


COVID-19 and cardiothoracic surgery: Effects on training and workforce utilization in a global pandemic

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Abstract

Background: The COVID-19 pandemic has disrupted all aspects of healthcare, including cardiothoracic surgery (CTS). We sought to determine the pandemic's impact on CTS trainees' educational experiences.

Methods: A survey was developed and distributed to members of the Thoracic Surgery Residents Association and other international CTS trainees. Trainees were asked to evaluate their cumulative experiences and share their overall perceptions of how CTS training had been impacted during the earliest months of the COVID-19 pandemic (i.e., since March 01, 2020). Surveys were distributed and responses were recorded June 25–August 05, 2020. In total, 748 surveys were distributed and 166

responses were received (overall response rate 22.2%). Of these, 126 of 166 responses (75.9%) met inclusion criteria for final analysis.

Results: Final responses analyzed included 45 of 126 (35.7%) United States (US) and 81 of 126 (64.3%) international trainees, including 101 of 126 (80.2%) senior and 25 of 126 (19.8%) junior trainees. Most respondents (76/126, 43.2%) lost over 1 week in the hospital due to the pandemic. Juniors (12/25, 48.0%) were more likely than seniors (20/101, 19.8%) to be reassigned to COVID-19-specific units ($p < .01$). Half of trainees (63/126) reported their case volumes were reduced by over 50%. US trainees (42/45, 93.3%) were more likely than international trainees (58/81, 71.6%) to report reduced operative case volumes ($p < .01$). Most trainees (104/126, 83%) believed their overall clinical acumen was not adversely impacted by the pandemic.

Conclusions: CTS trainees in the United States and abroad have been significantly impacted by the COVID-19 pandemic, with time lost in the hospital, decreased operative experiences, less time on CTS services, and frequent reassignment to COVID-19-specific care settings.

KEYWORDS

COVID-19, education, global surgery

1 | INTRODUCTION

The Coronavirus Disease-2019 (COVID-19) pandemic has impacted every area of healthcare, including cardiothoracic surgery (CTS). When COVID-19 began to surge in March 2020, most nonurgent procedures were canceled or delayed and hospital admissions and interventions for myocardial infarctions and acute aortic dissections declined.¹⁻³ Although these changes undoubtedly impacted CTS trainees around the world,⁴⁻⁹ the extent to which their education was affected during the earliest months of the COVID-19 remains incompletely understood.

This investigation sought to characterize the impact of the COVID-19 pandemic on CTS education as perceived by CTS trainees both in the United States (US) and abroad, as well as among junior- and senior-level trainees. The study aimed to describe (1) to what extent the clinical, operative, and educational experiences of CTS trainees were impacted during the earliest months of the COVID-19 pandemic and (2) how frequently and in what capacity CTS trainees were called upon to work in COVID-19-specific clinical settings.

2 | MATERIALS AND METHODS

2.1 | Survey development and distribution

The Thoracic Surgery Resident's Association (TSRA) developed a survey for evaluating the cumulative perceptions and overall experiences of CTS trainees during the earliest months of the COVID-19 pandemic (i.e., since March 2020). The final 19-question electronic survey (Supporting Information S1) was pretested by the

TSRA Executive Committee before its distribution to other CTS trainees via email. Responses were collected and recorded between June 25 and August 5, 2020. Follow-up emails were sent at 2 and 3 weeks after the initial distribution date. Trainees were informed that participation was voluntary and anonymous and that submitted responses would be used for research. The study was approved by the University of Pennsylvania Institutional Review Board (#842803).

The survey was emailed to a total of 748 CTS trainees. Of these, 532 of 748 (71.1%) were sent to members of the TSRA Listserv, which included all US trainees enrolled in CTS training programs accredited by the Accreditation Council for Graduate Medical Education. The other 216 of 748 (28.9%) surveys were emailed to international trainees, including 100 of 216 (46.3%) trainees in Canada (via program directors), 40 of 216 (18.5%) in Australia/New Zealand (via the Royal Australasian College of Surgeons Trainees' Association), as well as 15 of 216 (6.9%), 37 of 216 (17.1%), 12 of 216 (5.6%), and 12 of 216 (5.6%) individual CTS trainees in Asia, Africa, South/Central America, and Europe, respectively. Additional responses were solicited via social media using the TSRA's Twitter account. Only respondents who reported active enrollment in a dedicated CTS training program as of March 1, 2020 who also completed 100% of the survey were included in the final analysis.

2.2 | Definitions

Respondents who reported enrollment in a CTS program in the United States were considered "United States" trainees, regardless of nationality. CTS trainees enrolled in programs outside the United States were analyzed collectively as "international" trainees.

Trainees who completed other surgical training before their CTS training (i.e., traditional/advanced CTS fellows) as well as integrated CTS residents (e.g., integrated 6-year residencies, 4 + 3 Joint Thoracic/General surgery residencies, or similar programs) in at least their fourth post-graduate year (PGY) of training were considered "senior" trainees. Integrated residents who were PGY \leq 3 were considered "junior" trainees.

The survey defined CTS-related rotations as adult cardiac surgery, general thoracic surgery, congenital CTS, and nonoperative CTS-related rotations (i.e., cardiology, oncology, imaging, etc.). CTS trainees who reported being reassigned to work in drive-thru or off-site COVID-19 testing stations, COVID-19-specific wards (i.e., intensive care units, makeshift wards, etc.), procedure teams (i.e., on-call placement of central lines, chest tubes, etc.), and those who completed unanticipated emergency department rotations during the pandemic were considered to have been redeployed to COVID-19-specific units.

2.3 | Statistical analysis

Standard descriptive statistics were used to compare responses among United States and international trainees, as well as junior and senior trainees. Categorical variables are presented as frequencies and proportions relative to the whole (n/N , %) and were compared using the χ^2 or the Fisher's exact test, as appropriate. Continuous variables are reported as mean \pm standard deviation and were compared using the Student t test or Mann-Whitney U test, depending on normality of distribution. A significance level of $\alpha = .05$ was used for all analyses. All statistics were performed using STATA v16.1 (StataCorp, LLC).

3 | RESULTS

3.1 | Survey responses and trainee characteristics

Among 748 surveys distributed, 166 responses were received (overall response rate 22.2%). Of these, 126 of 166 (75.9%) met inclusion criteria for final analysis, which included 45 of 126 (35.7%) US trainees and 81 of 126 (64.3%) international trainees (Figure 1). A total of 24 countries were represented in the international cohort (Supporting Information S2). International responses came from trainees in Australia/New Zealand (7/81, 8.6%), Canada (17/81, 21.0%), Asia (22/81, 27.2%), Europe (13/81, 16.0%), Africa (16/81, 19.8%), and South/Central America (6/81, 7.4%).

Most respondents were enrolled in integrated CTS training programs (73/126, 57.9%) and most were male (93/126, 73.8%) (Table 1). Mean PGY was 6.8 ± 3.3 years. All respondents were PGY-2 or older. More respondents were classified as "senior" trainees (101/126, 80.2%) than "junior" trainees (25/126, 19.8%). In total, 22 of 126 (17.5%) respondents were credentialed to work as unsupervised attending providers, yet only one respondent reported serving in such a role as a result of the COVID-19 pandemic.

Geographic Distribution of Cardiothoracic Surgical Trainee Survey Respondents (N=126)

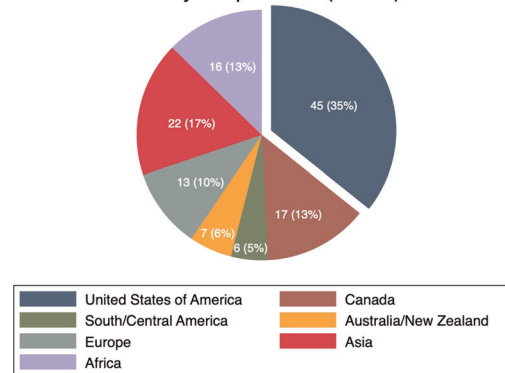


FIGURE 1 Training location of survey respondents ($N = 126$). The largest number of responses came from trainees in the United States

TABLE 1 Cardiothoracic surgery trainee survey respondent characteristics ($N = 126$)

	Frequency, n/N (%)
Training location	
United States Trainees	45/126 (35.7)
International Trainees	81/126 (64.3)
Trainee level	
Junior Trainees	25/126 (19.8)
Senior Trainees	101/126 (80.2)
Post-graduate year, mean \pm standard deviation	6.8 ± 3.3
Credentialed to work as unsupervised attending providers (before or during the COVID-19 pandemic)	22/126 (17.5)
Male	93/126 (73.8)
Enrolled in integrated cardiothoracic surgery programs	73/126 (57.9)

3.2 | Clinical experiences and trainee utilization during the pandemic

Most respondents (82/126, 65.1%) reported that they lost inpatient clinical time as a result of the pandemic due to staffing/scheduling changes and/or quarantines related to illness or exposure. Approximately half of respondents (67/126, 53.2%) indicated that they were removed from clinical duties for more than 1 week and 18 of 126 (14.3%) trainees were absent for more than 4 weeks (Figure 2).

The majority of respondents (91/126, 72.2%) reported that they were removed from or got less exposure to CTS-related rotations than they had anticipated before the COVID-19 pandemic (Table 2). A quarter of trainees (32/126, 25.4%) were reassigned to work in COVID-19-specific units. Although both junior and senior trainees were removed from CTS-related rotations at similar rates, junior trainees were more likely to be reassigned to work in

Cumulative Time Lost in the Hospital as a Result of COVID-19 Among Cardiothoracic Surgical Trainees (N=126)

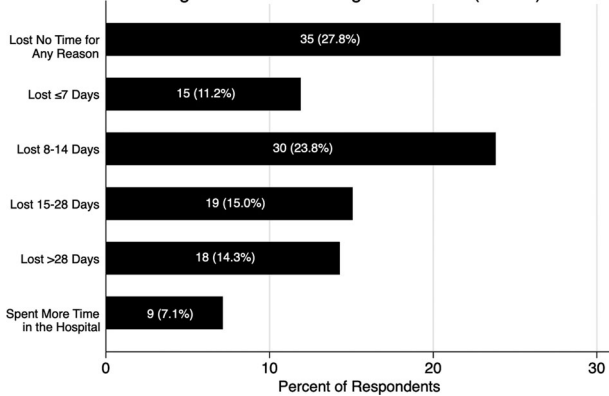


FIGURE 2 Cumulative time lost in the hospital as a direct result of the COVID-19 pandemic (N = 126), due to alternative staffing models, scheduling changes, quarantines related to illness or exposure, and so forth

COVID-19-specific units (12/25, 48.0%) compared to senior trainees (20/101, 19.8%, $p = .009$) (Table 3).

A minority of trainees (22/126, 17.5%) believed that their overall clinical (i.e., nonoperative) acumen had declined as a result of the pandemic, but this sentiment was more common among international trainees (19/81, 23.5%) than US trainees (3/45, 6.7%, $p = .026$) (Table 4). Few respondents (13/126, 10.3%) believed that their overall clinical acumen had improved as a result of the pandemic.

Some CTS trainees volunteered additional comments regarding their individual educational experiences during the COVID-19 pandemic, which are provided in Table 5.

3.3 | Operative experiences and training requirements

Between March 1, 2020 and the date of survey completion, a total of 116 of 126 (92.1%) trainees rotated on surgical services, of which 100 of 116 (86.2%) reported a reduction in their operative case volumes since the beginning of the COVID-19 pandemic. A majority of these trainees (63/116, 54.3%) reported that their operative case volumes had declined by 50% or more, including nearly a quarter of respondents (27/116, 23.3%) who indicated that their operative experiences had been essentially eliminated (Figure 3).

US trainees were more likely to report a reduction in personal case volumes (42/43, 97.7%) compared to international trainees (58/73, 79.5%) ($p = .005$) (Table 4). Although traditional CTS fellows more often reported reductions in their operative case volumes (51/52, 98.1%) compared to senior-level integrated CTS residents (30/41, 73.2%, $p < .001$), this difference was only significant among international trainees (28/28, 100% vs. 19/30, 63.3%, respectively, $p < .001$), and not US trainees (23/24, 95.8% vs. 11/11, 100%, respectively, $p = 1.000$).

Overall, 48 of 126 (38.1%) respondents indicated that they would be unable to meet or had concerns regarding their ability to

TABLE 2 Cardiothoracic surgery education changes during the early COVID-19 pandemic

	Frequency, n/N (%)
Lost time on cardiothoracic-related rotations	91/126 (72.2)
Adult cardiac	64/91 (70.3)
General thoracic	45/91 (49.5)
Congenital	15/91 (16.5)
Nonsurgical cardiothoracic surgery-related rotations	17/91 (18.7)
Reassigned to work in COVID-19-specific units	32/126 (25.4)
Emergency departments	9/32 (28.1)
Drive-thru or off-site COVID-19 testing stations	8/32 (25)
COVID-19-specific wards	12/32 (37.5)
Procedure teams	7/32 (21.9)
Multidisciplinary conferences and/or didactics affected by the COVID-19 pandemic	123/126 (97.6)
Continued with remote access and/or in smaller groups	117/123 (95.1)
Postponed indefinitely and/or canceled entirely	55/123 (44.7)
Participated in high-stakes exams	71/126 (56.3)
Performance hurt by pandemic	27/71 (38.0)
Performance helped by pandemic	10/71 (14.1)
Performance not affected by pandemic	34/71 (47.9)
Involved in research	109/126 (86.5)
Research limited	31/109 (28.4)
Research improved	37/109 (33.9)
Research conferences canceled, rescheduled, or moved online	31/109 (28.4)
Involved in COVID-19 research	13/109 (11.9)
Interviews scheduled during early COVID-19 pandemic	28/126 (22.2)
Interviews delayed or rescheduled	16/28 (57.1)
Virtual interviews	8/28 (28.6)
Interviews canceled	9/28 (32.1)
In-person interviews	2/28 (7.1)

meet case log minimums and/or other training requirements due to the pandemic (Tables 3 and 4). However, this was more common among international trainees (40/81, 49.5%) than US trainees (8/45, 17.8%, $p = .001$). Regardless, many of these individuals (21/48, 43.8%) did not believe that these shortcomings would ultimately extend their training or delay their graduation.

TABLE 3 Comparison of junior and senior trainees' experiences during the early COVID-19 pandemic

	Junior (N = 25) n/N (%)	Senior (N = 101) n/N (%)	p Value
United States trainees	8/25 (32.0)	37/101 (36.6)	.817
Male	17/25 (68.0)	76/101 (75.2)	.618
Enrolled in integrated cardiothoracic surgery training programs	25/25 (100.0)	61/101 (60.4)	<.001
Post-graduate year, mean ± standard deviation	2.6 ± 0.4	7.9 ± 1.7	<.001
Time lost in the hospital			
Lost any time in the hospital	19/25 (76.0)	63/101 (62.4)	.246
Lost more than 7 days in the hospital	16/25 (64.0)	51/101 (50.5)	.267
Lost time on cardiothoracic-related rotations	17/25 (68)	74/101 (73.3)	.623
Reassigned to work in COVID-19-specific units	12/25 (48.0)	20/101 (19.8)	.009
Originally scheduled to be on surgical rotations	23/25 (92.0)	93/101 (92.1)	1.000
Experienced any reduction in case volume	19/23 (82.6)	81/93 (87.1)	.520
Case volume was reduced by 50% or more	13/23 (56.5)	50/93 (53.8)	1.000
Operative experience was essentially eliminated	8/23 (34.8)	19/93 (20.4)	.171
Expect to be unable to meet, or increased concern regarding ability to meet training/graduation requirements	11/25 (44.0)	37/101 (36.6)	.500
Concerned/expect that inability to meet clinical requirements will delay advancements in training and/or graduation	8/11 (72.7)	19/37 (51.4)	.304
Overall clinical acumen (nonoperative) and ability to treat patients			
Declined	7/25 (28.0)	15/101 (14.9)	.143
No change	16/25 (64.0)	75/101 (74.3)	.325
Improved	2/25 (8.0)	11/101 (10.9)	1.000

3.4 | Education and scholarly activity

Almost all respondents (123/126, 97.6%) reported that their institution's educational conferences and/or didactics were affected by the pandemic. Although the vast majority of trainees (117/123, 95.7%) indicated that these meetings often continued with remote access and/or in smaller groups, nearly half (55/123, 44.7%) reported that at least some didactics or conferences were postponed indefinitely or canceled entirely (Table 2). Among 71 of 126 (56.3%) trainees who participated in high-stakes exams during the pandemic, 27 of 71 (38.0%) felt that the pandemic likely hurt their preparation and/or performance, whereas 10 of 71 (14.1%) believed the pandemic improved their studies and/or scores (Table 2).

Most respondents (109/126, 86.5%) reported active involvement with research during the study period. More trainees reported that their research involvement increased (37/109, 33.9%) rather than decreased (31/109, 28.4%) due to the pandemic and a small proportion of trainees (13/109, 11.9%) became directly involved in COVID-19-related research. Nevertheless, 31 of 109 (28.4%) trainees reported disruptions to academic conferences where they intended to present their research (Table 2).

Although only a minority of trainees (28/126, 22.2%) had interviews for additional training or jobs scheduled during the earliest months of the COVID-19 pandemic, those who did often had interviews delayed or rescheduled (16/28, 57.1%) and even canceled (9/28, 32.1%). Some trainees completed interviews virtually (8/28, 28.6%), but in-person interviews were rare (2/28, 7.1%).

3.5 | Preparation for the pandemic and exposure to COVID-19

The majority of trainees believed that their programs sufficiently prepared them for the pandemic (Table 6); however, international trainees more often reported that they felt underprepared or poorly prepared (33/81, 40.7%) compared to US trainees (4/45, 8.9%, $p < .001$).

Most trainees (87/126, 69.0%) indicated that they had certainly or likely provided direct care to patients with COVID-19. Half of trainees (63/126, 50.0%) reported the presence of at least one COVID-19 symptom during the study period and many reported at least two (53/126, 42.1%) or three (37/126, 29.4%) symptoms (Table 6). However, only 41 of 126 (32.5%) trainees received a viral test for COVID-19 during the study period and even fewer (20/126, 15.9%) were tested for antibodies.

TABLE 4 Comparison of United States and international trainee experiences during the early COVID-19 pandemic

	USA (N = 45) n/N (%)	International (N = 81) n/N (%)	p Value
Senior trainees	37/45 (82.2)	64/81 (79.0)	.817
Male	31/45 (61.9)	62/81 (76.5)	.400
Enrolled in integrated cardiothoracic surgery training programs	21/45 (46.7)	52/81 (80.2)	.062
Post-graduate year, mean ± standard deviation	6.7 ± 1.9	6.9 ± 3.4	.709
Time lost in the hospital			
Lost any time in the hospital	34/45 (75.6)	48/81 (59.3)	.080
Lost more than 7 days in the hospital	28/45 (62.2)	39/81 (48.1)	.141
Lost time on cardiothoracic-related rotations	37/45 (82.2)	54/81 (66.7)	.066
Reassigned to work in COVID-19-specific units	9/45 (20.0)	23/81 (28.4)	.394
Originally scheduled to be on surgical rotations	43/45 (95.6)	73/81 (90.1)	.493
Experienced any reduction in case volume	42/43 (97.7)	58/73 (79.5)	.005
Case volume was reduced by 50% or more	25/43 (58.1)	38/73 (52.1)	.567
Operative experience was essentially eliminated	9/43 (20.9)	18/73 (24.7)	.820
Expect to be unable to meet, or increased concern regarding ability to meet training/graduation requirements	8/45 (17.8)	40/81 (49.5)	.001
Concerned/expect that inability to meet clinical requirements will delay advancements in training and/or graduation	6/8 (75.0)	21/40 (52.5)	.437
Overall clinical acumen (nonoperative) and ability to treat patients			
Declined	3/45 (6.7)	19/81 (23.5)	.026
No change	35/45 (77.8)	56/81 (69.1)	.407
Improved	7/45 (15.6)	6/81 (7.4)	.220

Among these, 3 of 41 (7.3%) had a positive viral test and 2 of 20 (10%) had confirmed antibodies. All trainees with a positive viral test or confirmed antibodies reported that they had experienced symptoms related to COVID-19, although neither of the trainees who developed antibodies had received a prior viral test. There was no difference in symptoms, testing rates, or testing results among junior and senior trainees or US and international trainees.

In total, 41 of 126 (32.5%) respondents self-quarantined during the study period. Most of these individuals (36/41, 87.8%) were required to quarantine due to illness or exposure to COVID-19 (Table 6). Few respondents indicated that they had considered self-quarantining but ultimately chose not to because they felt that their symptoms were either minor (10/126, 7.9%), or because they felt compelled to keep working and/or were concerned about their perception among colleagues (4/126, 3.2%).

4 | DISCUSSION

In an attempt to better understand how COVID-19 has affected the specialty of CTS, a variety of surveys have been distributed to cardiac surgery units,¹ program directors,⁷ and even some patients.⁸

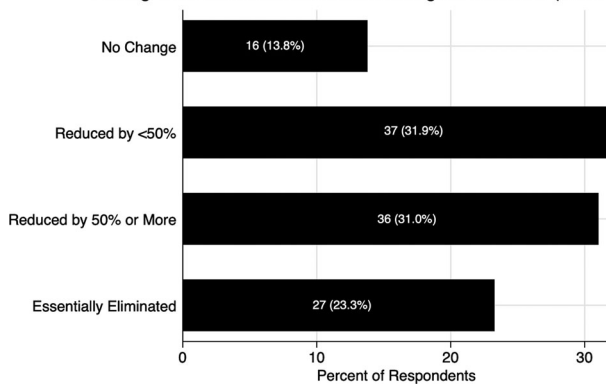
However, despite persistent concerns about the potential implications of COVID-19 on CTS education,⁹ the degree to which CTS trainees have been affected by the pandemic has been incompletely characterized. Acknowledging an early national survey by Caruana et al.⁵ analyzing the experiences of CTS trainees in the United Kingdom, our investigation is the first to evaluate the global impact of the COVID-19 pandemic on CTS education from the perspective of both US and international trainees.

4.1 | Diminished clinical and operative experiences in CTS during COVID-19

Underscoring the extent to which CTS training has been impacted by COVID-19, our results suggest that half of CTS trainees lost more than a week of clinical experiences as a direct result of the pandemic and a striking number (~15%) were absent for more than a month. Similarly, more than half of CTS trainees reported at least a 50% reduction in their operative case volumes since the onset of the pandemic, including almost a quarter of trainees who felt that their operative experience had been essentially eliminated.

TABLE 5 Comments from cardiothoracic surgery trainees regarding the effects of the COVID-19 pandemic on their education

I will probably meet my case requirement, but things are just now getting really bad where I train.
COVID-19 has substantially harmed my quality of training in ways not captured in this survey.
I could not complete my procurement numbers as COVID-19 restricted recoveries.
I really miss the wealth of knowledge that we enjoyed receiving from our senior colleagues.
COVID-19 has negatively affected cardiothoracic surgical training by reducing theater staff strength, especially after exposure to a COVID-19 positive patient.
I am losing valuable time in the operating room that would allow me to fine tune operative decision making, which I feel at times is more important than being able to suture.
The reduction in my case load has been significant. There has been an increase in call duties resulting from a decrease in available house staff.
Online conferences and increased research productivity have actually been beneficial.
We were denied from learning all airway procedures in the intensive care unit, even among patients without COVID-19.

Operative Experience and Case Volume Reduction Among Trainees Scheduled to be on Surgical Rotations (N=116)**FIGURE 3** Changes in operative experience among cardiothoracic trainees scheduled to be on operative rotations (N = 116) during the early phase of the COVID-19 pandemic

In many respects, our results corroborate the findings of other recent CTS-related surveys.^{1,5,7} For example, an international survey by Gaudino et al.¹ suggested that only about half of CTS institutions allowed trainees to perform cases early on in the pandemic, whereas a similar number of programs mandated trainees to stay home unless they were on call or in critical need. These authors also reported that institutional cardiac surgery case volumes declined by an average of 50%–75% during the pandemic and that a third of programs had reduced the number of dedicated cardiac operating rooms by at least a 50%. Meanwhile, a survey of CTS program directors in the United States by Cohan et al.⁷

TABLE 6 Preparation for the pandemic and exposure to COVID-19

	Overall (N = 126)
Felt prepared by training program for COVID-19	
Poorly prepared	13/126 (10.3)
Underprepared	24/126 (19.0)
Adequately prepared	82/126 (65.1)
Excessively prepared	7/126 (5.6)
Provided direct care to patients with COVID-19	
87/126 (69.0)	
Presence of COVID-19 symptoms	
At least one symptom	63/126 (50.0)
Two or more symptoms	53/126 (42.1)
Three or more symptoms	37/126 (29.4)
Had a viral test for COVID-19	
41/126 (37.3)	
Positive result for COVID-19 infection	
3/41 (7.3)	
Had a COVID-19 antibody test	
20/126 (15.9)	
Antibodies present for COVID-19 immunity	
2/20 (10.0)	
Quarantine	
Never required or wanted to quarantine	71/126 (56.3)
Required to quarantine	36/126 (28.6)
Elected to quarantine	5/126 (4.0)
Considered/wanted to quarantine, but elected not to	14/126 (11.1)

reported that ~70% of programs implemented alternative staffing strategies in which trainees were scheduled to be on- and off-service for 1- or 2-week blocks at a time, while noting that approximately half of CTS program directors anticipated that resident case volumes would decline as a result of the COVID-19 pandemic. Caruana et al.⁵ also observed a reduction in operative case volumes among CTS trainees in the United Kingdom, reporting that the number of cases in which trainees served as the primary surgeon declined from ~26% to ~13% when comparing experiences before and during the earliest months of the COVID-19 pandemic, respectively. Although the overall reduction in cardiac surgery cases during the COVID-19 pandemic certainly accounted for a substantial decline in case volumes among CTS trainees, others have also suggested that this effect was compounded by the cancellation of elective and nonurgent surgeries, which inflated the relative case load of challenging and high-risk operations and therefore further diminished operative opportunities for CTS trainees.^{6,8}

4.2 | Trainee perceptions of COVID-19-related educational disruptions

Despite these unanticipated disruptions, most trainees did not believe that their overall clinical (i.e., nonoperative) acumen had been adversely affected by the pandemic, and fewer than half expressed

concerns about potential extensions in their training or delays in their graduation. Nevertheless, our results suggest that these concerns were significantly more common among international trainees (~50%) than US trainees (~20%). For comparison, Caruana et al.⁵ found that nearly 90% of CTS trainees in the United Kingdom worried about how the COVID-19 pandemic would ultimately impact their education, with 71% citing specific concerns about the possibility of having to extend their training.

The relative lack of concern among US trainees is somewhat surprising, but could reflect the degree to which CTS trainees felt reassured and supported throughout the earliest months of the COVID-19 pandemic. For example, we found that only ~10% of US trainees felt underprepared by their institutions for the pandemic, whereas approximately half of international trainees expressed this sentiment. In this respect, it is worth noting that Coyan et al.⁷ reported that the vast majority of CTS program directors in the United States (~80%) anticipated that their trainees would be able to graduate on time, and only a small minority (~17%) expected the pandemic to adversely affect the future performance of their graduating trainees. In contrast, ~70% of CTS trainees in the United Kingdom expressed early concerns about poor communication and a lack of clarity from educational leadership regarding how their training might ultimately be impacted by COVID-19.⁵

With these considerations, the relatively favorable responses among CTS trainees in the United States might reflect swift efforts by the country's leadership in graduate medical education and CTS training to address the concerns of trainees and program directors early in the pandemic while simultaneously recognizing that "the moral obligation of all physicians during the pandemic is to do their part in the treatment of its victims."¹⁰ For example, by April 2020, the American Board of Thoracic Surgery and Thoracic Surgery Directors Association acknowledged that CTS trainees would likely experience reductions in their operative case volumes as a result of the COVID-19 pandemic.¹¹ However, in doing so, they offered important reassurance that they intended to be flexible when considering any gaps in training requirements that might result from the pandemic, while also providing important guidance for trainees and programs that anticipated potential problems in meeting training requirements.

Additionally, the disproportionate concerns of international CTS trainees could also reflect broader differences in global healthcare administration and varying national responses to the COVID-19 pandemic. For example, some nations like the United Kingdom implemented a centralized model for delivering CTS early in the pandemic, in which all centers offering CTS-related services within a region were reconfigured so that care could be consolidated and delivered by only a few select institutions.^{6,8,12,13} As a result, some CTS trainees were confronted with the sudden discontinuation of all CTS-related services at their institutions.^{6,8,13} Recognizing how even well-intentioned policies can have unintended consequences that adversely affect CTS trainees, leaders in CTS education must remain fully transparent of ongoing discussions and decisions being considered in graduate medical education that could potentially impact the future of CTS training. Furthermore, to quell the anxieties of

some CTS trainees around the world that have understandably resulted from uncertainties about the fate of CTS education since the onset of the pandemic, it remains imperative for leaders in CTS education to make a concerted effort to clearly articulate how they plan to advocate on behalf of CTS trainees.

4.3 | The role of CTS trainees during the COVID-19 pandemic

Cardiothoracic surgeons and trainees are skilled in the management of critically ill patients and their broad competencies make them attractive candidates as "surge" personnel during times in which medical staff may be strained by the COVID-19 pandemic. Exemplifying this, we report that a significant number of survey respondents (17.5%) were fully trained and/or board-certified in general surgery, critical care, or other related specialties during the earliest months of the pandemic. Moreover, we importantly demonstrate that CTS trainees of all levels responded to early calls to action during the COVID-19 pandemic. Consistent with what has been reported by Gaudino et al.,¹ we found that approximately 25% of CTS trainees around the globe were redeployed to work in COVID-19-specific settings during the earliest months of the pandemic.¹ In addition, we provide new evidence that junior trainees (~50%) were more often reassigned to COVID-19-specific units than senior trainees (~20%). Although Caruana et al.⁵ reported that redeployment rates in the United Kingdom exceeded 50% for trainees in both the early- and late-stages of their education, this apparent discrepancy could be accounted for by the fact that the authors defined late-stage trainees as only those individuals who were in their penultimate/final years of training, whereas our study used PGY ≥ 4 to define senior trainees.

In any case, we found that almost a quarter of CTS trainees reassigned to COVID-19-specific units were redeployed to drive-thru or off-site COVID-19 testing stations. Although this demonstrates an important commitment to public health, placing CTS trainees in these positions does not leverage their full capabilities, which should be considered if future surges of the COVID-19 pandemic require CTS trainees to be reassigned to new roles.

4.4 | Effects of COVID-19 on CTS education and scholarly activity

Others have estimated that approximately half of cardiac surgery institutions suspended all research activities during the earliest months of the COVID-19 pandemic.¹ However, despite losing significant amounts of time in the hospital and in operating rooms, our results suggest that CTS trainees used this time productively, as more respondents indicated that their research activity increased rather than decreased as a result of the pandemic. Although several trainees (>10%) became directly involved in COVID-19-related research, this was less common than what has been reported previously.⁵ In any case, 25% of CTS trainees indicated that the pandemic impeded important opportunities for them to present their work at major academic meetings.

Our investigation also provides novel evidence from the perspective of CTS trainees that training programs made important efforts to adapt their educational curriculum early in the pandemic.⁷ Specifically, the vast majority of training programs continued educational meetings online or made other similar accommodations. Still, it seems that virtual interviews were relatively underutilized during the study period, which suggests that trainees who sought additional training or those entering the job market likely faced unique challenges and uncertainties early in the pandemic. However, we expect that these disruptions have since been mitigated to some degree as programs have continued expanding the use of virtual communications in academic medicine.¹⁴

Of note, most trainees did not feel the COVID-19 pandemic hurt their performance on high stakes exams, suggesting that early disruptions to routine educational activities did not have a significant adverse impact on academic performance, at least subjectively. Still, because many of the earliest shutdowns and quarantines were only beginning to take place when in-training or Board exams were administered, further investigations are needed to assess how the COVID-19 pandemic has objectively impacted academic performance.

4.5 | Limitations and future investigations

It must be underscored that this investigation does not quantify the impact of the COVID-19 pandemic on all CTS trainees worldwide. Despite substantial efforts to distribute the survey to international trainees through official CTS trainee organizations around the globe, some organizations were unable to formally administer the survey to all of their trainees and many countries lacked such organizations. Therefore, the study's sample group was largely driven by TSRA membership. Although the response rate was consistent with other recent surveys by the TSRA,¹⁵ it was relatively low (~22%) and does not reflect responses received from social media interactions, which could skew the survey response rate.

Additionally, our attempts to capture the cumulative perceptions and overall experiences of CTS trainees during the earliest months of the pandemic did not account for regional and/or time-specific variations in cases of COVID-19.¹ As such, response biases likely exist in the data. Specifically, trainees might have answered questions differently depending on where they trained and how their institutions responded to the pandemic, when they took the survey and/or to what extent their answers were influenced by their earliest and/or most recent training experiences during the COVID-19 pandemic. Similarly, some trainees may have been more or less inclined to participate in the survey depending on how many years of CTS training they had remaining, or whether they were in a predominately cardiac- or thoracic-track CTS program. With these considerations, further investigations are needed to evaluate how the experiences and perceptions of CTS trainees worldwide might have evolved (and may continue evolving) throughout the COVID-19 pandemic.

It must also be recognized that there are significant differences in CTS training programs both around the world and within the United States.¹⁶ Therefore, although the limited sample size of our study

population precluded further regional analyses of CTS trainees, this should be a focus of future investigations. As such, additional studies aiming to improve CTS training and education around the globe could benefit from the development of other national and/or regional CTS trainee organizations, for which this investigation provides an important step in fostering further national and international collaborations among CTS trainees.

5 | CONCLUSION

CTS trainees in the United States and abroad have been significantly impacted by the COVID-19 pandemic in the form of lost time in the hospital, decreased operative volumes, less time on CTS services, and frequent reassignment to COVID-19-specific care settings. The development and dissemination of best practices for CTS education under such unique circumstances as those encountered during the COVID-19 pandemic could improve the ways in which CTS trainees are utilized during the remainder of the COVID-19 pandemic, while continuing to meet educational benchmarks.

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CONFLICT OF INTERESTS

The authors declare that there are no conflict of interests.

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REFERENCES

- Gaudino M, Chikwe J, Hameed I, Robinson NB, Fremes SE, Ruel M. Response of cardiac surgery units to COVID-19: an internationally-based quantitative survey. *Circulation*. 2020;142(3):300-302.
- Garcia S, Albaghdadi MS, Meraj PM, et al. Reduction in ST-segment elevation cardiac catheterization laboratory activations in the United States during COVID-19 pandemic. *J Am Coll Cardiol*. 2020;75(22):2871-2872.
- El-Hamamsy I, Brinster DR, DeRose JJ, et al. The COVID-19 pandemic and acute aortic dissections in New York: a matter of public health. *J Am Coll Cardiol*. 2020;76(2):227-229.
- Fuller S, Vaporciyan A, Dearani JA, Stulak JM, Romano JC. COVID-19 disruption in cardiothoracic surgical training: an opportunity to enhance education. *Ann Thorac Surg*. 2020;110(5):1443-1446.
- Caruana EJ, Patel A, Kendall S, Rathinam S. Impact of coronavirus 2019 (COVID-19) on training and well-being in subspecialty surgery: a national survey of cardiothoracic trainees in the United Kingdom. *J Thorac Cardiovasc Surg*. 2020;160(4):980-987.
- Shafi AMA, Atieh AE, Harky A, Sheikh AM, Awad WI. Impact of COVID-19 on cardiac surgical training: our experience in the United Kingdom. *J Card Surg*. 2020;35(8):1954-1957.
- Coyan GN, Aranda-Michel E, Kilic A, et al. The impact of COVID-19 on thoracic surgery residency programs in the US: a program director survey. *J Card Surg*. 2020;35(12):3443-3448.

8. Harky A, Harrington D, Nawaytou O, et al. COVID-19 and cardiac surgery: a perspective from United Kingdom. *J Card Surg.* 2021;36(5):1649-1658.
9. Olive JK, Luc JGY, Cerqueira RJ, et al. The cardiothoracic surgery trainee experience during the coronavirus disease 2019 (COVID-19) pandemic: global insights and opportunities for ongoing engagement. *J Thorac Cardiovasc Surg.* 2020;161(1):178-183.
10. Potts JR III. COVID-19: special communication to surgical program directors, including case log guidance. ACGME. 2020. <https://acgme.org/Portals/0/Documents/COVID-19/SurgCOVID19LTC.pdf>. Accessed January 6, 2021.
11. Thoracic Surgery Directors Association. TSDA response to COVID-19 impact on trainee case log requirements. TSDA. 2020. https://tsda.org/wp-content/uploads/2020/04/TSDA-COVID-Memo-4_9_20_Draft-3.0.pdf. Accessed January 6, 2021.
12. Bonalumi G, di Mauro M, Garatti A, Barili F, Gerosa G, Parolari A. Italian Society for Cardiac Surgery Task Force on COVID-19 pandemic. The COVID-19 outbreak and its impact on hospitals in Italy: the model of cardiac surgery. *Eur J Cardiothorac Surg.* 2020;57(6):1025-1028.
13. Harky A, Chen R, Pullan M. Examining the impact of COVID-19 on cardiac surgery services: the lessons learned from this pandemic. *J Card Surg.* 2020;35(9):2364-2366.
14. Antonoff MB, Mitzman B, Backhus L, et al. Society of Thoracic Surgeons (STS) Virtual Conference Taskforce: recommendations for hosting a virtual surgical meeting. *Ann Thorac Surg.* 2021;111(1):16-23.
15. Chow OS, Sudarshan M, Maxfield MW, et al. National survey of burnout and distress among cardiothoracic surgery trainees. *Ann Thorac Surg.* 2021;111(6):2066-2071.
16. Nissen AP, Smith JA, Schmitto JD, et al. Global perspectives on cardiothoracic, cardiovascular, and cardiac surgical training. *J Thorac Cardiovasc Surg.* 2021;161:168-174.

SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

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