction test result within 48 hours of operation. The Wilcoxon rank sum test was used to compare the fixed OR times between the pre- and post-COVID-19 eras.

Results: A total of 3189 procedures were evaluated: 2058 endoscopic operations (1124 in the pre-COVID-19 era and 934 in the post-COVID-19 era), 343 implant procedures (192 in the pre-COVID-19 era and 151 in the post-COVID-19 era), 222 major open procedures (119 in the pre-COVID-19 era and 103 in the post-COVID-19 era), and 566 robotic-assisted procedures (338 in the pre-COVID-19 era and 228 in the post-COVID-19 era). There were no fixed OR times in any of the examined groups that were negatively impacted by COVID-19. The percentage of the total OR time occupied by fixed OR variables in the pre-COVID-19 era was 40.6% for endoscopic operations, 41.1% for implant procedures, 29.8% for major open procedures, and 21.8% for robotic-assisted procedures.

Conclusion: A substantial portion of the total OR time includes fixed time points. Furthermore, COVID-19 did not have a negative impact on fixed OR times in a negative testing environment. Urologic OR efficiency should be maintained in the post-COVID-19 era.

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Coronavirus disease 2019 (COVID-19), caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has had a considerable impact on hospitals, patients, and operations worldwide. Elective operations were limited across the world in order to save resources for emergency operations and patients with COVID-19.[1] Numerous guidelines were provided by various surgical societies for triaging nonemergency operations.[1,2] Safety protocols were implemented in operating rooms as operations were reinitiated to minimize the risk of infections to operating room (OR) personnel, specifically, the separation of intubation and the OR and the use of low-energy settings on ultrasonic equipment.[3,4] For minimally invasive procedures, the avoidance of the venting of ports and the use of suction to remove aerosols were recommended.[4]

With these increased precautions, COVID-19 has been reported to decrease OR efficiency in Europe, but whether OR efficiency has been meaningfully impacted by increased COVID-19 precautions in the United States remains underexplored.[5] At our institution, all patients are required to undergo a COVID-19 test with nasal swabbing and reverse-transcriptase polymerase chain reaction for SARS-CoV-2 viral RNA within 48 hours of an operation.[6] Elective operations are only performed once the confirmation of a negative COVID-19 test result is received. For emergency operations performed on patients with COVID-19, our institution intubates the patient in a negative-pressure room and then transports the patient to the OR.[6] Nevertheless, there are limited data to inform whether ORs perform as efficiently with these added precautions. The development of a better understanding of the impact of COVID-19 precautions on OR efficiency is essential to optimize perioperative resource planning.

Operating room efficiency analyses often focus on surgeon operating time and variation in procedure steps[7,8]; however, fixed OR times have also been reported to be important for models designed to optimize OR efficiency.[5,8-10] Because the greatest risk of COVID-19 infection among health care personnel is during endotracheal intubation, which is considered a part of fixed OR time, it was thought that fixed OR times would be longer during the post-COVID-19 era, with downstream effects on OR efficiency.[11] In a negative testing environment without alterations in staffing or surgical technique, we hypothesized that there should be no changes in OR efficiency. Therefore, the aim of our study was to evaluate the effect of COVID-19 on OR efficiency, specifically on fixed OR times (all time points other than surgeon operating time) in a negative testing environment.

METHODS

Data Source and Study Population

Over a 24-month period (2019-2020), we prospectively collected all fixed OR time points for urologic operations performed at our tertiary care center. The fixed OR times were in-room to anesthesia-release time (IRAT), anesthesia-release to cut time (ARCT), in-room time to cut time (IRCT) (IRAT + ARCT), and close to wheels-out time (CTWO). Patients undergoing operation at our institution are tested for SARS-CoV-2 viral RNA within 48 hours of their OR time.[6] We used nasopharyngeal swabbing and reverse-transcriptase polymerase chain reaction for the detection of SARS-CoV-2 viral RNA.

Procedures performed from January 1, 2019, to December 31, 2019, were classified as pre-COVID-19 procedures, and those performed from April 1, 2020, to December 31, 2020, were classified as post-COVID-19 procedures. Procedures performed from January 1, 2020, to March 31, 2020, were excluded from our analysis.

Urologic operations were grouped into endoscopic, implant, major open, and robotic-assisted cases. The endoscopic procedures included were as follows: cystoscopy (biopsy, biopsy fulguration, insertion stent ureter, with transurethral prostatectomy, with transurethral resection bladder neck, with transurethral resection lesion bladder), Holmium laser enucleation prostate (<70, 70-150, and >150 g), and ureteroscopy (stone extraction, via ileal conduit, with laser ablation tumor, with laser lithotripsy). The implant procedures evaluated were as follows: male sling, correction Peyronie, implantation inflatable penile prosthesis, artificial genitourinary sphincter (AGS), pubovaginal sling, placement SpaceOAR, penile plication, removal procedures (AGS and prosthetic material or mesh), revision or replacement procedures (AGS and inflatable penile prosthesis), and urethroplasty with or without buccal grafts. The major open procedures evaluated were as follows: cystectomy (with continent diversion, with ileal conduit, partial, radical), laparoscopic nephrectomy (simple or radical), laparoscopic radical nephroureterectomy, laparoscopic radical nephrectomy, nephrectomy (partial or simple), radical retropubic prostatectomy, radical cystoprostatectomy (with or without ileal conduit), radical nephroureterectomy, radical open nephrectomy (with or without inferior vena cava tumor thrombectomy), revision ileal conduit, and urinary diversion Indiana pouch. The robotic procedures included

TABLE. Fixed Operating Room Times for Endoscopic, Implant, Major Open, and Robotic-Assisted Procedures Before and After Coronavirus Disease 2019[a]

Procedure	OR time	Before COVID-19 n	Before COVID-19 Median (p0, p25, p75, p100)	After COVID-19 n	After COVID-19 Median (p0, p25, p75, p100)	WRS P	WRS Adj. P[b]
Endoscopic	Fixed, %	1114	40.6 (15.4, 30.8, 52.5, 89.1)	910	38.8 (5.8, 29.4, 52.3, 97.5)	.031	.062
	IRAT, minutes	1118	11 (1, 9, 13, 42)	933	11 (2, 9, 13, 129)	.51	
	ARCT, minutes	1112	13 (2, 10, 16, 49)	926	12 (1, 9, 15, 34)	<.001	.005
	IRCT, minutes	1118	24 (11, 21, 28, 63)	934	23 (1, 20, 27, 80)	<.001	.005
	CTWO, minutes	1118	8 (1, 5, 10, 45)	910	8 (1, 5, 10, 59)	.020	.060
Implant	Fixed, %	190	41.1 (13.4, 33.4, 58.0, 76.5)	149	41.3 (15.5, 32.4, 63.8, 87.8)	.59	
	IRAT, minutes	192	12 (4, 9, 14, 41)	151	11 (3, 9, 14, 28)	.40	
	ARCT, minutes	191	30 (2, 15, 40, 61)	151	30 (6, 15, 37, 57)	.36	
	IRCT, minutes	191	42 (13, 27, 52, 75)	151	41 (17, 26, 50, 69)	.20	
	CTWO, min	191	8 (1, 5, 11, 31)	149	8 (1, 5, 10, 29)	.91	
Major open	Fixed, %	119	29.8 (10.7, 20.0, 35.3, 55.4)	102	27.2 (11.1, 21.0, 33.7, 61.5)	.30	
	IRAT, minutes	119	21 (7, 16, 29, 112)	102	22 (9, 16, 32, 66)	.80	
	ARCT, minutes	119	34 (10, 28, 42, 64)	101	33 (14, 25, 42, 79)	.43	
	IRCT, minutes	119	59 (30, 50, 66, 126)	103	57 (29, 51, 65, 101)	.54	
	CTWO, minutes	119	10 (1, 7, 13, 43)	102	10 (1, 6, 13, 39)	.41	
Robotic-assisted	Fixed, %	336	21.8 (8.9, 18.2, 26.2, 40.3)	228	18.9 (6.6, 16.0, 22.9, 49.3)	<.001	.005
	IRAT, minutes	337	17 (6, 13, 22, 80)	228	17 (1, 13, 22, 65)	.84	
	ARCT, minutes	337	33 (7, 27, 39, 65)	226	29 (3, 25, 37, 70)	<.001	.005
	IRCT, minutes	336	50 (21, 43, 60, 100)	228	47 (6, 41, 58, 92)	.007	.014
	CTWO, minutes	336	10 (1, 7, 14, 45)	227	9 (1, 5, 12, 51)	.002	.006

[a]Adj., adjusted; ARCT, anesthesia-release to cut time; COVID-19, coronavirus disease 2019; CTWO, close to wheels-out time; IRAT, in-room to anesthesia-release time, IRCT, in-room to cut time; OR, operating room; p0, minimum value; p25, 25th percentile; p7, 75th percentile; p100, maximum value; WRS, Wilcoxon rank sum test.
[b]The Holm method for multiple testing adjustment was done separately for each procedure type. Adjusted *P* values were only presented where the unadjusted *P* value was less than .05.

in our analysis were as follows: robotic-assisted partial nephrectomy, robotic-assisted radical prostatectomy, and robotic-assisted cystectomy (radical, simple, neobladder, and cystoprostatectomy).

Outcomes

The primary study outcome was the comparison of fixed OR times in the pre- and post-COVID-19 eras. The secondary outcomes included the proportion of the total OR time accounted for by fixed OR times for each subcategory, including endoscopic, implant, open, and robotic-assisted cases.

Statistical Analyses

Continuous variables were descriptively summarized using the median, minimum percentile, 25th percentile, 75th percentile, and maximum percentile and presented graphically using box plots. Categorical variables were summarized using the number and percentage of procedures. The Wilcoxon rank sum test was used to compare the fixed OR times between the pre- and post-COVID-19 eras. Owing to the number of Wilcoxon rank sum tests performed, which increases the likelihood of a type I error, we used the Holm method[12] of adjustment for multiple testing. Adjusted *P* values less than .05 (2-sided) were considered statistically significant without adjustment for multiple testing. *P* values adjusted for multiple testing were only presented when the unadjusted *P* value was less than .05. All *P* values should be assumed to be unadjusted for multiple testing unless specified. When the Wilcoxon rank sum test had an unadjusted *P* value of less than .05 but the medians were equal, we used quantile regression to estimate the difference (post- vs pre-COVID-19 era) in the 10th, 25th, 50th, 75th, and 90th percentiles; 95% confidence intervals (CIs) for the difference in each percentile of interest were estimated using bootstrap methods. Statistical analyses and

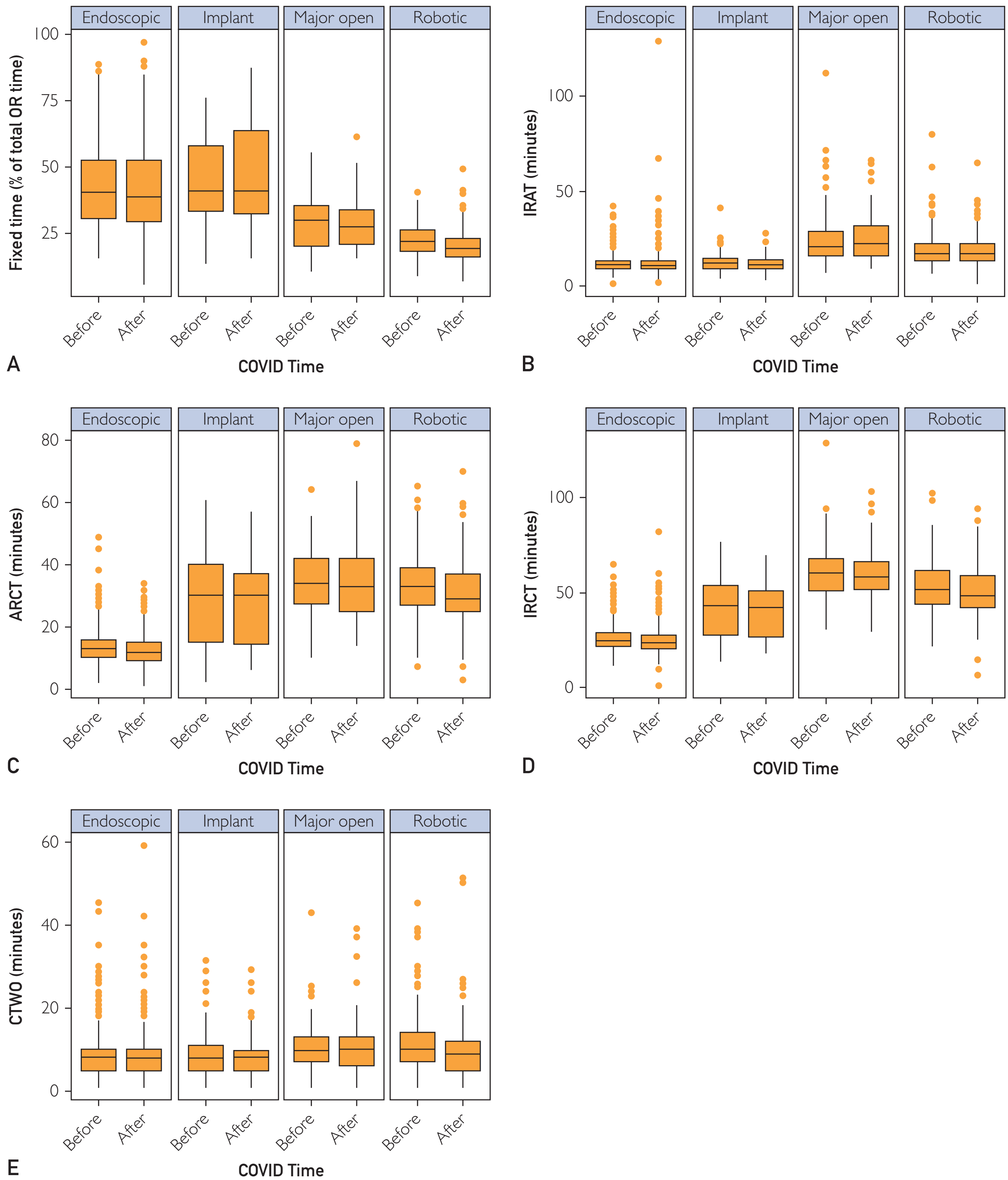

FIGURE. Box plots of fixed operating room (OR) times before and after coronavirus disease 2019 for each group of procedures (endoscopic, implant, major open, and robotic-assisted). The fixed OR times included the (A) percentage of total OR time occupied by fixed times, (B) in-room time to anesthesia-release time, (C) anesthesia-release time to cut time, (D) in-room to cut time, and (E) close to wheels-out time. ARCT, anesthesia-release to cut time; COVID-19, coronavirus disease 2019; CTWO, close to wheels-out time; IRAT, in-room to anesthesia-release time; IRCT, in-room to cut time; OR, operating room.

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graphics were performed using R, version 3.6.2 (R Foundation for Statistical Computing).

RESULTS

We evaluated a total of 3189 procedures: 2058 endoscopic operations (1124 in the pre-COVID-19 era and 934 in the post-COVID-19 era), 343 implant procedures (192 in the pre-COVID-19 era and 151 in the post-COVID-19 era), 222 major open procedures (119 in the pre-COVID-19 era and 103 in the post-COVID-19 era), and 566 robotic-assisted procedures (338 in the pre-COVID-19 era and 228 in the post-COVID-19 era). The median total OR time for the robotic-assisted procedures was 271 minutes (range, 75-716 minutes) in the pre-COVID-19 era and 288 minutes (range, 144-779 minutes) in the post-COVID-19 era. The median total OR time for the endoscopic operations was 82 minutes (range, 3-236 minutes) in the pre-COVID-19 era and 80 minutes (range, 27-452 minutes) in the post-COVID-19 era. The median total OR time for the implant procedures was 140 minutes (range, 33-384 minutes) in the pre-COVID-19 era and 128 minutes (range, 34-294 minutes) in the post-COVID-19 era. The median total OR time for the major open procedures was 238 minutes (range, 81-642 minutes) in the pre-COVID-19 era and 246 minutes (range, 65-775 minutes) in the post-COVID-19 era. A total of 1773 procedures were included in the pre-COVID-19 portion of our analysis. Of these procedures, 63.4% (1124) were endoscopic operations, 10.8% (192) were implant procedures, 6.7% (119) were major open procedures, and 19.1% (338) were robotic-assisted procedures. A total of 1416 procedures were included in the post-COVID-19 portion of our analysis. Of these procedures, 65.9% (934) were endoscopic operations, 10.7% (151) were implant procedures, 7.3% (103) were major open procedures, and 16.1% (228) were robotic-assisted procedures.

The comparison of the fixed OR times between the post- and pre-COVID-19 eras is shown in the Table for each group of procedures. Figure A shows the distribution of the percentage of the total OR time occupied by fixed times for all the procedure groups in the pre- vs post-COVID-19 eras. For the robotic-assisted procedures, the median fixed OR time occupied 21.8% of the total OR time in the pre-COVID-19 era and 18.9% in the post-COVID-19 era ($P<.001$, adjusted $P=.005$). For the endoscopic procedures, the median fixed OR time occupied 40.6% of the total OR time in the pre-COVID-19 era and 38.8% in the post-COVID-19 era ($P=.031$, adjusted $P=.062$). For the implant procedures, the median fixed OR time occupied 41.1% of the total OR time in the pre-COVID-19 era and 41.3% in the post-COVID-19 era ($P=.59$). For the major open procedures, the median fixed OR time occupied 29.8% of the total OR time in the pre-COVID-19 era and 27.2% in the post-COVID-19 era ($P=.30$).

Coronavirus disease 2019 did not have a marked effect on IRAT for any of the procedure groups (difference [post-COVID-19 − pre-COVID-19] in median IRAT for all 4 procedure groups≤1 minute, all $P\geq.40$) (Figure B). The ARCT was shorter in the post-COVID-19 era than in the pre-COVID-19 era for the endoscopic (difference in median ARCT, −1 minute; $P<.001$, adjusted $P=.005$) and robotic-assisted procedures (difference in median ARCT, −4 minutes; $P<.001$, adjusted $P=.005$) (Figure C). We did not observe evidence of the impact of COVID-19 on ARCT for the implant or major open procedures (differences in median ARCT, ≤0 minute; both $P\geq.36$) (Figure C). The IRCT was also shorter in the post-COVID-19 era than in the pre-COVID-19 era for the endoscopic (difference in median IRCT, −1 minute; $P<.001$, adjusted $P=.005$) and robotic-assisted procedures (difference in median IRCT, −3 minutes; $P=.007$, adjusted $P=.014$) (Figure D).

Compared with the median IRCT in the pre-COVID-19 era, the median IRCT in the post-COVID-19 era was 1 and 2 minutes shorter for the implant and major open procedures, respectively, but these differences were not substantial ($P=.20$ and $P=.54$, respectively) (Figure D). Comparisons of CTWO during the endoscopic procedures reported a statistically significant difference in the distributions in the post-COVID-19 era compared with those in the pre-COVID-19 era; however, the median was 8 minutes for both time points. Using quantile regression to better understand the differences in the distribution of CTWO during the endoscopic procedures, we found a difference (post- vs pre-COVID-19 eras) of 0 minutes for the 25th, 50th, and 75th percentiles. The 90th percentile for CTWO was 1 minute shorter in the post-COVID-19 era than in the pre-COVID-19 era (95% CI, 0-2 minutes). The 10th percentile for CTWO was 2 minutes shorter in the post-COVID-19 era than in the pre-COVID-19 era (95% CI, 1-3 minutes). The CTWO during the robotic-assisted procedures was also shorter in the post-COVID-19 era than in the pre-COVID-19 era (difference in median CTWO, −1 minute; P=.002, adjusted P=.006) (Figure E). Moreover, the CTWO for the implant or major open procedures was not impacted by COVID-19 (both differences in median CTWO, 0 minutes; P=.91 and .41, respectively) (Figure E). After adjustment for multiple testing, the difference in CTWO for the endoscopic procedures was no longer statistically significant (adjusted P=.060).

When the variance of pre-COVID-19 fixed OR times was evaluated, IRAT had the most variation for the major open operations (range, 7-112 minutes; interquartile range [IQR], 28-42 minutes). Furthermore, ARCT had the most variation for the implant procedures (range, 2-61 minutes; IQR, 15-40 minutes), followed by the robotic-assisted (range, 7-65 minutes; IQR, 27-39 minutes) and major open procedures (range, 10-64 minutes; IQR, 28-42 minutes). Additionally, IRCT had the most variation for the implant procedures, followed by the robotic-assisted and major open procedures, but this was primarily attributed to the variation in ARCT. The difference between the 25th and 75th percentiles was less than 10 minutes for all of the remaining fixed OR times and procedures (Table and Figure).

DISCUSSION

Herein, we evaluated 2 years' worth of prospectively collected OR data and observed that fixed OR times were not negatively impacted during COVID-19 compared with those at the pre-COVID-19 baseline. Contrary to previously published reports,[5,7] these results are encouraging and suggest that with careful COVID-19 screening protocols to ensure a negative testing environment, OR efficiency need not suffer when elective operations are performed in the era of COVID-19. Furthermore, we found that fixed OR times made up a considerable portion of the total OR time for all the procedure groups evaluated, 20%-40% on average, further reporting the importance of considering fixed OR times in addition to procedural variables while analyzing OR efficiency.

An orthopedic hospital in Italy performed an OR efficiency analysis specifically assessing first-case delay, occupancy rate, and turnover time in operations in both patients with and without COVID-19. They reported large increases in the turnover time and first-case delay after COVID-19.[5] Our analysis did not assess the turnover time, occupancy rate, or first-case delay. Instead, we focused on the efficiency of intraoperative time points for individual procedures. It was originally thought that the fixed OR times would increase in the post-COVID-19 era because of increased COVID-19 safety protocols. However, we found that the median fixed OR times decreased or remained the same for all the procedures that were evaluated. Der et al[7] focused specifically on how surgeon accuracy and efficiency was affected by COVID-19. They found that both experts and newly trained surgeons experienced a decrease in accuracy and efficiency while performing robotic simulations.

The evaluation of variability in each of the fixed time points further aided our analysis. This range of time is especially useful for scheduling purposes. Before the era of COVID-19, the major open procedures had the most variation in IRAT and IRCT and the implant procedures had the most variation in ARCT. Furthermore, the CTWO for the endoscopic and robotic-assisted procedures varied most in the pre-COVID-19 era. Although we evaluated the variation in the length of the time of the fixed OR variables, Meneghini[8] discussed how variation in the surgical steps of a procedure can affect efficiency by slowing down other OR staff because of unpredictability. Rozario and Rozario[9] discussed the use of machine learning in order to improve OR scheduling, decreasing procedure overtime and undertime, thus increasing efficiency. They used OR data from 3 years, specifically, total OR time, to improve their scheduling methods to improve cost efficiency and the allocation of resources. Their time was broken into wheels-in, anesthesia start, procedure start, procedure end, anesthesia end, and wheels-out; however, they specifically used patient-in-room and patient-out-of-room times to evaluate OR overtime and undertime. Our OR time was broken into similar time points; however, we analyzed the duration of these fixed time points to find areas in each procedure group that had variation or inefficiencies, whereas they analyzed the total OR time in comparison with how long the procedure was booked for.

Because of the novelty of COVID-19, there was concern and uncertainty with performing surgical procedures. Vigneswaran et al[13] discussed the mechanisms of the transmission of the coronavirus, which is transmitted through respiratory droplets; however, Ling et al[14] found traces of viral RNA in the urine of patients recovering from COVID-19, and Kunz et al[3] reported that the SARS-CoV-2 nucleocapsid antigen has been reported to accumulate in kidney tubules, causing concern for urologists. The risk of transmission during minimally invasive operations led to recommendations for increased precautions (the use of the lowest intra-abdominal pressure and controlled smoke evacuation systems).[4] However, the COVID-19 OR precautions did not increase the fixed OR times in our analysis, possibly because we were able to perform them in a negative testing environment. Tan et al[15] also performed their procedures in a negative testing environment; however, they only tested patients for COVID-19 if there was clinical suspicion, whereas we tested all patients undergoing elective operation at our institution. They specifically evaluated major genitourinary cancer operations and found that none of the 598 cases in their study died of COVID-19 through postoperative day 30.[15] Of all their cases, 499 were performed with a minimally invasive approach.[15]

The data in this study were prospectively collected, and the operations were performed in a closed hospital system with subspecialized surgeons and urology nursing teams. However, this study was not without limitations. First, no patient factors were recorded, and it is possible that these variables were confounding factors, thus affecting the fixed OR times. Second, the results of this analysis may not be generalizable to many hospitals because of the subspecialized anesthesia and nursing teams as well as the subspecialized surgeons involved in these operations. Lastly, although our hospital also performed emergency operations on patients with COVID-19,[6] only operations performed on patients confirmed to be without COVID-19 were included in this analysis. We focused our analysis on variables in the OR. Furthermore, we did not evaluate the turnover time.

CONCLUSION

Fixed OR times occupy a substantial portion of the total procedure time and, therefore, should be evaluated while assessing OR efficiency. Coronavirus disease 2019 did not have a negative impact on fixed OR time points in a negative testing environment. Operating room efficiency should be expected to be maintained after COVID-19.

POTENTIAL COMPETING INTERESTS

The authors report no competing interests.

Abbreviations and Acronyms: **AGS,** artificial genitourinary sphincter; **ARCT,** anesthesia-release to cut time; **CI,** confidence interval; **COVID-19,** coronavirus disease 2019; **CTWO,** close to wheels-out time; **IQR,** interquartile range; **IRAT,** in-room to anesthesia-release time; **IRCT,** in-room to cut time; **OR,** operating room; **SARS-CoV-2,** severe acute respiratory syndrome coronavirus 2

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