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ORIGINAL RESEARCH

Preparing anaesthesiologists to safely care for patients with COVID-19: an observational study of a simulation course

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Background: Anaesthesiologists are at high risk for exposure to SARS-CoV-2. We describe the development, implementation and efficacy of a high-fidelity simulation course for anaesthesiologists in response to this threat.

Methods: This is an observational study of preparedness conferred by a simulation course. The following four knowledge gaps were identified: i) personal protective equipment (PPE) selection and donning/doffing; ii) operating room and anaesthesia machine turnover; iii) routine and difficult airway management; and iv) emergent airway management and Advanced Cardiac Life Support (ACLS) protocols. Four simulations were developed and offered to faculty, residents and Certified Registered Nurse Anaesthetists (CRNAs) at an anaesthesiology department. A survey estimated prior knowledge and assessed knowledge gained after the course.

Results: Prior to the simulations, 27% and 26% of the participants estimated ability, respectively, to don and doff PPE, compared to 99% of the participants who demonstrated knowledge after the simulations: donning, odds ratio (OR) = infinity (19.6, infinity); doffing, OR = infinity (19.9, infinity). Prior to the simulations, 28% of the participants estimated knowledge specific to airway management; while after the simulations, 84% of the participants identified correct principles of airway management (OR = 9.1 [4.3, 20.2]). Prior to the simulations, 15% of the participants estimated knowledge of principles guiding emergency airway management and/or ACLS protocols, compared to 94% of the participants who correctly identified those principles after the simulations (OR = infinity [21.9, infinity]). Only 18% of clinicians estimated that they were competent prior to the simulations, while 89% of clinicians demonstrated competency on the written survey after the simulations (OR = 37 [10.8, 212]).

Conclusion: Our results suggest that this simulation course effectively prepared anaesthesiology faculty, residents and staff to select appropriate PPE, and don and doff it, as well as apply best practices during airway management and ACLS protocols.

Keywords: COVID-19, airway management, simulation, personal protective equipment, safety

Introduction

On 14 March 2020, the United States recorded 2 800 cases of COVID-19 and 58 related deaths. In response to the COVID-19 pandemic, Surgeon General Jerome Adams asked hospitals to consider halting elective procedures, a key measure to preserve personal protective equipment (PPE), sedative medications and ICU beds for anticipated critically-ill patients with COVID-19.[1]

Anaesthesiologists, surgeons and emergency physicians are at high risk for exposure to the virus by nature of their proximity to aerosol-generating procedures.[2-4] Historically, physicians have low levels of compliance with infection control guidelines, including hand hygiene and the selection and proper wearing of PPE.[5] We discovered, for example, that no clinician in our department had been fit-tested in the previous 12 months, although annual fit-testing is recommended for all clinicians.[6]

Simulation centres are uniquely positioned to educate physicians, nurses and other healthcare workers (HCWs) in the policies and procedures needed to mitigate the spread of this novel respiratory virus and particularly to provide hands-on experience with complex procedures. In response to this crisis, the Department of Anesthesiology simulation team at the University of Utah developed a two-hour simulation course addressing PPE, operating room and anaesthesia machine turnover, routine and difficult airway management in the operating room, as well as airway management and Advanced Cardiac Life Support (ACLS) protocols outside of the operating room.

This implementation of large-scale high-fidelity simulations during a global healthcare crisis required recognising and addressing multiple challenges, including the logistics of effectively teaching donning and doffing of PPE while PPE shortages were anticipated, achieving consensus on policies and procedures, and protecting participants, simulation faculty and staff from asymptomatic disease transmission.

Our objective is to describe the development, implementation and efficacy of large-scale high-fidelity simulations for anaesthesiologists in response to a novel infectious disease threat.

Methods

This is an observational study of a two-hour simulation course developed in response to the threat of SARS-CoV-2. Our needs assessment identified four knowledge gaps: i) PPE selection as well as donning/doffing procedures; ii) environmental safety: operating room and anaesthesia machine turnover; iii) routine and difficult airway management in a patient with confirmed or suspected COVID-19 scheduled for surgery or a procedure under anaesthesia; and iv) emergent airway management and ACLS protocols in the intensive care unit (ICU) or a patient ward in a patient with confirmed or suspected COVID-19. A set of four simulations were developed to address these knowledge gaps (Table I). The curriculum was developed using a modified Delphi approach involving physician thought leaders in airway management, PPE, hand hygiene, patient safety protocols, quality improvement and simulation. Consensus was defined as agreement among the group of seven. See Appendix 1 for a full description of the curriculum, equipment and timing.

The simulation course was offered by the Department of Anesthesiology's simulation centre beginning on 16 March 2020 until operations were disrupted two days later by a 5.7 magnitude earthquake with its epicentre less than twenty miles (32 km) from the hospital. Pending assessment and clearance of the building in which the simulation centre was housed, the simulation course was moved to clinical areas of the main hospital of which normal operations had been suspended in anticipation of a surge of patients with COVID-19. It moved back to the formal simulation centre a week later. The course was offered for two and a half weeks to faculty, residents and Certified Registered Nurse Anaesthetists (CRNAs) in the department. Several faculty members from the Department of Surgery also participated, at their request. Concurrent with the simulation course, all clinicians in the Department of Anesthesiology were fit-tested for N95s and powered air-purifying respirators (PAPRs).

The Institutional Review Board of the University of Utah determined that this study was exempt from review. Three weeks after the course was first offered, an electronic survey evaluating the outcomes was delivered to all participants. The survey was developed using an abbreviated, modified Delphi process that included the course developers and instructors (EMT, KBJ, DA, MC, AS). Because this educational offering was developed in response to a rapidly emerging public health crisis, the survey instrument was created after the completion of the course. Thus, participants were asked to *estimate* their knowledge prior to the course. We attempted to limit acquiescence bias by assessing specific knowledge related to the four outcomes of interest, rather than relying on qualitative estimates of knowledge before and after. Email requests with an electronic link to the survey were sent twice, 12 days apart, and a third request was sent by the department chair two weeks later. See Appendix 2 for the survey questions.

Variables

The following outcomes were identified in order to evaluate the efficacy of the training:

1. Selection and use of PPE when treating patients with COVID-19.
2. Placement of HEPA or HME filters on the expiratory limb of the anaesthesia machine and between the endotracheal tube and Y of the anaesthesia circuit or bag-valve mask apparatus.

Table I: Four simulation stations using both low- and high-fidelity techniques to train personnel to care for patients with COVID-19

Stations	Learning objectives	Equipment/supplies	Cognitive aids used and developed	Time
PPE	• Identification of the level of personal protective equipment (PPE) needed for aerosolising procedures and non-aerosolising procedures • Correct donning/doffing protocols	• Gloves • Plastic gown • Shoe covers • Powered air-purifying respirator (PAPR) • Sani-Wipes • Hand sanitiser	Modifications made to the Centers for Disease Control (CDC) PPE infographic	15 minutes
Anaesthesia machine	• Location of high efficiency particulate air (HEPA)/heat-moisture exchange (HME) filters on the anaesthesia circuit • Anaesthesia machine turnover • OR cleaning	• Anaesthesia machine • Anaesthesia circuit • Two HME filters (HEPA filters not available at the time) • Washcloths (to simulate Sani-Wipes) • Hand sanitiser		15 minutes
Operating room airway	• Practice PPE donning/doffing order • Best practices during routine airway management • Best practices during difficult airway management	• High-fidelity mannequin • Anaesthesia machine • Two HME filters • Gloves • Simulated PPE • Simulated induction medications • Laryngoscopes • Videolaryngoscope • Laryngeal mask airway (LMA) • Cricothyrotomy kit • Hand sanitiser	Modifications made to the *Principles of airway management in Coronavirus* COVID-19 infographic from @gasxchange	45 minutes
Non-OR airway and Advanced Cardiac Life Support (ACLS)	• Practice PPE donning/doffing order • Best practices of non-OR airway management • Best practices during cardiopulmonary resuscitation (CPR)	• High-fidelity mannequin • Airway box • HME filter • Gloves • Simulated PPE • Crash cart • Hand sanitiser	Modifications made to the *Principles of airway management in Coronavirus* COVID-19 infographic from @gasxchange	45 minutes

3. Identification of best practices around routine operating room airway management in patients with COVID-19.
4. Identification of best practices around emergent out-of-operating room airway management and ACLS protocols in patients with COVID-19.

Competence prior to the simulation course was defined as participants who answered "somewhat agree" or "strongly agree" to at least three of the four knowledge questions (e.g. "Prior to the simulations, I knew where HME or HEPA filters should be placed to protect the anaesthesia machine and the OR personnel from contamination with COVID-19"). Competence after the simulation course was defined as participants who selected the correct response on at least three of the four knowledge questions.

We defined a survey response rate of 60% as adequate. Because of the importance of proper practices, a minimum of 75% accuracy on knowledge items was arbitrarily defined as competence.

In this observational study, subjects were not randomised. Survey comments were evaluated with a qualitative analysis in which two independent reviewers categorised the feedback.

Statistical methods

Proportions are reported as counts of positive responses/total participants completing the survey. There were six domains in the survey: i) knowledge of PPE type; ii) donning confidence; iii) doffing confidence; iv) filter placement; v) airway management principles; and vi) ACLS principles. An overall competence score was calculated from the survey domains as described above. For each domain and the competence score, the two proportions (before training versus after training) are paired binomial variables. The proportions are shown graphically as percentages. The comparison of before training versus after training was estimated by i) an unconditional test for equality and ii) a conditional estimation of odds ratio (OR). Additionally, the confidence interval for the difference of proportions and the confidence interval of the OR were estimated. An alpha of 0.05 was set for rejection of the null hypothesis of no difference.

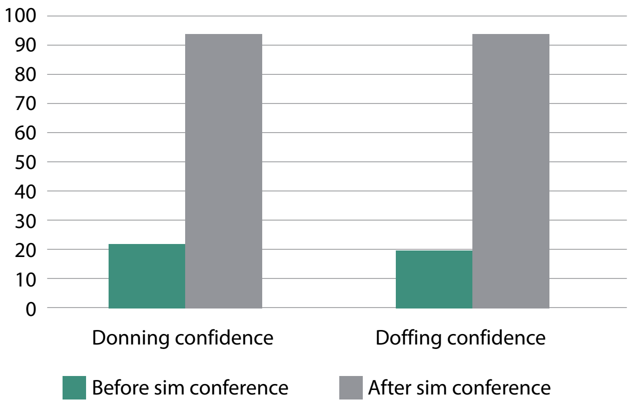

Figure 1: Results of a post-hoc survey assessing provider preparedness to minimise transmission of COVID-19 during aerosolising procedures
Survey respondents estimated confidence in donning and doffing skills prior to the simulations, and reported confidence in donning and doffing skills after the simulations. Data are expressed as a percentage of respondents.

A familywise error rate protection procedure (Bonferroni adjustment) was considered unnecessary as all *p*-values were less than 0.000 and the lower bounds of all confidence intervals (CIs) were far from the line of identity. ORs are reported with 95% CI. The point estimate of some ORs was undefined because of zero division; however, the lower bound of the 95% CI can still be estimated. Statistical procedures used exact estimation and were run in StatXact 11.1.0 (Cytel Inc; Waltham, MA).

Results

Over the course of two and a half weeks, 89 faculty, 41 residents and 29 CRNAs completed the simulation course (a total of 159 participants), representing a saturation rate of the target audience of 91%. Of the faculty participants, two taught all elements of the course at some point and were thus excluded from completing the survey. The response rate of the survey was 65%, as 102 of 157 eligible participants completed the survey. Respondents included 50 faculty, 31 residents and 15 CRNAs.

For all six domains and the summary competence rating, the test of no difference for the equality of two related binomial proportions was rejected at $p < 0.0000$.

Prior to the simulations, 27% and 26% of the participants estimated adequate ability to don and doff PPE, respectively, compared to 99% who demonstrated knowledge (for both donning and doffing) after the simulations: donning, OR = infinity (19.6, infinity); doffing, OR = infinity (19.9, infinity) (Figure 1).

Prior to the simulations, 44% of the participants estimated adequate knowledge of the type of PPE needed to perform aerosolising procedures on patients with COVID-19, while 94% demonstrated knowledge in the follow-up survey (OR = 26.50 [7.5, 152.9]) (Figure 2).

Prior to the simulations, 33% of the clinicians estimated knowledge of placement of HEPA/HME filters in the anaesthesia

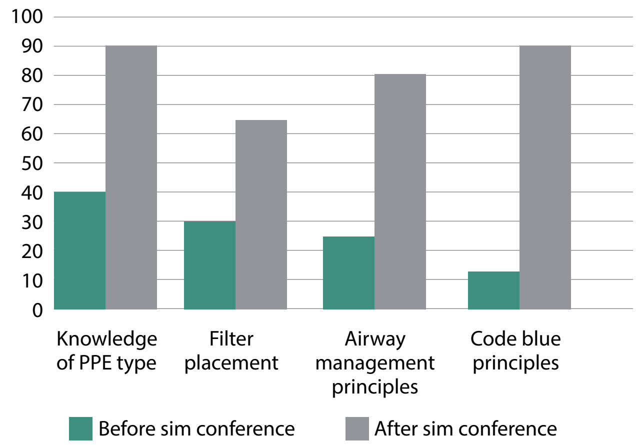

Figure 2: Results of a post-hoc survey assessing provider preparedness to minimise transmission of COVID-19 during aerosolising procedures
Respondents were asked to *estimate* their knowledge prior to the simulations in four areas, and to select the best response based on their knowledge after the simulations. Questions included the type of PPE required, the location of HEPA/HME filters in an anaesthesia circuit, principles of controlled airway management, and principles of emergent airway management and application of ACLS algorithms. Data are expressed as a percentage of respondents.

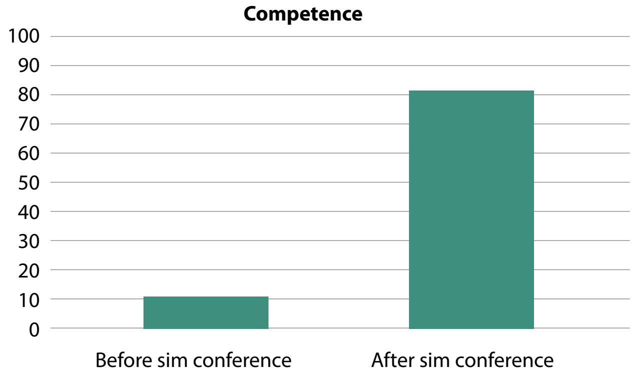

Figure 3: Results of a post-hoc survey assessing provider preparedness to minimise transmission of COVID-19 during aerosolising procedures. Competence was arbitrarily defined as 75% correct on the knowledge questions (see Figure 2 and Appendix 2). Competence prior to the simulations was defined as a response of "Somewhat agree" or "Strongly agree" on 75% of questions estimating knowledge prior to the simulation course (e.g. "Prior to the COVID-19 simulation sessions, I knew the type of personal protective equipment needed for caring for COVID-19 patients"). Data are expressed as a percentage of respondents.

circuit, in contrast with 68% accuracy after the simulations (OR = 4.5 [2.3, 10.0]) (Figure 2).

Prior to the simulations, 28% of the participants estimated knowledge of principles of airway management for affected patients; after the simulations, 84% identified correct principles of airway management (OR = 9.1 [4.3, 20.2]) (Figure 2).

Prior to the simulations, 15% of the participants estimated knowledge of principles guiding actions during emergency airway management and/or ACLS protocols, compared to 94% of the participants who correctly identified those principles following the simulations (OR = infinity [21.9, infinity]) (Figure 2).

Prior to the simulations, 18% of the clinicians estimated that they were competent at caring for patients with COVID-19, while 89% of clinicians demonstrated competency (defined as ≥ 75% accuracy) on the knowledge portions of the survey (OR = 37 [10.8, 212]) (Figure 3).

Participants were also asked for additional comments for the simulation team. Of the 102 participants who responded to the survey, 26 provided additional comments. Fourteen participants thanked the group for conducting the training. Comments about how the training increased confidence and comfort, and was thus helpful in the current climate, were provided by seven participants. Two participants would have liked to practice donning and doffing PPE in the simulation centre and one participant provided recommendations on how to improve the course. Four participants specifically commented on the importance of the knowledge gained and critical learning obtained. Two participants found the training engaging and interactive. Finally, two participants commented on how the skills learnt in the simulation would save lives and help flatten the COVID-19 curve.

Between 14 March 2020 and 19 May 2020, the University of Utah tested 1 394 HCWs for SARS-CoV-2. Of these, 65 HCWs were positive for the virus, and no direct links between patient

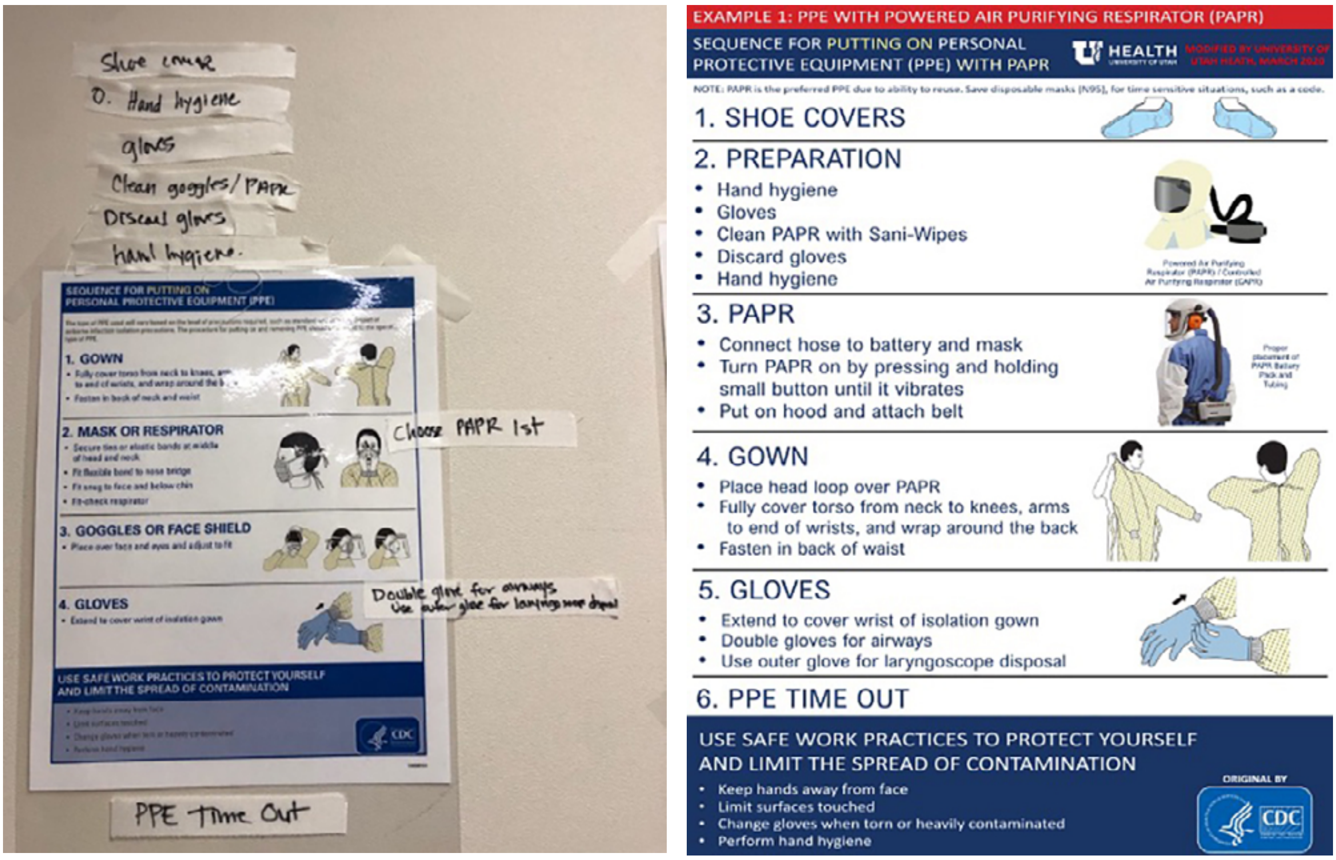

Figure 4: Real-time modification of infographics during simulation course
Left: PPE infographic prepared by the CDC showing real-time modifications added during the simulation course. *Right:* Edited infographic for dissemination within the department.

care and employee seroconversion were identified. Over the same period, anaesthesiologists performed the majority of endotracheal intubations throughout the hospital as well as 114 other anaesthesia services for patients with COVID-19; no anaesthesiologists contracted the virus.

An unexpected result was the value of simulation in clarifying policies and procedures in the department. Existing infographics were modified in real-time (Figure 4) prior to dissemination and a communication pathway between the simulation team and the departmental COVID-19 leadership transmitted questions from clinicians, honed proposed practices and procedures through practice and experimentation, and returned clarifications from departmental leadership involved in hospital-level preparations. Lessons learnt included the difficulty of "version control" for endurable cognitive aids, the value of a single communication channel, and most importantly, the benefit of simulation in identifying weaknesses of workflows developed on paper.

Discussion

We demonstrated significant improvement following the simulations in knowledge of PPE, airway management and ACLS principles; in confidence of donning and doffing procedures; and in overall competence. We conclude that an improved ability to safely manage patients with COVID-19 was associated with participation in the simulation course.

Participants recalled overall low levels of confidence in their knowledge and understanding of practices to mitigate the spread of COVID-19 during airway management under controlled and emergency situations prior to completing the simulation course. Participation was associated with a large increase in knowledge of the principles of application as demonstrated by correct survey responses.

These data are limited in several regards. Knowledge was not directly assessed prior to participation in the simulations but was estimated retrospectively. The survey instrument is not a validated assessment tool. It is likely that written knowledge does not directly translate into behaviour during the clinical care of patients. The simulation course was developed prior to the care of any patients with COVID-19; the actual workflow in caring for these patients was affected by decisions made at the hospital level, as well as by the needs of nursing and surgery colleagues. As participants included all clinical faculty, residents and CRNAs, participants had varying degrees of experience with simulation. The survey instrument did not assess prior experience with simulation. Self-confidence is not always a good reflection of knowledge or skill.[7] There was also no control group, and participants had access to multiple sources of information regarding the care of patients with COVID-19. It is, therefore, possible that clinicians actively sought information which was assessed in the survey. As with all survey-based research, we acknowledge nonresponse bias is likely to be present.

The course seems to have effectively prepared department faculty, staff and residents to care for patients with COVID-19, but ideally, that preparation would be linked to an outcome like infection rates among our faculty and residents. At eight weeks after the course, the infection rate in our state was approximately 4% of those tested and there had been no cases of transmission to HCWs in the Department of Anesthesiology at the time. The low overall incidence of the disease to that point in our state affects the assessment of the impact of the training.

Adult learning theory suggests that timeliness and problem-centred learning are important to adult learners.[8] Given that the content of these simulations was both timely and addressing a critical need (helping physicians and nurses avoid infection with a highly infectious and potentially lethal virus, transmissible through respiratory droplets and aerosols), faculty and staff exhibited tremendous engagement throughout the simulations. This no doubt had an impact on their learning, and suggests that a similar course offered at a different time might be less effective.

Conclusion

The COVID-19 pandemic revealed multiple knowledge gaps among anaesthesiology residents, CRNAs and faculty at an academic medical centre. The creation of a two-hour simulation course was challenged by the relative dearth worldwide of basic knowledge about transmission of the virus and best practices, the need to rapidly update the curriculum as information changed, and a compressed time frame of 48 hours from origination to implementation. These efforts were assisted by the cessation of all but the most emergent surgeries, which allowed the Department of Anesthesiology dedicated time to participate, as well as the very high levels of engagement and buy-in of clinicians, staff and leadership.

Our results suggest that a two-hour simulation course effectively prepared faculty, residents and staff to select appropriate PPE, don and doff it correctly, place HEPA or HME filters in appropriate locations relative to the patient and the anaesthesia machine circuit or bag-valve mask apparatus, and apply best practices during airway management and ACLS protocols under routine and emergent conditions.

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Conflict of interest

Only Dr Johnson reports grants from GE Healthcare, during the conduct of the study; other from Applied Medical Visualizations, LLC, outside the submitted work; and is an author on several published manuscripts that describe the models used in the drug display presented in this manuscript.

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The course was supported by the Department of Anesthesiology at the University of Utah. No other external funding was required.

Ethical approval

The Institutional Review Board of the University of Utah determined that this study was exempt from review (exemption number 132023).

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Appendices available online.