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Covid-19 Clinical Research

Dissecting the Management and Outcomes of Thoracic Aortovascular Disease During the COVID-19 Pandemic

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Objective: The COVID-19 pandemic has forced the cancellation of planned surgery and led to significant surgical service reductions. Early intervention in aortovascular disease is often critical and cannot be deferred despite these reductions. There is urgent need to evaluate the provision and outcomes of thoracic aortovascular intervention during the peak of the pandemic.

Methods: Prospective data was collected for patients receiving open and endovascular thoracic aortovascular intervention over two-time points; January-May 2020 and January-May 2019 at three tertiary cardiovascular centres. Baseline demographics, cardiovascular risk and COVID-19 screening results were noted. Primary outcomes were median length of intensive care unit and hospital stay, intra-operative mortality, 30-day mortality, post-operative stroke, and spinal cord injury.

Results: Patients operated in 2020 (41) had significantly higher median EuroSCORE II than 2019 (53) (7.44 vs. 5.86, $P=0.032$) and rates of previous cardiac (19.5% vs. 3.8%, $P=0.019$), aortic (14.6% vs. 1.9%, $P=0.041$), and endovascular (22.0% vs. 3.8%, $P=0.009$) intervention. There was an increase in proportion of urgent cases in 2020 (31.7% vs. 18.9%). There were no intra-operative deaths in 2020 and 1 in 2019 ($P=1.00$). There were no significant differences ($P \geq 0.05$) in 30-day mortality (4.9% vs. 13.2%), median intensive care unit length of stay (72 vs. 70 hr), median hospital length of stay (8 vs. 9 days), post-operative stroke (3 vs. 6), or spinal cord injury (2 vs. 1) between 2020 and 2019 respectively.

Conclusions: Despite the increased mortality risk of patients and urgency of cases during COVID-19, complicated by the introduction of cohorting and screening regimens, thoracic aortovascular intervention remained safe with comparable in outcomes to pre-COVID-19.

Conflict of Interest: None.

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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Abbreviations: MI, myocardial infarction; ICU, intensive care unit; SOP, standard operating procedure; NYHA, New York heart association; CAD, coronary artery disease; LVEF, left ventricular ejection fraction; NCEPOD, national confidential enquiry into patient outcome and death; SCI, spinal cord ischaemia; AGP, aerosol generating procedure.

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INTRODUCTION

The SARS-CoV-2 disease (COVID-19) pandemic has pressurized healthcare systems and presented unforeseen challenges for healthcare. In anticipation of the predicted surge of patients, the National Health Service optimized patient pathways and guidelines to increase resources

Ann Vasc Surg 2021; 75: 120–127

<https://doi.org/10.1016/j.avsg.2021.04.008>

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Manuscript received: February 16, 2021; manuscript revised: April 8, 2021; manuscript accepted: April 13, 2021; published online: 24 April 2021

availability. Elective operations were cancelled, and patients discharged where possible.

In reality, total Emergency Department attendances dropped in April 2020 to 689,720 compared with 1,330,825 the previous year¹. This is likely explained by the psychological impact of nationwide lockdown and fear of contracting the COVID-19 forcing patients to avoid attendance. This is reflected in the data for myocardial infarction (MI) and stroke presentations across Europe and the United States, which have been noted to be reduced by between 40–90%² and 30%³, respectively. The reduction in presentation of cardiovascular pathologies are concerning as there may be a long-term morbidity consequence perhaps reflected in the Office for National Statistics data showing that the increased death rate observed in the UK was not fully explained by patients dying with a positive COVID-19 test⁴. Patients not seeking medical advice despite acute, life-threatening pathologies are likely to be contributing to this.

Aorto-vascular disease, particularly acute pathologies, can carry a high mortality and warrant urgent management. In theory these conditions should present as the same rate irrespective of the COVID-19 pandemic. Alterations to admission pathways and patient fears could result in delayed presentation, and this coupled with the management changes forced by service alterations could lead to increased mortality.

Three tertiary referral centers, dealing with the resource restrictions that COVID-19 placed on our intensive care unit (ICU) capacity and staff, and the unknown risk of COVID-19 peri-operatively, this study reviews the outcomes from this period and compares to a similar time period not in the COVID-19 era for the major thoracic aortic service that is provided to the North East of England. This is particularly pertinent as the North-East had the highest rate of COVID-19 infection in England⁵.

MATERIALS AND METHODS

All adult patients undergoing open or endovascular intervention for thoracic aortovascular disease at three regional tertiary centers were identified with consent for data collection obtained pre-operatively. Aortovascular pathologies included acute dissection (including intra-mural haematoma and penetrating arterial ulcer), all thoracic aneurysms and pseudoaneurysms, thoracoabdominal aneurysm and thoracic aortic trauma. Primary data collection occurred during

the COVID-19 peak in the UK (January-May 2020) and the second was a comparator group from the previous year (January-May 2019) from COVID-19 screening policy and hospital wide COVID-19 standard operating procedure (SOP) implemented during the period of data collection at both hospitals.

Data was prospectively collected from electronic patient databases. This included baseline demographics including age, gender, smoking status, and significant past medical history (including previous cardiac or aortic intervention). Patient mortality risk was assessed by EuroSCORE II⁶. EuroSCORE II describes a logistic model using pre-operative factors that describe patient co-morbidity and complexity to generate a predicted post-operative mortality score (Fig. 1)⁷. Cardiovascular status including New York Heart Association (NYHA) functional classification⁸, presence of coronary artery disease (CAD) and left ventricular ejection fraction were noted. Presenting aortic pathology and intervention for each patient was collected. Admission priority was also recorded, with emergency defined as requiring immediate operation on day of admission, urgent requiring intervention during the same admission, and elective patients admitted from home for a planned procedure. Testing for SARS-CoV-2 infection was performed as per local hospital policy and results noted for the 2020 group. Broadly, testing of oro- and naso-pharyngeal swabs were based on viral RNA detection by quantitative RT-PCR. After the introduction of SOPs, patients were screened pre-operatively where possible and if they developed symptoms suspicious of COVID-19, including pyrexia, dry cough, and myalgia. Operation urgency was classified according to the National Confidential Enquiry into Patient Outcome and Death (NCEPOD)⁹ n classification.

Primary outcome was 30-day post-operative mortality. Secondary outcomes included median length of ICU stay, median hospital length of stay, intra-operative mortality, presence of post-operative stroke and spinal cord ischaemia (SCI), need for re-operation/return to theatre/bleeding, mesenteric ischaemia or gastro-intestinal bleeding, new renal failure, and wound infection. Patient outcomes in those diagnosed with COVID-19 are described individually.

Statistics are described as mean (standard error of the mean, SEM) or median (interquartile range, IQR) as appropriate. Prism (ver. 8, GraphPad) was used to perform unpaired *t*-test and fisher's exact test for continuous and categorical data,

EuroSCORE II⁶

Pre-operative Factor				
Patient sex	Male		Female	
Patient age	Continuous variable (18-95 years)			
Creatinine clearance (ml/min)	>85	51-85	<51	Dialysis
Extracardiac arteriopathy	Yes		No	
- Claudication				
- >50% carotid stenosis				
- Amputation for arterial disease or planned intervention on aorta, limbs, carotid				
Poor mobility	Yes		No	
- Severe impairment secondary to Musculo-skeletal or neurological dysfunction				
Previous cardiac surgery	Yes		No	
Chronic lung disease	Yes		No	
- With steroid or bronchodilators use				
Active endocarditis	Yes		No	
Critical pre-operative state	Yes		No	
- VF/VT, ventilated, cardiac massage				
- Intra-aortic balloon pump or inotropes				
Diabetes on insulin				
New York Heart Association (NYHA) Class	I	II	III	IV
Angina at rest (CCS class IV)	Yes		No	
Left ventricular ejection fraction	>50%	31-50%	21-30%	<21%
Recent myocardial infarction	Yes		No	
Pulmonary artery systolic pressure (mmHg)	>55	31-55	>55	
Urgency of intervention	Elective	Urgent	Emergent	Salvage
Thoracic aortic surgery	Yes		No	
Procedure	- Isolated coronary artery bypass grafting (CABG)			
(1 procedure = CABG, valve intervention, replacement one part of aorta etc.)	- Single procedure – non-CABG			
	- Two procedures			
	- Three or more procedures			

Fig. 1. EuroSCORE II – All patients have their risk of mortality calculated via their EuroSCORE II using the listed pre-operative factors⁶.

respectively, with Mann-Whitney U test used for non-parametric data. Results with $p \leq 0.05$ were considered statistically significant. Significance in tables is denoted by * $p < 0.05$ and ** $p < 0.01$. Reporting is in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology Statement guidelines¹⁰.

RESULTS

Forty-one patients received intervention for thoracic aortic disease between January and May 2020 during the COVID-19 pandemic period (21 emergency and urgent, and 20 elective cases). This was a reduction from 2019 where 53 patients received intervention (21 emergency and urgent, and 32 elective cases) ($P = 0.14$). Mean patient age was 66.3 (2.1) in 2020 and 65.7 (2.1) in 2019 ($P = 0.86$). Twenty-eight (68.3%) patients

were male in 2020, compared with 35 (66.0%) in 2019 ($P = 0.99$). There were no significant differences between the groups with regards to co-morbidity. Patients had a significantly higher median EuroSCORE II in 2020 of 7.44 (12.9) compared with 5.86 (4.2) in 2019 ($P = 0.032$). Patients operated on in 2020 had significantly higher rates of previous cardiac surgery (19.5% vs. 3.8%, $P = 0.019$), previous aortic surgery (14.6% vs. 1.9%, $P = 0.041$), and previous endovascular intervention (22.0% vs. 3.8%, $P = 0.009$). There were similar rates of CAD, previous MI (including percutaneous coronary intervention (PCI)) and pre-operative arrhythmia within the groups. Pre-operative NYHA scores and left ventricular function were comparable between the groups (Table I).

There were no statistical differences in presenting pathology between the two groups, with the

Table I. Baseline demographics and cardiovascular risk assessment.

	2020	2019	P value
Mean age	66.3 (2.1)	65.7 (2.1)	0.86
Male sex (%)	28	35	0.99
Hypertension	30	32	0.27
COPD	5	11	0.41
Diabetes mellitus	3	3	1.00
Diet controlled	0	0	
Oral medication	3	2	
Insulin dependent	0	1	
Smoking history			
Ex-smoker	8	20	0.07
Current smoker	4	8	0.54
Dyslipidaemia	14	20	0.67
Median euroscore II (IQR)	7.44 (12.9)	5.86 (4.2)	*0.03
NYHA classification			
1	17	23	
2	6	11	
3	5	10	
4	6	3	
1–2	23	34	0.68
3–4	11	13	1.00
CAD	9	11	1.00
Previous MI (PCI)	8 (1)	4 (2)	0.13
ECHO			
>50% EF	20	27	1.00
30–50% EF	10	9	0.44
<30% EF	4	5	1.00
Pre-operative cardiac rhythm			
Sinus	28	40	
AF/Flutter	6	6	
PPM	0	1	
Bicuspid aortic valve	13 (29)	9 (35)	
Previous cardiac surgery	8	2	*0.019
Previous aortic surgery	6	1	*0.041
Previous endovascular	9	2	**0.009

CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; ECHO, echocardiography; EF, ejection fraction; MI, myocardial infarction; NYHA, New York Heart Association; PCI, percutaneous coronary intervention.

majority of patients presenting with either thoracic aneurysm or dissection in 2020 (63.4% and 19.5%) and 2019 (75.4% and 20.7%). There was an observed reduction in elective work in 2020 with 20 elective cases performed compared with 32 in 2019. The rates of urgent (31.7% vs. 18.9%) and emergency cases (19.5% vs. 20.8%) showed no significant difference between 2020 and 2019, despite an observed increase in raw numbers of urgent cases performed in 2020 (Table II). Median time from admission to surgery was 1 (5) day in 2020 and 1 (2) day in 2019 ($P=0.84$). The interventions performed in each group are outlined in Table III.

Elective patients who did not meet updated covid-19 size guidelines for aortic intervention¹¹

had their operation delayed in order to minimize their risk of peri-operative covid-19. None of these patients who remained on waiting lists developed an acute aortic syndrome or died awaiting intervention.

Thirty-day mortality rate was 4.9% (2) in 2020 versus 13.2% (7) in 2019 ($P=0.17$). Median ICU length of stay in 2020 was 72 (97.7) hr versus 70 (130.1) hr in 2019 ($P=0.98$). Median hospital length of stay was 8 (3.4) days in 2020 versus 9 (3.9) days in 2019 ($P=0.88$). There were no intra-operative deaths in 2020 and 1 (1.9%) in 2019 ($P=1.00$). Only 3 patients developed a post-operative stroke in 2020 compared with 6 patients in 2019 ($P=0.73$). Two patients had a post-operative SCI in 2020, one patient

Table II. Presenting pathology, urgency of intervention, and approach.

	2020	2019	<i>P</i> value
Admission			0.30
Elective	20	32	
Urgent	13	10	
Emergency	8	11	
Acute aortic syndrome	11	13	0.82
Pathology			
Dissection	8	11	
Aneurysm	26	40	
IMH	0	1	
Pseudo-aneurysm	3	1	
Aneurysm + dissection	2	0	
Dissection + IMH	2	0	
PAU + IMH	2	0	
Extent of disease			
Root	7	11	
Ascending thoracic	10	14	
Arch	3	6	
Descending thoracic	5	6	
TAAA	10	10	
Approach			
Open	29	35	
Endovascular	12	18	

IMH, intramural haematoma; PAU, penetrating atherosclerotic ulcer; TAAA, thoraco-abdominal aortic aneurysm.

Table III. Thoracic aortic Interventions performed.

	2020	2019
Aortic root replacement	0	8
Aortic root replacement + AVR		
Biological	3	5
Mechanical	1	4
Ascending aorta replacement	4	5
Ascending aorta + aortic root replacement	8	6
Ascending aorta replacement + AVR		
Biological	7	6
Mechanical	7	4
Including arch replacement	4	6
Hemiarch	0	2
Including FET	3	3
Descending thoracic aorta		
Open	1	1
Endovascular	13	18
TAAA repair	3	10

AVR, Aortic valve replacement; FET, frozen elephant trunk; TAAA, thoraco-abdominal aortic aneurysm.

developed a paraplegia and one a paraparesis, both patients had partial recovery of symptoms. In 2019, only 1 patient developed paraplegia but experienced no recovery ($P=0.58$). There were no significant differences in the post-operative

complication secondary outcomes as outlined in [Table IV](#).

DISCUSSION

Patients presented during the pandemic for thoracic aortovascular intervention with increased urgency and mortality risk, with an associated reduction in elective cases. Outcomes remained similar to 2019 in 2020, despite the demonstrated increased patient mortality risk (EuroSCORE II 7.44 vs. 5.86, $P=0.032$). The increased risk is likely explained by the higher rate of redo and urgent procedures compared to first time and elective operations in 2019. Redo procedures are normally associated with worse outcomes¹² however the gap appears to be closing, particularly in higher volume centres¹³.

Mortality and length of stay outcomes were similar between the two time periods. There were no significant differences in post-operative events including re-exploration, re-intubation and cardiac, renal, or neurological complications ([Table IV](#)). Therefore, despite being a higher risk group of patients, patients operated during the COVID 19 had comparable outcomes. There are likely multiple factors contributing to this. Our units were prepared to re-deploy staff to critical care areas, but due to protected green areas and resource management did not require to do so. This resulted in on hand consultant surgeons, anaesthetic and intensive care doctors with heavy involvement in pre- and post-operative care, possibly beyond standard pre-COVID-19 levels. This enabled patients to have involved care with prompt response to evolving complications. Additionally, rigid COVID-19 screening programmes and patient isolation and cohorting SOPs were developed to keep patients safe throughout their admission.

The noted drop in case volume in 2020 was not unique to our centers. UK aortic dissection presentation rates reduced by 53% and repair rates reduced by 88.2% after instigation of lockdown in March 2020¹⁴. This was reflected in the US, with 11 hospitals in New York having a reduction from 12.8 cases per month to 3 ($P=0.007$)¹⁵. Where these acute aortic syndrome patients have gone is not clear. However, there has been an eight to ten-fold increase in overall at home mortality noted during the pandemic of all causes. This suggests that it is a decreased presentation to hospital and not incidence of acute, life threatening pathologies that is to blame. It is possible that non-diagnosed acute aortic syndromes are contributing to this increased rate in at home mortality and explains some of the reduction in acute presentations. There are

Table IV. Post-operative complications.

	2020	2019	P value
Re-intubation	1	7	0.13
Tracheostomy	3	0	0.08
Chest re-opening/bleeding/return to theatre	0	3	0.25
GI Bleeding	2	1	0.58
Mesenteric ischaemia	1	0	0.44
New post-operative stroke			0.46
Permanent	1	3	
Recovery	2	3	
Spinal cord Injury			0.58
Paraplegia + complete recovery	0	0	
Paraplegia + partial recovery	1	0	
Paraplegia + no recovery	0	1	
Paraparesis + complete recovery	0	0	
Paraparesis + partial recovery	1	0	
Paraparesis + no recovery	0	0	
Post-operative MI	0	0	1.00
Renal failure			
Not requiring dialysis	9	5	0.14
Temporary dialysis	2	3	1.00
Permanent dialysis	0	0	1.00
Post-operative arrhythmia			
AF	13	12	
CHB	2	3	
VT/VF	1	0	
Wound infection	2	1	0.58

MI, myocardial infarction.

likely multiple reasons for this including fear of presenting to hospital and contracting COVID-19, delays in emergency response resulting in death before ambulance arrival and inability to access diagnostic computed tomography scans that were reserved for COVID-19 patients. Additionally, with the increased risk of post-operative complications in COVID-19 disease¹⁶, there was a reduced enthusiasm and confidence to offer patients surgery on an elective basis¹⁷, contributing to the risk of dissection in aneurysmal disease. However, with staff re-deployment to critical care areas and re-allocation of resources, maintaining elective work was not possible.

The trend in decreased overall elective aneurysmal work also reflects the increase in size criteria for intervention that were adopted both in the UK^{18,19} and internationally^{20,21} in addition to altered healthcare resource management. Fewer patients therefore met these revised thresholds. Where indicated, the recommendation internationally has been to continue employing endovascular techniques where possible¹⁹. As well as being recommended strategy this also has the benefit of minimize the precious critical care resource. Interestingly, despite this

recommendation, we have seen our endovascular numbers decrease by a third to 12 in 2020, and not increase as might be expected to meet demand.

Despite efforts, COVID-19 infection is not entirely avoidable. There have been multiple documented cases of COVID-19 positive patients undergoing complex aortic intervention²²⁻²⁷ as well as post-operative patients contracting COVID-19 with no adverse outcome²⁶. Timing of surgery is particularly important, particularly as up to 27.8% of COVID-19 inpatients have been found to have evidence of myocardial injury²⁸. It is imperative that this is considered on a case-by-case basis considering symptom severity, both cardiovascular and COVID-19 related, and urgency of intervention. In our cohort of patients, one tested positive preoperatively and surgery was postponed until they had recovered. They were monitored throughout in case deterioration warranted the surgery being expedited. A second patient became COVID-19 positive post operatively. Despite readmission to intensive care, they did not require re-intubation and made a good recovery. In this way, we were able to offer appropriate intervention to all patients in our region regardless of COVID-19 status.

The ever-changing national and international picture has made planning and implementation of aortovascular care guidelines difficult²⁹. It is therefore paramount that decisions are made on a case-by-case basis³⁰, involving multidisciplinary team discussions which themselves are not isolated from the effects of COVID-19 due to staff shortages or distance working. A reduction in elective work is good for critical care capacity but must minimize the risk of turning elective aortovascular patients into emergency presentations. We must move forwards as the situation improves with care, with sustainable pathways³¹. We will likely see a large backlog of delayed presentations as well as facing increasing waiting lists from patients delayed throughout the multiple peaks of the pandemic. Vaccination pre-operatively in elective cases should help minimize peri-operative COVID-19 risk, in addition to vaccination rate and herd immunity in the general public increasing. It is also possible that areas with low COVID-19 infection rates and green areas, like our own units, could be prioritized to keep operating and help reduce waiting lists whilst keeping risk to patients at a minimum.

Limitations

Our relatively low COVID-19 screening rate is secondary to the instigation of the regimens midway through the data collection period, with the study designed to describe the outcomes of thoracic aortovascular disease patients in a healthcare system learning to cope and evolve with the emerging pandemic. Finally, we did not have access to data regarding community deaths, although that in itself is unlikely to be entirely accurate during such times. Given observed changes in health-seeking behavior, it is likely that acute thoracic aortic pathology has been responsible for greater numbers of deaths than we currently appreciate.

CONCLUSION

Urgent and emergency thoracic aortovascular surgery can continue to be carried out safely where essential during these new normal times with very acceptable outcomes despite the associated increased risk. A rigorous system of appropriate PPE utilization, screening and isolation ensures the safety of patients and staff. Case-by-case decisions regarding suitability and timing of surgery for COVID-19 positive patients are also crucial. With multiple peaks expected across the world at varying times, waiting lists and the complexity of patients are expected to increase. Vaccination provides a

key tool in allowing elective surgery to re-start and limit at home mortality, but identification of clean units with ring fenced resources and staff offer a possible option to quickly reduce waiting lists whilst maintaining safety for patients.

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