

# Surgery during the COVID-19 pandemic: operating room suggestions from an international Delphi process

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**Background:** Operating room (OR) practice during the COVID-19 pandemic is driven by basic principles, shared experience and nascent literature. This study aimed to identify the knowledge needs of the global OR workforce, and characterize supportive evidence to establish consensus.

**Methods:** A rapid, modified Delphi exercise was performed, open to all stakeholders, informed via an online international collaborative evaluation.

**Results:** The consensus exercise was completed by 339 individuals from 41 countries (64.3 per cent UK). Consensus was reached on 71 of 100 statements, predominantly standardization of OR pathways, OR staffing and preoperative screening or diagnosis. The highest levels of consensus were observed in statements relating to appropriate personal protective equipment (PPE) and risk distribution (96–99 per cent), clear consent processes (96 per cent), multidisciplinary decision-making and working (97 per cent). Statements yielding equivocal responses predominantly related to technical and procedure choices, including: decontamination (40–68 per cent), laminar flow systems (13–61 per cent), PPE reuse (58 per cent), risk stratification of patients (21–48 per cent), open *versus* laparoscopic surgery (63 per cent), preferential cholecystostomy in biliary disease (48 per cent), and definition of aerosol-generating procedures (19 per cent).

**Conclusion:** High levels of consensus existed for many statements within each domain, supporting much of the initial guidance issued by professional bodies. However, there were several contentious areas, which represent urgent targets for investigation to delineate safe COVID-19-related OR practice.

\*Members of the Welsh Surgical Research Initiative (WSRI) Collaborative are co-authors of this study and are listed in *Appendix S1* (supporting information)

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## Introduction

The COVID-19 pandemic has all but stopped planned surgical treatment<sup>1</sup> as a result of hospital capacity constraints, and the swift recognition that COVID-19 poses an important danger to patients and healthcare professionals alike<sup>2</sup>.

Operating room (OR) practice, like many aspects of the response to COVID-19, has been driven predominantly by basic principles and shared experience, in the absence of a reliable evidence base<sup>3</sup>. Wide variation in practice is therefore predictable, and early clinical guidance is disproportionately reliant on the expert opinion of small committees<sup>4–8</sup>. Although beneficial in aligning early OR practice, such leadership cannot hope to integrate the perspectives of the wider medical community. Moreover, contemporary research methods appear of limited use

when confronted with serious, changing and evidence-poor states<sup>3</sup>. The aim of this study was to identify the knowledge needs of the global OR workforce, to characterize the available supporting evidence, and to establish consensus by means of a rapid modified Delphi process to inform safe surgical practice.

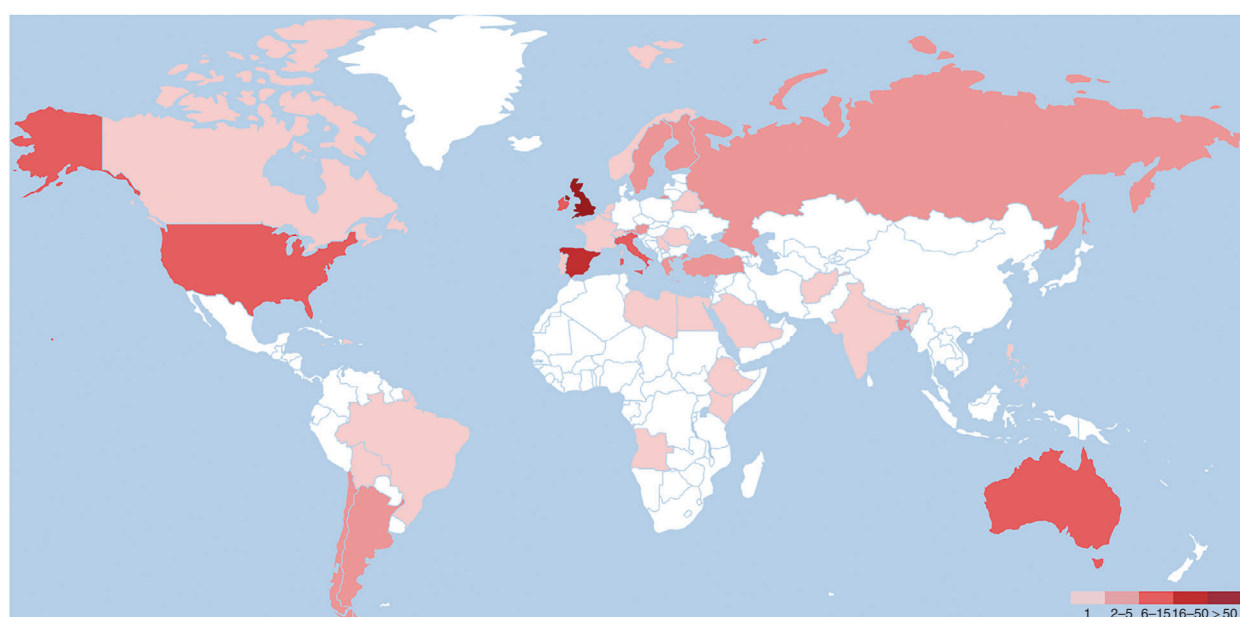
## Methods

Full details of the study design, methods employed and statistical analysis can be found in *Appendix S2* (supporting information). In brief, a collaborative evaluation process was undertaken using social media, informing the development of a series of statements in a single-phase Delphi exercise.

**Table 1** Specialty, grade and highest academic achievement of participants

Specialty	No. of participants	Grade	No. of participants	Highest academic achievement	No. of participants
Surgeon	279 (82.3)	Consultant/attending/equivalent	204 (60.2)	Doctorate	137 (40.4)
Anaesthetist/intensivist	29 (8.6)	Registrar/resident/equivalent	96 (28.3)	Masters	119 (35.1)
Other medical professional	15 (4.4)	Foundation/intern/core/senior house officer/equivalent	21 (6.2)	Bachelor	74 (21.8)
Nurse	9 (2.7)	Not known	18 (5.3)	Other professional qualification	6 (1.7)
Operating department practitioner	5 (1.5)			High school	3 (0.9)
Microbiologist/virologist	1 (0.3)				
Other non-medical professional	1 (0.3)				

Values in parentheses are percentages.

**Fig. 1** World map choropleth of Delphi consensus exercise participation

Numbers in the key represent Delphi participants.

## Results

### Phases I and II

Phase I generated 127 questions, which were rationalized to 104 questions for use in phase II (*Appendix S3*, supporting information). A total of 345 responses were received during phase II, and 108 sources of evidence/policies shared by participants. All contributed interactions and information sources were collated to produce the 100 consensus statements. A high level of engagement via Twitter® (<http://twitter.com>) was achieved, with more than 475 000 impressions across 28 days (*Table S1*, supporting information).

### Phase III

The consensus exercise was completed by 339 individuals (279 surgeons, 82.3 per cent). Respondents were predominantly consultants/attendings (204, 60.2 per cent), and a majority reported their highest academic achievement as a doctorate (137, 40.4 per cent) or masters degree (119, 35.1 per cent) (*Table 1*). Responses were received from 41 countries, across all six WHO regions<sup>1</sup>, with a majority based in the UK (64.3 per cent) (*Fig. 1*; *Table S2*, supporting information).

Consensus was determined across four domains: physical resources, personnel, patients and procedures.

**Table 2** Consensus appropriate in domain 1: physical resources

	Agree (%)	Unsure (%)	Disagree (%)	No. responding 'outside of my expertise' (n = 339)
<b>Consensus agree</b>				
Single-use equipment should be used preferentially in patients with COVID	88	5	7	5
Reusable equipment should be covered with impermeable coverings, while ensuring machinery safety is maintained (e.g. vents unobstructed)	78	16	6	33
ORs should be filtered and ventilated, ideally with negative pressure, for patients with COVID	87	10	3	19
Intubation and extubation should take place within a negative pressure room where possible	89	9	2	27
Where possible, elective surgery should be conducted in hospitals designated as non-COVID or clean sites	81	8	11	4
Separate ORs and access routes should be used for patients with COVID	94	3	3	2
Donning/doffing should take place in clearly identified clean, partially contaminated, and contaminated areas according to a clear protocol	96	3	1	5
<b>Equivocal</b>				
Surgical equipment used in patients with COVID should have separate decontamination pathways	60	19	20	48
Where laminar flow is available this should be active for at least 20 min before intubation and after any procedure	61	29	10	13
OR temperature makes a difference to transmission risk in patients with COVID	13	73	15	61
The effects of laminar flow, negative and positive OR pressure on droplet spread in COVID are well understood	13	33	54	42
The OR can safely be used again 20 min after cleaning following the previous procedure, keeping the ventilation running	40	45	15	45
Suitable surface cleaning agents are: 68–72% ethanol, or 0.5% peroxide; combined or separate detergent and disinfectant (1000 ppm available chlorine). Chlorhexidine is ineffective against coronavirus	61	37	2	62
OR cleaning should be performed after waiting at least 20 min from the end of procedure/patient extubation	68	27	5	38

Consensus agree: more than 70 per cent agree, less than 25 per cent disagree; consensus disagree: more than 70 per cent disagree, less than 25 per cent agree; non-consensus: at least 33 per cent agree, at least 33 per cent disagree; equivocal: all other combinations. OR, operating room.

Domain 1 (physical resources) comprised 14 statements (Table 2), seven of which were deemed appropriate by consensus (agreement range 78–96 per cent); the remaining seven statements were equivocal (13–68 per cent agreement).

Statements with consensus agreement supported a distinction between protocols involving patients with suspected COVID-19 and those perceived to be free from infection. Suggestions from this domain included clear demarcation of clean *versus* contaminated areas, OR access routes, and hospitals, as well as utilizing single-use equipment with disposable protective equipment covering. Although firm evidence is lacking for these approaches, emerging guidance documents support their implementation<sup>4,6–8</sup>. Statements that failed to garner consensus related to decontamination processes for the OR and surgical equipment, laminar flow and OR

temperature. In particular, there was doubt regarding the effects of OR pressure and flow systems on droplet spread, as well as the timing of subsequent OR use. However, there was consensus that intubation and extubation should be performed in a negative pressure environment, which is supported by anaesthetic and intensive care professional organizations<sup>4,8</sup>.

Domain 2 (personnel) included 25 statements (Table 3), 19 of which reached consensus agreement (74–99 per cent agreement). Five statements were equivocal (45–68 per cent agreement), and there was clear consensus disagreement with the statement: 'the coronavirus transmission risk of anaesthetic and surgical procedures is well understood'.

There was a clear desire for uniformity of practice, and strong support for national and international guidance, in preference to local policies. Participants supported universal adoption of WHO personal protective equipment

**Table 3 Consensus appropriate in domain 2: personnel**

	Agree (%)	Unsure (%)	Disagree (%)	No. responding 'outside of my expertise' (n = 339)
<b>Consensus agree</b>				
Every staff member must receive formal training in PPE use before any contact with potential patients with COVID	99	0	1	0
PPE definition should universally be based on WHO guidance to avoid confusion	83	9	9	6
PPE level should be determined by (inter)national guidance rather than local policy	85	7	8	1
The minimum standard for 'full' PPE should include: double layers of disposable gloves, water-resistant gown with full-length sleeves, eye protection and N95–99/FFP2–3 mask	92	4	4	5
In non-theatre environment PPE should follow WHO guidance: close contact – mask, gown, gloves, face mask/goggles; AGP – respirator (FFP2/N95), gown, gloves, face mask/goggles, sleeved apron	89	6	6	5
Clear local plans should be outlined in case supplies of PPE run low or run out	96	3	2	2
All staff in theatre should use the same level of PPE for patients with COVID, regardless of proximity to the patient	74	11	15	5
Teams should practice doffing procedures in advance, following an agreed protocol	97	1	2	2
Dentists should follow the same PPE guidance as other disciplines working close to upper airways	95	4	1	42
Mask fit testing hoods should be cleaned between each tested person	86	13	1	24
Where adequate PPE is unavailable, procedures should not be performed	74	19	7	3
Only essential staff should be in the OR for patients with COVID, with no exchange of room staff, except for emergency situations	98	1	1	1
The minimum number of necessary providers should attend patients during rounds and other encounters	99	1	0	1
The most senior person available should perform procedures (e.g. operating/intubating)	75	9	15	2
Duties involving close contact should be shared out or spaced out to minimize viral exposure of OR personnel	78	16	6	9
Staff at high risk (e.g. immunosuppressed) should be shielded from patient-facing duties	96	4	0	2
Communication devices can help minimize staff entry and exit frequency in the OR	94	5	0	4
Asymptomatic patients with COVID present a risk of transmission during AGPs	91	8	1	4
Specialties involved in procedures involving and close to the upper airway are at greater risk (e.g. anaesthetics, ear, nose and throat, maxillofacial, dentistry, neurosurgery)	95	4	1	7
<b>Equivocal</b>				
In non-AGP operations, standard PPE is acceptable if the aerosol has been cleared by OR ventilation after intubation	45	31	24	26
Prolonged use of PPE can lead to staff injury or harm (e.g. pressure necrosis)	68	23	9	9
Where demand outstrips supply, reuse of disposable N95/N99/FFP2/FFP3 masks is feasible if following specific evidence-based guidance	58	27	15	34
Dual-consultant operating can be clinically beneficial in patients with COVID	60	26	14	14
The transmission risk differs between individual patients with COVID	59	36	5	43
<b>Consensus disagree</b>				
The coronavirus transmission risk of anaesthetic and surgical procedures is well understood	15	13	72	6

Consensus agree: more than 70 per cent agree, less than 25 per cent disagree; consensus disagree: more than 70 per cent disagree, less than 25 per cent agree; non-consensus: at least 33 per cent agree, at least 33 per cent disagree; equivocal: all other combinations. PPE, personal protective equipment; AGP, aerosol-generating procedure; OR, operating room.

**Table 4 Consensus appropriate in domain 3: patients**

	Agree (%)	Unsure (%)	Disagree (%)	No. responding 'outside of my expertise' (n = 339)
<b>Consensus agree</b>				
All patients should be considered to be COVID contagious unless proven otherwise during the pandemic	90	4	6	4
All patients attending hospital during the pandemic should wear a surgical mask from arrival	75	16	9	10
The thorax should be included in emergency abdominal CT in patients with unknown COVID status	90	6	4	12
Although false-negative rates remain substantial, COVID status should be assessed using CT of the thorax in patients with unknown COVID status requiring (non-emergency) urgent surgery (e.g. cancer)	71	19	10	34
Where safe and possible, surgical patients should be tested before operation for COVID-19	95	4	2	1
Screening questions are a poor way to identify potential patients with COVID	73	17	9	18
Despite the effect of COVID on practice, the consent process should keep the patient as the main focus	91	5	4	3
Consent discussions with patients must cover the added risk of COVID exposure and the potential consequences	96	4	0	1
Patients with COVID should be on a separate operating list, or last on the list where this is not possible	87	7	6	2
Patients COVID with should be isolated after surgery	94	6	1	1
<b>Equivocal</b>				
Negative CT of the thorax, or at least two negative swabs without subsequent exposure, are sufficient to define negative COVID status	48	31	21	41
The patient's viral load can help predict postoperative outcomes and aid decisions on management	27	65	8	75
Coronavirus in gastrointestinal secretions and faeces does not represent a transmission risk	9	31	60	36
Risk scores such as P-POSSUM are equally applicable to patients with COVID	21	54	25	61
Surgery should be contraindicated in patients with COVID and related poor prognostic indicators (e.g. raised D-dimer/LDH)	31	40	29	31
Perioperative antibiotic regimens should take consideration of the level of suspicion of COVID	44	25	31	35

Consensus agree: more than 70 per cent agree, less than 25 per cent disagree; consensus disagree: more than 70 per cent disagree, less than 25 per cent agree; non-consensus: at least 33 per cent agree, at least 33 per cent disagree; equivocal: all other combinations. LDH, lactate dehydrogenase.

(PPE) definitions, and suggest training and protocolized deployment of PPE, which was largely recommended by government agencies<sup>9–12</sup> and professional bodies<sup>4–8,13,14</sup>. Moreover, there was consensus that appropriate PPE was not only essential, but that procedures should not be performed where adequate PPE was unavailable, a sentiment supported by the Royal College of Surgeons of England<sup>6</sup>. Disposable PPE reuse was not generally supported, despite evidence outlining several potentially effective and safe methods<sup>14</sup>. Dual-consultant team operating practice was perceived to be equivocal, which arguably reflects concern relating to the exposure of two senior specialists to a risk of COVID-19 infection, limited efficiency, or the variety of procedural complexity undertaken by Delphi participants.

Domain 3 (patients) yielded consensus agreement in ten of 16 statements (71–96 per cent agreement) (Table 4). The

remaining six statements were equivocal (9–48 per cent agreement).

Responses highlighted uncertainty regarding the risk of transmission of COVID-19, as well as diagnostic measures. Caution in OR practice was suggested, treating all patients as suspected cases, using patient masks where status is unknown, testing early, avoiding reliance on screening questions, and isolating patients around the time of surgery. This approach reflects an appreciation of the silent phase of COVID-19, when patients may be contagious, but asymptomatic<sup>15</sup>. Consensus was poor regarding the adequate definition of true-negative COVID-19 status, arguably reflecting suboptimal diagnosis by means of oropharyngeal (32–72 per cent) and nasopharyngeal (63–73 per cent) tests<sup>16</sup>. Thoracic CT use was strongly supported in patients undergoing emergency abdominal

Table 5 Consensus appropriate in domain 4: procedures

	Agree (%)	Unsure (%)	Disagree (%)	No. responding 'outside of my expertise' (n = 339)
<b>Consensus agree</b>				
Laparoscopy should be considered a coronavirus AGP	75	19	7	33
Filter devices should be used for releasing smoke and CO <sub>2</sub> during and after laparoscopy	88	10	2	36
Laparoscopic port-site incisions should be kept as small as possible	85	11	5	37
Laparoscopic CO <sub>2</sub> insufflation pressure should be kept to a minimum	83	16	2	38
Predicted length of stay and impact on need for ICU should be taken into account in the choice of procedure	91	7	2	10
Viral contamination of staff is possible during surgery, either open, laparoscopic or robotic	92	6	2	16
COVID status and its implications should be included in the WHO checklist	91	4	6	2
All elective work should be postponed at present unless delay substantially affects the prognosis	91	4	4	1
All in-person clinic/office work should be cancelled or delivered electronically, unless this substantially affects the prognosis	94	4	2	1
AGPs should generally be avoided as far as possible during the pandemic	85	8	7	8
Electrocautery should be used sparingly and on the lowest possible settings for the desired effect	76	17	6	29
Use of devices that can lead to aerosolization (monopolar electrosurgery, ultrasonic dissectors, advanced bipolar devices) should be minimized	80	16	3	13
Monopolar diathermy pencils with attached smoke evacuators should be preferred if electrosurgery is required	88	12	1	25
MDTs should be conducted virtually where possible	97	2	1	2
Maximal PPE should be worn for any laparotomy in patients with COVID	93	4	3	21
Decisions regarding management strategies should be taken by the MDT wherever possible	97	2	1	4
A short operating time should be prioritized in the procedure choice	75	13	12	8
Non-operative management should be preferentially implemented where possible	85	8	7	15
Routine audit data collection should continue	84	7	9	4
Specific CT features can help determine the safety of conservative management of the acute abdomen	81	11	8	58
Endovascular approaches should be used as a bridge to open surgery to expedite discharge where feasible	78	18	3	107
Trauma injuries should preferentially be managed non-surgically where this appears safe in the short term	78	15	7	37
Sawing or shaving bone constitutes an AGP	72	23	5	99
Endoscopic trans-sphenoidal surgery should be avoided where possible	84	16	0	189
All procedures involving close contact with the face, head and neck should be considered high risk for staff in patients with COVID	96	4	1	27
Use of any drill in the mouth should be considered an AGP; a rubber dam and high-volume suction should be used where possible	94	6	0	118
Where endoscopy is essential, staff should wear the recommended PPE appropriate for an AGP	96	4	0	23
Only emergency endoscopy and urgent cancer evaluations should be performed during the pandemic	91	6	4	21
Air or CO <sub>2</sub> insufflation should be kept to a minimum in endoscopy	89	8	2	56
Endoscopic procedures involving additional insufflation (e.g. endoscopic mucosal resection), should be avoided during the pandemic	75	21	5	87
Removal of caps on endoscopes could release fluid and/or air and should be avoided	76	20	4	106
PPE practice in endoscopy should mirror that of any other AGP	95	4	1	44
The patient's temperature should be taken before undertaking endoscopy	76	18	6	44
Patients on immunosuppressive drugs for inflammatory bowel disease or autoimmune hepatitis should continue taking them as the risk of disease flare outweighs risk of contracting COVID	76	23	1	104



Table 5 Continued

	Agree (%)	Unsure (%)	Disagree (%)	No. responding 'outside of my expertise' (n = 339)
<b>Equivocal</b>				
Where a CO <sub>2</sub> extraction filter is unavailable, an underwater extraction device can safely be used instead	31	61	9	75
An open approach should be favoured over laparoscopy unless the clinical benefit substantially exceeds the risk of potential viral transmission	63	16	21	30
It is clear which procedures are aerosol-generating	19	21	61	2
Resected specimens should generally not be examined in the OR	64	23	13	37
Alcoholic povidone-iodine is preferred in COVID as chlorhexidine may not be effective against coronavirus	43	52	5	66
Stoma formation should be considered rather than anastomosis to reduce the need for unplanned postoperative critical care for complications	64	16	20	42
Cholecystostomy should be considered in preference to cholecystectomy in acute severe cholecystitis	48	25	27	76
Laparoscopic cholecystectomy should still be performed for acute gallstone pancreatitis	46	29	25	67
Specific biochemical marker cut-offs can help determine the safety of conservative management of the acute abdomen (e.g. C-reactive protein, white cell count)	47	23	29	49
A preprocedural mouth rinse containing 1% hydrogen peroxide or 0.2% povidone should be used in oral procedures. Chlorhexidine is not effective	54	43	3	187
Gastrointestinal endoscopes should be cleaned as normal	42	35	24	127

Consensus agree: more than 70 per cent agree, less than 25 per cent disagree; consensus disagree: more than 70 per cent disagree, less than 25 per cent agree; non-consensus: at least 33 per cent agree, at least 33 per cent disagree; equivocal: all other combinations. AGP, aerosol-generating procedure; MDT, multidisciplinary team; PPE, personal protective equipment; OR, operating room.

CT or requiring urgent surgery, as supported by the UK Royal Colleges of Radiologists and Surgeons<sup>17</sup>, but not by the American College of Radiologists<sup>18</sup>. Within the consent process, inclusion of the potentially substantial impact of COVID-19 on risk was strongly supported, but participants were unsure how best to use risk prediction tools, such as P-POSSUM<sup>19</sup>, and other novel predictive measures in COVID-19, such as D-dimer and lactate dehydrogenase<sup>20</sup>.

Domain 4 (procedures) comprised 45 statements (Table 5), 34 of which reached consensus (72–97 per cent agreement). Eleven statements yielded equivocal responses (19–64 per cent agreement).

Statements related to the postponement of scheduled elective work (unless delay substantially affects the prognosis), and provision of virtual multidisciplinary team (MDT) meetings achieved consensus, consistent with international guidance<sup>4,6</sup>. There was support for cross-specialty MDT decision-making to determine management strategies, prioritizing procedures associated with shorter operating times and duration of hospital of stay, avoiding intensive care requirement, and preferential non-operative management where possible. Avoidance of aerosol-generating procedures (AGPs) was also favoured, but many respondents disagreed regarding which procedures were actually aerosol-generating. Nevertheless,

it has been proposed that electrocautery and ultrasonic dissector use, which may promote aerosolization, should be minimized. Two research groups have reported findings regarding surface stability<sup>21</sup> and elimination<sup>22</sup> of novel coronavirus, the latter demonstrating that chlorhexidine performed poorly in eliminating novel coronavirus. Despite highlighting this evidence within the Delphi exercise, no consensus was achieved regarding the choice of decontamination agent.

With regard to specific surgical specialties and procedures, a number of themes arose related to the relative risks and benefits to both patients and staff conferred by the type of surgical approach. In general surgery, there was consensus that laparoscopy represents an AGP, but also that laparotomy requires full PPE and, regardless of approach (open, laparoscopic or robotic), the potential for viral transmission remains potent. No consensus was achieved regarding an open *versus* laparoscopic approach and, indeed, although initial official guidance advised strongly against laparoscopy, more recent European and US iterations advise a cautious patient-tailored strategy<sup>4,6</sup>. Consensus was also poor regarding preferences for specific management options, such as stoma formation *versus* gastrointestinal anastomosis, cholecystostomy *versus* cholecystectomy in acute cholecystitis, and conservative management of gallstone pancreatitis. A pragmatic,

patient-specific decision-making process is likely to be necessary, taking into consideration local factors such as hospital and regional COVID-19 rates, and critical care capacity, for example. Participants agreed that all procedures involving the head and neck should be classed as high risk, endoscopic trans-sphenoidal surgery avoided, and intraoral drilling classified as an AGP. Consensus was lacking regarding preprocedural mouthwash, despite 1 per cent hydrogen peroxide and 0.2 per cent povidone-iodine having been recommended as more effective than chlorhexidine<sup>23</sup>.

In vascular surgery, an endovascular approach was favoured over open surgery, a position supported in abdominal aneurysm repair alone in Vascular Society (UK) guidance<sup>13</sup>. Consensus supported conservative trauma management where possible, and procedures involving sawing or cutting bone were deemed AGPs, as demonstrated previously<sup>24</sup>. For gastrointestinal endoscopy there was clear consensus that this represented an AGP and should be limited to emergencies only with appropriate PPE, concurring with UK and US guidance<sup>5,7</sup>.

## Discussion

This study has a number of limitations. Consensus was achieved using a single-phase Delphi exercise, although this was considered a valid compromise, considering the time-sensitive nature of the project and the pandemic. The use of an online platform enabled engagement from all six WHO global regions, although participation from the original epicentre in China was limited by restrictions on regional social media use. Some reluctance was also documented from certain Western geographical areas, because of perceived whistle-blower concerns regarding reporting unsatisfactory government strategies. Demographic details of participants, such as professional credentials, were not validated, although it is anticipated that the large number of participants mitigated against any self-reporting inaccuracy.

This study has revealed global expert consensus related to OR practice during the COVID-19 pandemic. Among 339 worldwide multidisciplinary experts, consensus was evident regarding 71 of 100 statements, supporting much of the initial guidance issued by a number of professional organizations. The remaining areas of contention, which were deemed important by stakeholders during the initial phases of this study, should be considered key targets for urgent research. The next steps should map these findings to published guidance to appraise and validate specific recommendations against global consensus.

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*Disclosure:* The authors declare no conflict of interest.

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### Supporting information

Additional supporting information can be found online in the Supporting Information section at the end of the article.