The RCS England COVID-19 Surgical Research Group

early findings and lessons to influence surgical practice

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The RCS England COVID-19 Surgical Research Group: early findings and lessons to influence surgical practice

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ABSTRACT

Introduction Surgeons and allied professionals have been quick to respond to the need for evidence during the COVID-19 pandemic. The Royal College of Surgeons of England (RCS England) has provided formal recognition, support and guidance to all members of its interdisciplinary collaborative COVID Research Group (RCS CRG). We describe research conducted by members of this group, initial findings and lessons for clinical practice so far.

Methods Members of the more than 50 projects included so far in the RCS CRG portfolio were invited to provide a summary of their project and findings to date. The 26 summaries received were collated and broad themes identified to produce this summary document.

Results Wide-ranging projects have been conducted by members of the RCS CRG, rapidly yielding crucial insights into the behaviour of the SARS-CoV-2 pathogen, its impact on patients and staff, the challenges it presents to surgical practice and investigation into methods to adapt and overcome such challenges.

Conclusions The response of the surgical research community to COVID-19 has been rapid and well-organised. Early establishment of a formal network under the auspices of RCS England has assisted efficient research collaboration and delivery, while avoiding academic duplication between groups. This has led to a high research output, directly informing and substantially influencing practice throughout and beyond the pandemic.

KEYWORDS
Surgery – Coronavirus – COVID-19 – Surgical research

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Introduction

The COVID-19 pandemic has challenged the surgical research community like never before. Many ongoing research projects were rapidly halted, reflecting an instant cessation of normal elective activity and an increased need for new clinical duties from all available healthcare professionals, both fire-fighting to protect emergent and urgent patient care, and delivering specific SARS-CoV-2 care in support of other departments. At the same time, novel research has been desperately needed to provide understanding of a pathogen and disease that simply did not exist before, and required at a pace that outstrips all previous norms for research development and delivery as the pandemic unfolded rapidly.

The surgical community has been highly proactive in developing collaborative research networks across the past decade.[1] With the rise of collaborative research, the impact of geographical distance and boundaries has diminished and the feasibility of high-impact international research has become overtly apparent. Faced with a pathogen that discriminates between neither location nor medical specialism, the importance of geographically diverse interdisciplinary collaboration has been amplified substantially.

The need for isolation in attempts to 'contain' the virus has resulted in a rapid shift toward virtual interaction using electronic communication systems, presenting both benefits and challenges. One clear benefit has been the ability to transcend geographical boundaries and instantly bring relevant experts together to collaboratively develop, deliver and disseminate research to navigate immediate and future challenges presented by this pandemic, while minimising duplication of effort during this time-critical period. The Royal College of Surgeons of England (RCS England) was quick to lead in this respect, bringing together a group of surgical

*Members of the RCS COVID Research Group are listed in the Supplementary Information.

research experts as the pandemic began to unfold, to develop its RCS COVID Research Group (RCS CRG). Under the leadership of Professor Peter Hutchinson, and with active participation and integral support from the recently demitted RCS President, Professor Derek Alderson, the group has grown rapidly to encompass more than 50 research groups, supported and guided by RCS England. An open access approach was taken by the group, welcoming all interested parties to contribute. New projects were given the opportunity to attend and present a project summary at the beginning of each online meeting. RCS England and RCS CRG members responded as a community to help provide the support and collaboration needed for projects to flourish.

In this article, we summarise the activity of the RCS CRG thus far, under the broad headings of transmission and personal protective equipment (PPE), the direct impact of COVID-19 on patients as well as the indirect impact of COVID-19 on surgical services, and staff wellbeing and training (Table 1). We highlight the important findings from these studies and their current and potential impact on surgical practice.

Sharing early knowledge

As the effects of the COVID-19 pandemic began to unfold in the UK, it became clear that defining the 'enemy' would require more than simply looking to the literature for shared knowledge and experience and scientific work. This was exemplified by the Welsh Surgical Research Initiative, whose Operation COVID project began with a systematic review of the literature regarding operative best practice during the pandemic.[2] The group highlighted a paucity of evidence, comprising fewer than a dozen items, all experiential reports from East Asia. The absence of evidence served as a springboard for their international Delphi exercise to determine consensus best operative practice through early knowledge-sharing and expert opinion from around the world. Using novel methodology, the Operation COVID group utilised social media networks to streamline the development of 100 statements to populate a Delphi consensus process, completed by more than 300 international experts across all six WHO regions of the world.[3] Encouragingly, when the group used these statements to validate early guidance issued by professional organisations in Europe, the United States and Australasia, including that of the UK Surgical Colleges, greater than 90% consensus support was demonstrated.[4]

Another study contributing knowledge in this area is LOTUS C-19. This study from the Bristol Surgical Trials Centre, one of six RCS England-supported research hubs, involved interviews with surgeons in the UK and internationally, to understand the in-depth experience of operating theatre teams during the pandemic. The group sought to understand how surgical teams were required to respond urgently to the crisis by modifying tools and pathways, mitigating and managing service disruption and the rising backlog, and crucially, addressing mounting concerns about patient safety. To date, this study has highlighted wide variation in practice during the pandemic and a clear need for future research to optimise our response to the many resultant challenges.

Transmission and PPE

There has been widespread uncertainty regarding disease transmission and the behaviour of the virus, particularly in aerosol. In response, a group from Brighton and Sussex partnered with experts in aerosol science in the laboratory-based Mitigating Aerosol Transmission study, to explore the behaviour of SARS-CoV-2 within common aerosol-generating procedures, developing prototype devices to reduce aerosol generation and permit extraction of aerosols.

The University of Edinburgh interdisciplinary COVID-19 Airflow Research Group developed and tested a novel prototype, the Aerosol Extractor, to control an aerosol close to its source. Based on the experimental data, they developed mathematical models of the impact of the Aerosol Extractor on aerosol and droplet behaviour[5] and defined the minimum specifications for the Aerosol Extractor. In their COVID Airflow PPE study, the COVID-19 Airflow Research Group used a background-oriented schlieren technique to study various types of PPE and quantified the extent of backward and side-jet leakage around surgical masks, which is of particular relevance to team members operating in close proximity while wearing masks.[6] This work was reported in more than 18 countries with over 500 media reports.

The Antimicrobial Aerosol Study, another highly interdisciplinary collaboration between the University of Edinburgh and the University of the West of England, focuses on the optimum chemical and physical characteristics of a hypochlorous acid fog for air decontamination. Other studies contributing to this domain include SAFE-SURGERY and the COVID-19 PPE Challenge. SAFE-SURGERY is a laboratory-based prospective study, delivered by the PanSurg group (https://www.pansurg.org), using polymerase chain reaction swabs to assess the behaviour of SARS-CoV-2 within the peritoneal cavity. By providing information about the risk posed to staff and patients, this study has contributed to a return to minimally invasive and elective surgery. The COVID-19 PPE Challenge has been conducted by the NIHR Surgical MedTech group, a collaborative interdisciplinary group comprising healthcare and non-healthcare professionals. In its first month, the group responded to 68 submissions of real-world challenges, providing technology solutions and shortening translation pathways, to quickly impact upon patient care and protect healthcare workers during the pandemic.[7] Finally, this group is also studying the use of antimicrobial aerosols in dental and other clinical spaces.

Determining the longitudinal impact of COVID-19 on patients

There has been an urgent need to understand outcomes for patients undergoing surgery who are, or become,

Table 1 Details of the RCS COVID research group projects

Study name	Area of study	Design	Reach
Sharing early knowledge			
Operation COVID	Surgical practice	Systematic review and international Delphi consensus	International
LOTUS C-19	Surgical practice and staff wellbeing	Interview-based study	National
Transmission and personal protective equipment			
Mitigating aerosol transmission risk when treating COVID-19	Transmission of virus	Laboratory-based study	National
COVID Airflow PPE	Transmission of virus	Laboratory-based study	National
Aerosol Extractor	Transmission of virus	Laboratory-based study	National
Antimicrobial Aerosol Study	Transmission of virus	Laboratory-based study	National
SAFE-SURGERY	Transmission of virus	Laboratory-based prospective study	National
Surgical MIC COVID-19 PPE challenge	Transmission of virus and PPE	Questionnaire-based study	National
Determining the longitudinal impact of COVID-19 on patients			
COVIDSurg	Surgical outcomes	Prospective observational (cohort) study	International
HAREM	Management of acute appendicitis in adults	Longitudinal observational study	National
CASCADE	Management of acute appendicitis in paediatric patients	Longitudinal observational study	National
PREDICT	Emergency surgery outcomes	Multicentre observational (cohort) study	International
COVERT	Orthopaedic trauma	Observational study	International
UK CoTS	Orthopaedic trauma	Observational study	National
ORCA	Orthopaedic trauma	Observational study	International (Africa)
COVID Cleft	Cleft surgery	Prospective observational (cohort) study	International
COVIDSurg-Cancer	Oncology (pan surgery)	Cohort study	International
B-MaP-C	Oncology (breast cancer)	Audit	National
ReCap	Oncology (rectal cancer)	Cohort study	National
CovidNeuroOnc	Oncology (neuro-oncology)	Cohort study	National
COVID-CNSMDT	Oncology (neuro oncology)	Prospective survey-based study	National
ABC COVID-19	Surgical oncology	Survey-based study	National
RSTNCOVID	Oncology (skin cancer) and hand surgery	Cohort study	National
CHOLECOVID	Benign surgery outcome (cholecystitis)	Audit	International
COMS-UK study	Benign surgery outcome (obesity surgery)	Cross-sectional study	National
COVER	Benign surgery outcome (vascular surgery)	Prospective cohort study	National
COPE	Frailty	Observational study	International
Changes in practice in surgical services			
COVIDSurg initial guidance	Safe reintroduction of services	Guidance document	International
RSTNCOVID	Oncology (skin cancer) and hand surgery	Cohort study	National

(*Continued*)

Table 1 Continued

Study name	Area of study	Design	Reach
HAREM	Management of acute appendicitis in adults	Longitudinal observational study	National
CASCADE	Management of acute appendicitis in paediatric patients	Longitudinal observational study	National
ATAC-19	Disease effect	Case series	Regional
Staff wellbeing			
SSAFE	Staff wellbeing	Survey-based study	International
Global COST	Staff wellbeing	Survey-based study	National
LOTUS C-19	Surgical practice and staff wellbeing	Interview-based study	National
Training			
CONSULT	Training	Survey-based study	National
COVID STAR	Training	Survey-based study	National

infected with SARS-CoV-2. The COVIDSurg group was among the earliest responders and has quickly gained international renown, having launched their international observational studies with incredible pace of turnaround from concept to delivery. The initial COVIDSurg cohort study[8] was a large-scale international observational study capturing real-world data and sharing international experience to determine 30-day mortality among more than 1,100 patients with COVID-19 undergoing any surgery during the early part of the pandemic. This study found a 30-day mortality rate of 24% among patients with perioperative COVID-19, and 38% among the 51% of patients who experienced pulmonary complications. The study also identified male sex, age above 70 years, ASA grade 3–5, cancer, emergency and major surgery as risk factors for mortality. This early landmark paper was published in the *Lancet*, recommending postponement of all non-critical procedures during the height of the pandemic, as well as consideration of nonoperative treatment to delay or avoid the need for surgery. These findings have been hugely influential, informing future risk stratification, decision-making and the patient consent process. At the time of writing, more than 90 news outlets around the world have mentioned this paper.

Further work from COVIDSurg has evaluated several methods of protecting patients from the consequences of perioperative SARS-CoV-2 infection. For example, COVID-19-free surgical pathways, in which patients are segregated completely from hospital zones that treat COVID-19 patients, have been shown to reduce nosocomial transmission and pulmonary complications after elective surgery.[9] A strategy of preoperative swab testing to identify and delay surgery for pre-symptomatic infected patients has also been shown to reduce complications;[10] where surgery is postponed, a minimum of delay of 4 weeks has been shown to be of benefit.[11] Further work is ongoing to allow more accurate patient-level risk stratification with the application of machine-learning techniques.[12]

Finally, COVIDSurg has collaborated with the GlobalSurg network to conduct a global study exploring the impact of previous COVID-19 infection on the safety of subsequent surgery.[13] By December 2020, 15,000 surgeons from 116 countries had recruited almost 150,000 patients to this study, making it the largest global prospective collaborative study ever conducted. These data will also be used to update modelling studies from the Lancet Commission on Global Surgery and estimate the impact of COVID-19 on surgical services and patients worldwide.

Acute appendicitis is one of the most common surgical emergencies. The HAREM (Had Appendicitis and Resolved/Recurred Emergency Morbidity/Mortality) and CASCADE (Children with AppendicitiS during the CoronAvirus panDEmic) groups designed observational studies for adult and paediatric patients, respectively. These service evaluation studies aimed to capture data on practice and outcomes in appendicitis, crucially documenting deviation from normal practice in the management of acute appendicitis during the COVID-19 pandemic. The HAREM study suggested imaging should be routinely performed for acute appendicitis and antibiotic treatment is safe in the short term with long-term follow-up awaited.[14] Meanwhile, the CASCADE study demonstrated widespread and initially safe uptake of nonoperative management of appendicitis in children.[15]

Also in the field of emergency surgery is the PREDICT study. Delivered by the PanSurg group, this is an ongoing global pan-specialty multicentre cohort study aiming to quantify additional morbidity and mortality risk resulting from emergency workforce service provision models, coupled with the risks associated with the illness itself. Its outcomes are eagerly awaited.

Three studies in the RCS CRG focus on orthopaedic trauma. COVERT (COVID Emergency Related Trauma & orthopaedics) is an international observational study that has assessed referral patterns and workload during the pandemic, developing guidelines for elective orthopaedic

practice in alliance with professional bodies. Key findings include a significant initial drop in acute trauma and sports injury referrals, seemingly due to government lockdowns and social distancing. The group highlighted a greater appreciation, during the pandemic, of scenarios in which acceptable functional outcomes may be achieved with nonoperative management. UKCoTS (UK Corona Trauma Surgery) is a multicentre study comparing outcomes following trauma surgery performed at the peak of the pandemic across more than 50 UK hospitals with those from the same time in the previous year. This is anticipated to provide valuable information to guide future orthopaedic practice in the context of persistent background levels of SARS-CoV-2 infection, or indeed further spikes in case numbers. ORCA (Orthopaedic Research Collaborative in Africa) is a multicentre international observational study being delivered in Africa, which aims to capture the real-time effect of COVID-19 on orthopaedic trauma services across African health services.

Elective paediatric surgical care was suspended early in the pandemic and has only recently restarted. COVID Cleft is investigating the impact of SARS-CoV-2 on paediatric patients undergoing all types of cleft surgery, as well as the impact of wearing PPE during long operations that involve loupes, headlights or a microscope.

Beyond emergency care, the provision of oncological surgical services has been an area requiring urgent attention and action during the pandemic. The safety of urgent elective surgical interventions in patients with or at risk of COVID-19 was unknown. The COVIDSurg-Cancer study was conducted in parallel with the COVIDSurg cohort study, and focused on 30-day SARS-CoV-2 infection rates in elective cancer surgery during the pandemic, while also evaluating the effects of service disruption on cancer care. This large multicentre cohort study enlisted the participation of around 4,000 international collaborators, comprising data points on more than 45,000 patients around the world. Although their initial outcomes data have yet to be published, the group was quick to produce and disseminate important and worrying findings from their statistical modelling, including predictions that over 28 million operations will be cancelled or postponed during the 12 weeks of disruption globally, equating to approximately >70% of all operations. In the UK alone, the group calculated that more than 500,000 operations would be cancelled, creating a backlog that would require 11 months and 20% additional activity to clear, at a cost to the NHS of approximately £2 billion.[16] RCS England has drawn attention to these findings in attempts to ensure political support is available to overcome the far-reaching consequences and minimise any further impact as the peak passes and the virus continues to circulate. Together with the Faculty of Surgical Specialty Associations and other professional surgical bodies, RCS England has disseminated guidance for prioritisation during the 'restart'.[17]

The COVIDSurg group has also published guidance for reintroducing surgical services, encompassing strategies such as separation of COVID-19 'cold' and 'hot' centres with separate surgical care pathways, mandatory preoperative screening and self-isolation before and after surgery, where feasible. The B-MaP-C study (Breast cancer Management Pathways during the COVID-19 pandemic) is a national audit examining data from more than 2,400 patients to describe the management of newly diagnosed breast cancer during the pandemic. The study group plans to disseminate its findings imminently, including confirmation that safe oncological practice was maintained in breast surgery throughout the pandemic, impressively leading to minimal impact on long-term outcomes.

Another national study contributing to knowledge in oncology surgery in the UK is ReCaP (Rectal Cancer Provision), which aims to assess the long-term impact of multimodality management of rectal cancer during the pandemic and beyond. In particular, this study is working towards preparation for rectal cancer management during any further surges of COVID-19, with a view to minimising any future disruption to rectal cancer management.

There was a requirement to understand the impact of COVID-19 on the management and outcomes of newly diagnosed and recurrent neuro-oncology patients. The CovidNeuroOnc national cohort study (Outcomes of Neuro-Oncology patients during COVID-19), which has yet to report its observations on the effect of COVID-19 on management decisions in neuro-oncology, is being delivered by the British Neurosurgery Trainee Research Collaborative.

The COVID-CNSMDT (COVID-19 NeuroSurgery MDT) study is a national survey-based study assessing the impact of the pandemic on management of patients with brain tumour, based on changes in multidisciplinary team decision-making.[18] This study reported that one in ten patients had their treatment changed as a result of the pandemic. Most patients received nonsurgical treatment or no treatment at all. This was helpful in understanding changes in management that can be implemented during future phases of the pandemic.

The ABC COVID-19 (Addressing Barriers to Cancer management from COVID-19) study investigates diagnostic timelines in cancer, assessing the effects of the gap between demand and capacity in patients with cancer during the pandemic. This ongoing survey-based study aims to identify the issues contributing to the deficit and improve access to diagnostic testing and treatment by developing novel multidisciplinary pathways.

The Reconstruction Surgery Trial Network (RSTN) is delivering a project examining the delivery of skin cancer operations during the pandemic. This is one of five key areas being investigated by the group; the others are hand surgery, burns, lower limb trauma and steroid injections. Initial findings include a substantial decrease in skin cancer surgery, along with changes to the availability of standard treatment.

In the face of a completely unquantified and uncharacterised threat, healthcare systems across the world cut back, or completely stopped, elective surgery as the pandemic unfolded, as illustrated by the aforementioned modelling from the COVIDSurg group. Because the direct

care of patients with COVID-19, alongside efforts to sustain emergent and urgent surgery, have consumed most of the available resources, the implications for benign surgery have been profound. A number of studies have been developed to investigate these effects. CHOLECOVID is an international multicentre audit examining management of acute cholecystitis during the pandemic. Although the key findings are not yet available, this will provide a global perspective on the impact of new guidelines for disease management and inform the development of new guidance for the recovery phase and any potential future phases.

Also within benign surgical provision, the COMS-UK study (Impact of COVID-19 on Obesity Management Services in the United Kingdom), is a cross-sectional questionnaire-based study, which asked participants about modifications to obesity management services in the UK. This group has highlighted the importance of obesity as a risk factor for contracting COVID-19, and for morbidity and mortality if infected with the virus. This was concerning because nearly all (97.8%) elective bariatric surgery was stopped indefinitely from April 2020, and there is a clear need to restart services, likely with modifications to surgical pathways, such as those outlined by the COVIDSurg group.[16]

Within vascular surgery, the COVER group has led a prospective cohort study assessing short- and long-term outcomes for vascular patients during the COVID-19 pandemic, showing a major reduction in the availability of surgery for vascular patients, and higher postoperative mortality even without SARS-CoV-2 infection. This represents the loss of outcome gains achieved across the past 10 years regarding early intervention in vascular disease.

National Institute for Health and Care Excellence guidelines state that frailty is a useful prognostic tool[19] and the COPE group, an international multicentre observational study, has examined the utility of frailty measures during the pandemic. The group identified that frailty predicted survival in COVID-19.[20]

Changes in practice in surgical services

From the start of the pandemic it has been clear that surgical practice could not continue unaltered, and there was an immediate need for change in practice. The early action of the COVIDSurg group provided much sought after initial guidance, taking into account the very large number of operations projected to be cancelled or postponed, and the need for clear recovery plans and implementation strategies.[3] In addition, the consensus work from the OpCOVID group, including data validating the influential guidance issued by RCS England and other professional bodies, supported a coherent message for teams struggling to determine how best to deliver surgical services safely in the pandemic. In response to changes in surgical practice, some studies came up with procedure specific changes. COVID HAREM and CASCADE have demonstrated important safety data supporting alternative management strategies in appendicitis.[14,15] RSTNCOVID has shown that a greater proportion of hand surgery can be safely performed under local anaesthesia than had previously been standard practice, which may facilitate a shift of this workload to less resource-consumptive settings, without the need for general anaesthetic provision.[21]

Regarding the disease effect of COVID-19, the ATAC-19 (Acute mesenteric Thrombosis Associated with COVID-19) group has observed that medical management with treatment dose anticoagulation appears more effective than surgical treatment for patients presenting with acute mesenteric thrombosis secondary to COVID-19, which will lead to new guideline development.

Staff wellbeing

This pandemic placed an extraordinary demand on healthcare systems and services worldwide. The widespread changes to service delivery were made possible largely as a result of an immense and immediate response on the part of the healthcare workforce. However, numerous factors related to this vast team effort had potential to detrimentally influence staff wellbeing, with many being required to work additional hours, outside their comfort zone, often taking on extraordinary responsibilities, all in the face of an unquantified contagious threat to loved ones and self. To understand this issue in depth, the SSAFE (Staff and Safety Effects of Epidemics) group conducted an international survey, identifying a significant proportion of healthcare workers exhibiting symptoms of burnout, anxiety and depression during COVID-19. Another study providing understanding in this area was Global impact of COVID19 on surgeons and team members (Global COST) survey, which aimed to highlight any potential health impacts of the virus on the workforce and implement strategies to address this. The LOTUS C-19 study group, along with their other important findings, examined this area showing significant psychological impact on healthcare professionals working in the operating theatre.[22]

Training

To understand the impact of COVID-19 on surgical training and career progression, the CONSULT study group swiftly designed a UK-wide survey-based study and identified that only 40% of trainees felt they would be likely to progress to their next training year as planned, owing to cancellation of elective work or redeployment to other departments. Although trainees felt supported at work, there were concerns regarding lack of childcare and remuneration. The group found that, to mitigate further impact, deaneries and local trusts would need to apply an adaptive process that takes training into consideration. Another study sharing knowledge in this was COVID-19 impact on Surgical Training and Recovery planning (COVID STAR), a pan-specialty pan-grade national survey-based study conducted by the Association of Surgeons in Training. This study identified similar findings, with 40% of core and 20% of higher surgical trainees redeployed during the pandemic. A majority of responding trainees felt that their training was compromised by the cancellation of elective work and dual-consultant operating, likely leading to fewer

workplace-based assessments and possibly to unfavourable outcomes at their annual review. This study has influenced the Joint Committee on Surgical Training and other educational bodies to plan for the recovery phase of COVID-19 and future surgical training needs.

Discussion

COVID-19 placed surgeons in situations in which they needed to make decisions and deliver care, despite a dearth of evidence and no experience of delivering surgical care through a novel pandemic. There was a need for expedient, but scientifically robust answers; and a key approach was the rapid initiation of observational studies, with wide collaboration. RCS England set up the RCS CRG early in the pandemic and played crucial roles in coordinating research efforts, supporting and publicising studies to maximise collaboration and patient recruitment, as well as minimising duplication and research waste.

Uncertainties requiring investigation included the direct impact of COVID-19 on surgical patients, the indirect impact of treatment delays with unavoidable deviation from usual protocols, the impact on healthcare professionals of working in unfamiliar settings, the psychosocial effects of fear and uncertainty around best care for their patients and themselves, challenges of working while wearing PPE, and the substantial disruption to training.

Findings from the COVIDSurg cohort study, published early in the pandemic, reported a 24% 30-day mortality in patients with perioperative COVID-19 and identified male sex, age over 70 years, ASA grade 3–5, cancer, emergency and major surgery as risk factors for mortality, recommending postponement of all non-critical surgery at the height of the pandemic and the consideration of nonoperative treatment where possible.

A number of projects studied the impact of such nonoperative treatment, as well as the impact of disruption and delays to routine treatment pathways secondary to diversion of resources (staff, theatres, equipment) towards the COVID-19 effort. Thus, the data generated were unique and possibly unlikely to be generated in future, making it imperative that the surgical community reacted quickly to study these observational data to inform service planning during any further waves or the next pandemic.

The scale of the disruption to established treatment pathways is illustrated by the fact that, despite best efforts to prioritise urgent care, COVIDSurg-Cancer's models indicated that in the UK alone, more than 500,000 cancer operations would be cancelled during the pandemic.[25] At the time of writing, they calculated that it would require 11 months, 20% additional activity and a cost to the NHS of approximately £2 billion to clear the backlog. However, the ongoing pandemic and the second wave may mean these figures need to be revised upwards. Attempts to maintain timely access to newly diagnosed breast cancer treatment were audited in B-MaP-C, and ABC COVID-19 reported on the barriers to cancer management. Lessons from these studies will help guide planning during the further waves and future pandemics.

Non-cancer services were more severely affected. Some 97.8% of bariatric surgery was stopped indefinitely in April 2020 (COMS-UK) and there was a marked reduction in vascular surgery, with an increase in postoperative mortality even in patients without COVID-19. Postoperative mortality figures during the pandemic (even in patients not diagnosed with COVID-19) may need to be interpreted with caution, because it is possible that only the more severely ill patients were being operated upon, whereas surgery for with less-advanced disease was delayed.

All these unavoidable factors led to unprecedented changes to almost every aspect of surgical practice, constituting a series of 'natural experiments', many of which could not have been studied with a conventional randomised controlled trial (and indeed, many could not have been justified ethically). Therefore, the surgical community had a responsibility to learn as much as possible, as quickly as possible, from these 'natural experiments' with high-quality observational studies, ideally with widespread participation, to derive meaningful outcomes.

All study outcomes will help inform treatment during a future pandemic, or while dealing with mutant or more virulent strains of COVID-19, but interestingly, some also have implications for changes to routine surgical practice, having generated evidence to support a more conservative approach to the management of acute appendicitis in adults (HAREM) and children (CASCADE), a more conservative approach to orthopaedic trauma (UKCoTS), decreased use of general anaesthesia for hand surgery (RSTNCOVID) and the effectiveness of non-surgical management of acute mesenteric thrombosis associated with COVID-19 (ATAC-19).

Three international studies (SSAFE, Global COST and LOTUS C-19) reported on the adverse psychological effects of the pandemic on surgical team members, highlighting the high prevalence of psychological symptoms and the importance of appropriate support for surgical team members, both during and after the pandemic.

Surgical training was affected very significantly as a consequence of trainees being redeployed to help with the COVID-19 effort and secondary to the marked decrease in operative procedures. CONSULT and COVID STAR rapidly surveyed trainees and reported that the majority felt their training had been compromised. These studies were pivotal in influencing the Joint Committee on Surgical Training and training bodies in planning for and making changes to training during the pandemic.

A range of studies (Mitigating Aerosol Transmission, COVID Airflow PPE, Aerosol Extractor, Antimicrobial Aerosol Study and COVID-19 PPE challenge) demonstrated the value of interdisciplinary collaborations with aerosol scientists, fluid dynamicists, mathematicians, physicists, chemists, engineers and others, to address virus transmission and PPE-related challenges.

A number of common successes and limitations have emerged during the conduct of these projects thus far. Many project leaders described a welcome improvement in the timelines for processing applications for audit and research approvals. This reflects a great deal of hard work from researchers and the relevant research and development departments around the country in response to the pandemic. However, a small number of projects were hampered by the familiar slow-moving cogs of such processes. Another success was the impressive level of collaboration between departments, professions and nations. Examples of this include projects involving engineers, technology-based solutions and global participation. Without the ability to meet face-to-face, delays usually presented by the wait for physical meetings were avoided. The necessary implementation of technology, such as video conferencing, also facilitated the rapid pace and wide reach of collaboration, as well as dissemination of findings. Many projects found the need to adapt their protocols and delivery of projects in response to the quickly changing healthcare setting and developing understanding of SARS-CoV-2 to be a limitation. Another limitation, common to studies examining outcomes, was the necessary reliance upon short-term outcomes in lieu of long-term outcomes yet to come.

As such, the portfolio of work described herein will be important as we continue to move forward in surgical practice, adopting new ways of working to mitigate future transmission of SARS-CoV-2, but also ensuring greater preparedness for future strains and novel pathogens with potential to cause a pandemic. The group's work is ongoing and is anticipated to encompass prolonged research activity, coordinated by RCS England via the RCS CRG. Several areas clearly require long-term research, which this group will be well-positioned to deliver. Of particular importance to surgical practice are areas surrounding the reintroduction and expansion of services to catch up on lost surgical provision, follow-up of outcomes following unanticipated changes to practice, integration of novel successful approaches to optimise the provision of both acute and elective surgical services, ensuring staff wellbeing now and in the aftermath of the pandemic, and addressing training deficits resulting from service disruptions past, present and future. Details on how to contribute to the group's activity can be found on RCS England's website (https://www.rcseng.ac.uk/coronavirus/rcs-covid-research-group/) and interested parties are encouraged to make contact.

Conclusion

The RCS CRG has played a pivotal role in coordinating, supporting and improving recruitment to this rapidly developed and very broad portfolio of studies on surgical patients and surgical teams. Lessons learnt will not only inform surgical care during pandemics, but also provide evidence to change some pre-existing surgical protocols. The weekly meetings maintained momentum and were a unique opportunity for surgeons running research projects across the breadth of surgical specialities to learn from and support each other. This would not have occurred in the absence of the RCS CRG, which highlights the increasing importance of RCS England as surgery becomes increasingly sub-specialised.

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