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Guidelines

Surgical site infections: guidance for elective surgery during the SARS-CoV-2 pandemic – international recommendations and clinical experience

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SUMMARY

Background: The COVID-19 pandemic not only had an impact on public life and healthcare facilities in general, but also affected established surgical workflows for elective procedures. The strategy to protect patients and healthcare workers from infection by SARS-CoV-2 in surgical departments has needed step-by-step development. Based on the evaluation of international recommendations and guidelines, as well as personal experiences in a clinical 'hot spot' and in a 450-bed surgical clinic, an adapted surgical site infection (SSI) prevention checklist was needed to develop concise instructions, which described roles and responsibilities of healthcare professionals that could be used for wider guidance in pandemic conditions.

Method: Publications of COVID-19-related recommendations and guidelines, produced by health authorities and organizations, such as WHO, US-CDC, ECDC, the American College of Surgery and the Robert Koch Institute, were retrieved, assessed and referenced up to 31st January 2020. Additionally, clinical personal experiences in Germany were evaluated and considered.

Results: Part 1 of this guidance summarizes the experience of a tertiary care, surgical centre which utilized redundant hospital buildings for immediate spatial separation in a 'hot spot' COVID-19 area. Part 2 outlines the successful screening and isolation strategy in a surgical clinic in a region of Germany with outbreaks in surrounding medical centres. Part 3 provides the synopsis of personal experiences and international recommendations suggested for implementation during the COVID-19 pandemic.

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Conclusion: Understanding of COVID-19, and SARS-CoV-2-related epidemiology, is constantly and rapidly changing, requiring continuous adaptation and re-evaluation of recommendations. Established national and local guidelines for continuation of surgical services and prevention of SSI require ongoing scrutiny and focused implementation. This manuscript presents a core facility checklist to support medical institutions to continue their clinical and surgical work during the COVID-19 pandemic.

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Introduction

By 9th February 2021, accumulated global data indicated that approximately 102 million people had become infected with SARS-CoV-2, approximately 2.2 million had died, and 57 million recovered. A cohort study from Heinsberg, the region with the highest SARS-CoV-2 incidence in Germany, which involved antibody and swab polymerase chain reaction (PCR) tests of 919 participants in 405 households, showed an infection rate of 15%; 22% of affected individuals were completely asymptomatic, and fatality rate was 0.37% [1].

According to the authors of the COVIDSurg Collaborative [2], who commented on an international cohort study of mortality and pulmonary complications in patients with perioperative SARS-CoV-2 infection undergoing surgery, an estimated 28.4 million elective operations were cancelled because of the disruption caused by COVID-19. The authors opined that it was the correct decision to postpone operations at a time when patients were at risk of being infected with SARS-CoV-2 perioperatively. Indeed, when a patient developed COVID-19 perioperatively, postoperative pulmonary complications occurred in 51.2% of patients and were associated with a 30-day mortality of 23.8%, with pulmonary complications at 38% [2]. Data from the UK show a clear difference between patients, infected with the virus, who were either conservatively treated and those who had laparoscopic appendectomy. At 30-day follow-up, complications were significantly higher in the operative group ($P < 0.001$). Thus COVID-19 may change the management of acute appendicitis to favour non-operative management, which has now been shown to be safe and effective in the short term [3]. A meta-analysis confirmed a high rate of post-operative mortality among COVID-19 patients of 20% and a postoperative intensive care unit (ICU) admission rate of 15% [4]. Consequently, it was suggested that there is an urgent need for investigations by governments and health providers into measures that ensure safety of patients and healthcare workers (HCWs), as elective surgery restarts. A clear guideline, which has been adapted for this unique epidemiological challenge, is essential for the protection of patients and HCWs against infection. A proposal for guidance is presented in this manuscript, which is based on the authors' experience and the evaluation of the current scientific literature.

Methods

COVID-19-related recommendations and guidelines, produced by health authorities and organizations, such as WHO, US-CDC, ECDC, the American College of Surgery and the Robert Koch Institute, were searched, assessed and referenced [3–26] up to 31st January 2021. After consideration of all these

guidelines the WHO-Patient Care Checklist was selected as a 'master document', modified and adapted, to be shared with partners in relevant medical and clinical fields. Additionally, our own experiences and data from the management of elective surgical procedures in one hospital in a local COVID-19 'hot spot', and in another hospital where nosocomial outbreaks with temporary closure occurred in three hospitals within a radius of 50 km, were included.

Results and discussion

This document is divided into three parts. In Parts 1 and 2, the clinical experiences are presented and discussed. In Part 3, all recommendations are listed (CORE CHECKLIST) and directly linked to the challenges for interventions undertaken on SARS-CoV-2 patients.

PART 1: clinical experiences from a COVID-19 "hot spot" centre in Germany

Local experience

The Diakonie Klinikum (DIAK) is a regional, tertiary-care centre, which provides healthcare to a region of approximately 300,000 inhabitants. The COVID-19 pandemic stressed the resources of the hospital to a degree never seen before. The displacement of standard care soon became evident: the surgical unit came to a complete standstill, with no elective operations, to accommodate the influx of COVID-19 patients in the ICU and general wards. It was soon decided to establish separate 'black' and 'grey' areas for confirmed and suspected SARS-CoV-2-infected patients. Fortunately, a recently built hospital complex allowed the reopening of redundant wards in the old hospital, so that COVID-19 patients could be isolated in separate wards. Similarly, the ICU and IMCU (intermediate care unit) were split into separate entities treating COVID-19 and uninfected patients. In both areas, externally diagnosed SARS-CoV-2 patients were delivered into the hospital through separate entrances. Nurses and doctors from other departments had to be recruited to the ICUs and COVID-19 wards; teaching and training had to be implemented and was supported by a continuously updated software programme on the current knowledge of patient care (SOPHIA®, Standard Operating Procedure Healthcare Information Assistant). This became relevant in surgery with respect to differentiating between a surgical site infection (SSI) and COVID-19 infection, and in ICU for decision of early compared with late intubation in critical respiratory conditions, or the need for tracheostomy [27]. In the latter, the discussion is ongoing and a clear decision for or against invasive measures is pending [28]. Furthermore, the

hospital management had daily update meetings on current local and regional developments, and the decisions from those meetings were communicated through the public relations office and the intranet to hospital staff.

COVID-19 infections

Despite the initial implementation of infection and prevention control measures against COVID-19, 45 (15.2%) of 297 treated patients died, and 47 required ICU care, with 10 (21.3%) deaths. Some patients with respiratory insufficiency were transferred to other hospitals for extracorporeal membrane oxygenation (ECMO). It was initially thought that early intubation was beneficial because prolonged spontaneous breathing, with or without non-invasive assistance, increased respiratory work and worsened the risk of respiratory failure. However, this needed to be balanced against unacceptability of intubating patients too early merely out of concern that the medical staff might be at greater risk of contracting COVID-19 if patients were ventilated non-invasively. A stepwise treatment strategy was later introduced, with appropriate intensive-care monitoring and regulation of all relevant preventive precautions. This depended on the availability of intensive-care beds. In a US single-centre comparative cohort study, the ventilatory parameters and lung mechanics of consecutive early and late intubated and ventilated patients with COVID-19 acute respiratory distress syndrome (ARDS), were measured using descriptive analysis [29]. The authors concluded that larger cohort studies were needed to detect a difference in mortality between early and late intubation. Other studies have found no advantage for early or late intubation [27,30]. Current mortality data suggest an advantage for patients in whom intubation is completely avoided, but these data may be confounded.

Conclusion

Two aspects determined the successful management of COVID-19: the immediate reopening of redundant wards in an old hospital to separate the patients into white, grey or black areas and the continuous evaluation of sometimes contradicting evidence (e.g., early compared with late intubation, introduction of tracheostomy) as well as the use of digital tools (SOPHIA) for training and decision making.

PART 2: experiences from a 450-bed surgical clinic with immediately instigated management to prevent COVID-19 outbreaks

The Immanuel Hospital is a church-backed community hospital that provides care for approximately 300,000 inhabitants in the state of Brandenburg and Berlin. During the early phase of the pandemic in Berlin, the main ICU resources of the University Hospitals were occupied by COVID-19 patients and a massive reduction in elective surgery resulted. A strategy was developed around maintaining dedicated ICU and non-ICU areas for COVID-19 patients that also allowed continuation of elective and emergency surgery for as long as possible.

The following requirements for the surgical clinic were needed: (1) definition of the range of surgical procedures which could be continued according to the regulation of the Federal Minister of Health; (2) creation and management of patient

waiting lists; (3) surgical patient care with reduced ICU and inpatient bed capacity; (4) an admission-screening strategy to separate infected, suspected, and non-infected patients; (5) establishment of care structures for COVID-19 patients in the operating theatre (OT) during surgical procedures; (6) maintaining training and education during the pandemic. The last two points are further explained below.

Admission screening

Prior to elective surgery, patients were asked to record the following symptoms of COVID-19 in a 'health diary' starting 5 days prior to admission: fever $>37.8^{\circ}\text{C}$, dry cough, shortness of breath, anosmia and loss of taste, sore throat, headache, weakness, fatigue, tachypnoea with breathing frequency ≥ 30 , hypotension (systolic BP <90 mmHg or diastolic BP ≤ 60 mmHg) and pulse oximetry values of $<85\%$. In the admission interview (in a separate screening area of the hospital) contact with COVID-19 patients, recent travel history, occupation, social contacts and contact with a hot spot or cluster were questioned. At this consultation, Class II surgical masks were routinely worn by HCWs and patients, and a minimum 1.5 m social distancing was maintained; HCWs wore an FFP2 respirator if the patient had respiratory symptoms.

Patients with risk factors of symptoms were admitted to the grey area. A COVID-19 test was taken with a combined nose-throat swab (PCR) and, in addition, symptomatic patients underwent a low-dose computed tomography (CT) scan of the thorax. If the PCR was positive, the patient was transferred to the black (COVID positive/isolation) area and the decision to operate assessed on the basis of clinical urgency. Acutely symptomatic patients were admitted directly to the black area of the ICU in a single room. If the PCR was negative, patients were transferred to the white area.

After the cumulative incidence of COVID-19 rose to >50 patients/100,000 per week, all patients were screened pre-operatively using a PCR test.

As there was a shortage of nurses in Germany before the pandemic, the clinic has been forced to reduce the number of inpatient beds or carry out short-term personnel rescheduling. This did not increase planning security for patients who required intensive medical monitoring and care in the early postoperative phase.

Establishment of isolation care structure

The clinic was separated into a SARS-CoV-2-free ward (white area), wards for suspected infections (grey area) and wards for confirmed infections (black area). The ICU was divided in the same way. All patients and HCWs in the white area screened negative for COVID-19; HCWs were tested weekly and maintained health diaries with daily documentation of any symptoms. Based on proven efficacy of class II surgical face masks, in combination with social distance [31], patients and HCWs were required to wear class II surgical masks, and alcohol-based hand hygiene was promoted.

The most challenging structural requirement for the black area was the creation of specific sluice rooms adjacent to every patient room or the areas required for donning and doffing personal protective equipment (PPE). Nurses and physicians, when possible, only treated COVID-19-positive patients. Additionally, every patient received education and instructions

concerning isolation protocols, safety measures and proper hand disinfection procedures. Patients were only allowed to contact and communicate with friends and family members via mobile telephone, tablets or laptops.

Care of COVID-19 patients during anaesthesia

All symptomatic COVID-19 patients were monitored continually for respiratory and cardiovascular function. If oxygen saturation fell below 94%, supplemental oxygen therapy was started. Advanced monitoring was started if the patient's general condition deteriorated, particularly if there was somnolence, delirium, dyspnoea or reduction in oxygen saturation, as recommended by Mueller *et al.* [32].

Surgical care of suspected or confirmed COVID-19 patients

The spatial care of patients needed to be reorganized because few clinics had separate surgical units for suspected or confirmed COVID-19 patients. This involved transfer into the OT and ended with the outward transfer. The hygiene requirements of pandemic regulation in Germany required that central areas of the OT and associated areas, such as induction and recovery rooms, must not be used simultaneously for treatment of COVID-19 and non COVID-19 patients. Therefore, the OT was used for induction of anaesthesia and early post-operative monitoring. The route of COVID-19 patients in the OT pathway was thereby reduced to the OT: preparation for anaesthesia, induction and discharge were all undertaken in the closed OT. The OT also served as a recovery room. Post-operatively, patients were transferred to the isolation area of the ICU or directly to the pre-isolation ward (grey area) if SARS-CoV-2 was suspected, or to the isolation ward if SARS-CoV-2 had been proven. To prevent airborne infection, a simple control protocol for the room air-conditioning system (RATS) has been devised and validated. Compared with OT standard ventilation, the RATS protocol was adapted with the air supply reduced from 360 Pa to 200 Pa and the exhaust air increased from 180 Pa to 300 Pa, thus creating a negative flow of 100 Pa whilst the laminar flow ceiling remained active. In the OT, as a minimum FFP2 respirators and two pairs of gloves were worn [33] in accordance with the Robert Koch Institute recommendation [34]. The automated OT door activation function was deactivated to reduce the door opening frequency, and the time the patient was in the OT was minimized. Likewise, the number of OT personnel was kept to a minimum, usually one surgeon and one assistant; one physician's assistant and one anaesthetist and one anaesthesia nurse. The work of the circulating nurse in the OT was delegated to the anaesthesia nurse; the circulating nurse communicated by telephone with the room team for additional requirements. As the risk of exposure to patient-related aerosols was considered to be highest during intubation and extubation, and also during aerosol-generating surgical procedures, the 'keep your distance' advice was observed by everyone in the OT, even during surgical procedures. Virucidal gargling was implemented [35,47].

Conclusion

Since the COVID-19 pandemic began, 23 COVID-19 patients had surgery: 12 orthopaedic patients with femoral neck fracture or fractures of the pelvis; eight patients had surgery for acute appendicitis; and one patient each had surgery for a perforated gall bladder, bowel obstruction and a Caesarean section. All operations were performed without transmission of SARS-CoV-2 to the surgical team. This was in contrast to three nearby hospitals where outbreaks amongst HCWs led to temporary closures.

It is believed that the greatest risk for a COVID-19 outbreak in hospital comes from staff and not patients. Admission of planned, as well as emergency, procedures can be managed and controlled as long as there are sufficient protective materials and adequate facility capacity. It is imperative to reduce the regular number of beds for patient care by 20% of regular bed capacity. Medical and nursing staff leave the hospital every day, with family and other outside contacts, and can introduce the virus into the hospital, from asymptomatic carriers of SARS-CoV-2 in particular. Fixed routines of regular self-testing are required, twice weekly for all asymptomatic staff with a PCR or an antigen rapid test, as well as independent maintenance of a diary of symptoms. Symptomatic staff must remain in quarantine until a negative result is available. Although there may be initial shortages of PPE, these need to be available in sufficient quantities. All staff in direct patient contact should wear an FFP2 respirator which provides additional protection for all in the event of an unexpected internal COVID-19 outbreak.

PART 3: core checklist (aide memoire)

General information SARS-CoV-2 patients – hospital precautions

- Demand on healthcare organizations (e.g., hospital/clinics) varies. Therefore, recommendations need to be implemented, and standard operating procedures (SOPs) adapted. A simple software program, installed on mobile devices, is available for rapid implementation of SOPs and spread of innovative measures and procedures (i.e. www.sophia.online).
- Following any shortfall of supply or stock, an adaptation of these SOPs may be necessary for a limited amount of time.
- The surgical team should, in collaboration with the purchasing department, and based on daily use and consumption, ensure procurement and stock management for personal protection equipment [PPE], together with cleaning and disinfection procedures. The PPE and disinfecting products should have proven or depending on resources definitive efficacy against coronaviruses.
- Traceability of internal and external contact points of patients and limited visitors needs to be ensured.
- Suspected (potentially infected/incubating) and proven (definitive COVID-19 infections) cases have to be isolated from other patients who are cared for in a designated 'white area'. Patients with proven COVID-19 infection should be managed in a designated 'black area'. However, suspected cases must be isolated in a single room until the result of a SARS-CoV-2 PCR is known ('grey area'). Suspected and proven cases need to be reported to local authorities.

- A list of contact individuals (contact > 15 min and distance < 1.5 m) and traceability of internal and external contact points of patients and limited visitors needs to be maintained.
 - Rotating teams (two or more teams with no physical contact separated on an either daily, weekly or fortnight basis).
 - Monitoring of COVID-19 rates is needed by Health Authority (including basic reproduction rate, and prevalence according to local recommendations).

Before arrival to a clinical setting/health diary and tele-triage

- It is advisable to implement a tele-triage system, before elective surgery, to implement a risk assessment. Alternatively, a special temporary area can be integrated into the entrance area or prior to hospital admission. Uncontrolled patient access, without triage, has to be prevented by strict control of access.
- If possible, 5 days before admission each patient keeps a health diary to record symptoms suggestive of COVID-19, such as fever >37.8°C, runny nose, dry cough, shortness of breath, loss of smell and taste, sore throat, headache, weakness, fatigue, tachypnoea with breathing frequency ≥ 30 , hypotension (systolic BP <90 mmHg or diastolic BP ≤ 60 mmHg) and pulse oximetry (values <85% are critical).
- The most reliable method to assess the current pre-operative SARS-CoV-2 status of a patient is PCR-testing, ideally 48 to 24 h prior to any surgical procedure. However, the appropriate timeline for preoperative laboratory screening is not known at present. The Dutch Guidelines, [13] for elective surgery on COVID-19 asymptomatic patients, recommend either no pre-operative SARS-CoV-2 screening or within 48 h before elective surgery, depending on the mean of the three-day average of new infections in the Netherlands (above or below 40 new infections per day). A recent survey among 479 arthroplasty surgeons from 44 countries and six continents agreed that "...it would be ideal for all patients to undergo RT-PCR testing for SARS-CoV-2 before the operation ... [however], if there is a paucity of available tests, then only high-risk patients should be tested" [14].
- Alternatively, a rapid SARS-CoV-2 antigen test, which takes approximately 15–20 min, can be performed at the point of care. It indicates virus excretion with a high degree of certainty (>95%) in patients infected with COVID-19, provided the viral load is sufficiently high (i.e. positivity means infectivity). The positive rapid test enables a rapid decision to be made for immediate transfer to the black area (see below) particularly in symptomatic patients and those with a history of contact with SARS-CoV infections, and PCR is unnecessary. However, a negative test does not exclude COVID-19 infection, thus in this case the procedure described below is analogous to that for a non-feasible PCR test.
- If preoperative PCR testing for each patient is not feasible, then general procedures have to be followed, including a decision about the necessity of PCR testing and the use of PPE by staff before, during and after a surgical procedure.
 - *Triage Step 1:* Screening for symptoms of COVID-19 with TOCC (travel history, occupation, social contacts,

household members, origin from a hot spot or cluster, contact with SARS-CoV-2 individuals) using a questionnaire; the result of which enables stratification into different risk groups.

- *Triage Step 2a:* If patients are not identified as being at risk, they still need to be informed, using an agreed protocol, about the required procedures: such as wearing a mouth-nose protection (class II surgical mask or FFP respirator depending on the classification of the patient on leaving a patient's room), proper hand hygiene, preoperative bathing, stopping smoking [36], and nutritional management.
- *Triage Step 2b:* If a patient, based on the questionnaire, is assessed as being at risk, PCR-screening should be arranged prior to admission into hospital.
- *Triage Step 3:* Depending on the epidemiological situation where the patient lives, two risk-groups have to be distinguished: (1) in an epidemic timeslot, where the reproduction rate [R] is <1, but infectivity still occurs (screening is only recommended when infection is suspected); (2) in an epidemic timeslot, where the reproduction rate [R] is >1 (every new patient admitted should be screened) or local hot spots are known. If the patient is given an RT-PCR test for SARS-CoV-2, the test should be performed no less than 72 h, but ideally 24 h, prior to elective surgery and the result documented in the clinical records.
- *Triage Step 4:* If a patient is tested as being SARS-CoV-2 positive, surgery should be postponed, if possible, with isolation of the patient for 10–14 days prior to operation either at the hospital or at home, depending on their medical condition. After the quarantine period a repeated test will verify whether infectivity persists. Admission has to be postponed until diagnostic results are available.
- Except for emergency surgery, and cancer surgery that cannot be postponed from a medical perspective, consider the GRADE system [20,26] for surgical decisions. In case of the slightest suspicion of an infection or confirmed SARS-CoV-2 infection, surgery should be postponed until recovery. COVID-19 symptoms, including fever and increased temperature, should be constantly monitored until the day of surgery. Frequent SARS-CoV-2 testing should be considered.

At patient arrival, ensure patient and staff safety:

- The risk of infection and transmission should be minimized by utilizing general principles such as social and physical distancing (at least 1.00 m [37], although the Robert Koch Institute recommends at least 1.50 m [38]), wearing an appropriate mouth-nose protection as well as proper hand hygiene. Eye protection is also associated with fewer infections [37].
- If tele-triage cannot be executed, as in the case of an emergency, all patients planned for surgery should be submitted for SARS-CoV-2/COVID-19 testing, including temperature and pulse oximetry measurements; an admission can only be allowed into a predefined holding area (grey area) until the screening result is available.
- Procedures to separate definitively, and suspected, infected SARS-CoV-2 patients (isolation) from patients who are

not considered to be at risk should be established (based on information such as hand and respiratory hygiene, use of PPE and toilet use). Patients with COVID-19-like symptoms should be directed to designated waiting areas and transferred to the grey area. SARS-CoV-2 positive patients need to be transferred to a black area.

- In case-positive hospitals which do not possess the potential of spatial separation into these three risk-categories, patients need to be assigned and transferred to a regional tertiary hospital which is able to provide spatial separation [32,33].
- Diagnostic-based screening for potentially SARS-CoV-2-positive patients depends on the availability of appropriate testing. During the initial phase of the pandemic, the backbone of diagnostic testing was laboratory-based PCR investigation of naso-pharyngeal specimens. Currently, there are several laboratory- and point of care- (POC) based diagnostic methods available, which are either molecular-biology- or antigen detection-based. PCR is highly sensitive and specific, but results are not usually available immediately; antigen testing, although less accurate (see below), can give results within 15 min.
- The diagnostic efficacy of different commercially available, antigen lateral-flow POC tests has been evaluated [39–41]. Depending on the diagnostic antibody test used, sensitivities of 76.6% (95% confidence interval (CI): 62.8–86.4%) [40] and 72.6% (95% CI: 64.5–79.9%) [42] and specificities of 99.3% (95% CI: 98.6–99.6%) [41] and 99.3% (95% CI: 99.7–100.00%) [42] have been reported.
- If a rapid pre-surgical SARS-CoV-2 assessment is required without time to wait for a PCR result, POC antigen tests may also be considered. However, only validated POC tests with known sensitivity and specificity should be used, and surgical staff trained and informed in the interpretation of results.

Prevention of nosocomial spread after identification of SARS-CoV-2 in hospitalized patients or HCWs

- Decisions on quarantine and further activities of HCWs (Figure 1) and transfer of contact patients in the grey area, and infection control by PCR at intervals of 5 days, depend on type of contact. If a patient tested positive for SARS-CoV-2 by an RT-PCR test after a surgical procedure, all HCWs who had contact with the patient, without using PPE, and who are not known to have antibodies against SARS-CoV-2, should be tested and quarantined for eight days until their test results of the fifth day of quarantine become available. Decisions to quarantine staff should be made in consultation with the hospital Infection Prevention Control team and the Occupational Health Department. The patient should also be isolated and any contact with the patient should include the use of full PPE.
- Nurses and physicians should, if possible, only treat COVID-19-positive patients.

Spatial requirements for the operating area and operating procedure

- **Operating areas:** If possible, place SARS-CoV-2 positive (CoV+) and negative (CoV-) patients into spatially separated operating areas. Central areas of surgical departments (e.g., induction areas/recovery rooms) should not be used simultaneously with CoV+ patients.

patients into spatially separated operating areas. Central areas of surgical departments (e.g., induction areas/recovery rooms) should not be used simultaneously with CoV+ patients.

Nevertheless, the anaesthetic room/OT/recovery room has to be accessible for induction of anaesthesia and for early postoperative surveillance and monitoring. The pathway of a CoV+ patient in the operating unit is therefore constrained to individual OTs with direct access. The induction of anaesthesia, intubation and extubation should be undertaken in a closed room of the operating unit which could also act as recovery room for patients. Alternatively, if a separate room is not available, intubation can take place in the OT where only the anaesthetic staff, wearing FFP2/3 respirators, are present. After intubation the surgical team can enter the OT, wearing class II surgical masks after 15 min, by which time the ventilation system will have diluted the aerosolized viral load in the OT. The postoperative transfer of a recovered CoV+ patient should take place either to the isolation area of the ICU (black area) or directly to the pre-isolation area or to the isolation ward.

- **Ventilation:** No evidence is available upon which to base a risk assessment of ventilation systems, but the following conclusions can be drawn from the results of the assessment of different room airflow patterns [42]:
 - In OTs with laminar air flow (LAF) additional protection for the surgical team and patients is ensured by directed ventilation in the operating area. If the exhaust air from the OT flows directly to the outside via the exhaust-air device, the OT can be used without restrictions. The usual protective measures would be sufficient in the OT and a switch to negative pressure in the OT [42] should reduce the risk further [22].
 - In an OT with mixed ventilation, due to the significantly lower ventilation volume with swirling of aerosols, it is questionable whether the FFP3 respirator ensures a seal tight enough to exclude putting the team at risk. In this event, protection of the surgical team can be achieved by wearing overpressure body exhaust suits [43].
 - OTs without mechanical ventilation are not acceptable, because released aerosols are not diluted.
- **Open surgery:** It has been suggested, that during the COVID-19 pandemic that a return to open, instead of laparoscopic surgery, is made as there may be less risk of aerosols with faster operating times. No study has demonstrated the ability for a virus to be transmitted during a surgical procedure whether open or laparoscopic [44]. Even if laparoscopic surgery is associated with a lower risk of SSI, faster healing time and lower risk for incisional hernia, an advantage of open surgery may be the isobaric setting around the surgical field. However, during any use of electrocoagulation, tissue-specific aerosols may develop.
- **Insufflation:** Laparoscopic, minimally invasive techniques produce aerosols derived from the induced pneumoperitoneum. The risk of an aerosol carryover is reduced by insufflation-systems equipped with smoke-gas elimination (smoke evacuation) and defined CO₂ feeding and discharge; therefore, these systems are to be preferred. Alternatively, it is recommended that older insufflator-instruments are used which have disposable

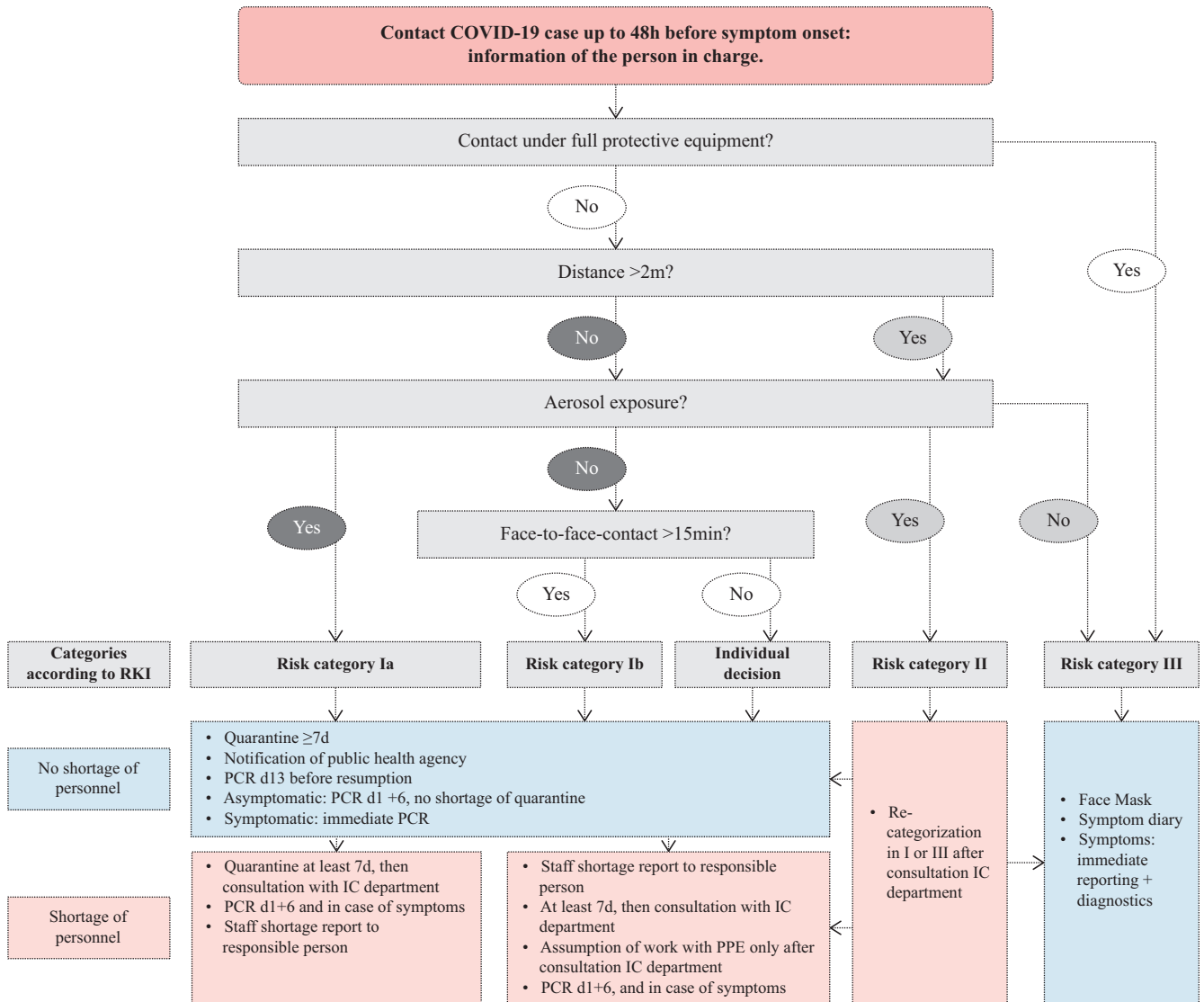


Figure 1. Decision on quarantine and further activities of HCWs depending on their exposure to SARS-CoV-2 (based on the recommendations by the Robert Koch Institute (RKI) Germany 2021). IC, infection control; PPE, personal protective equipment.

smoke gas-filters (acc. to ISO 29463 [45]) with a Luer-taper connection to remove smoke-gases by filtering.

- **Robotic-assisted surgery:** This allows further reduction of the number of surgeons and assistants in the high-risk field around the patient. Only the first assistant in the field of intervention is needed to change instruments, or for introducing a suture or swab into the operating field. The operator is working from a console positioned at any distance from the operating area.

Pre- and intraoperative assessment

- Any close contact with patients should include use of appropriate PPE.
- Preoperative antibiotic prophylaxis should be given according to accepted local guidelines. Selection and administration of preoperative antibiotic prophylaxis, to prevent SSIs, is not specifically related to SARS-CoV-2.

- Surgical face masks should be routinely replaced prior to each operation, if visibly dirty or moist and after 2 h of surgery.
- Observe correct hand hygiene when replacing masks.
- A number of precautions, in addition to normal practice, should be taken by the operative staff, including:
 - Prior to intubation, rinsing of the oral cavity with 1.25% aqueous povidone-iodine-solution (PVP-I), in combination with gargling if possible, should be considered; if PVP-I is contraindicated because of allergy or thyroid disorders, the combination of ethanol 21–27% with etheric oils may be applied [35,47],
 - Limiting movement and number of people and equipment in the OT should be encouraged with cautious use of electrocautery and parallel use of suction to remove smoke, labelling specimens, for example for histology, correctly using local regulations and bio-hazard precautions.

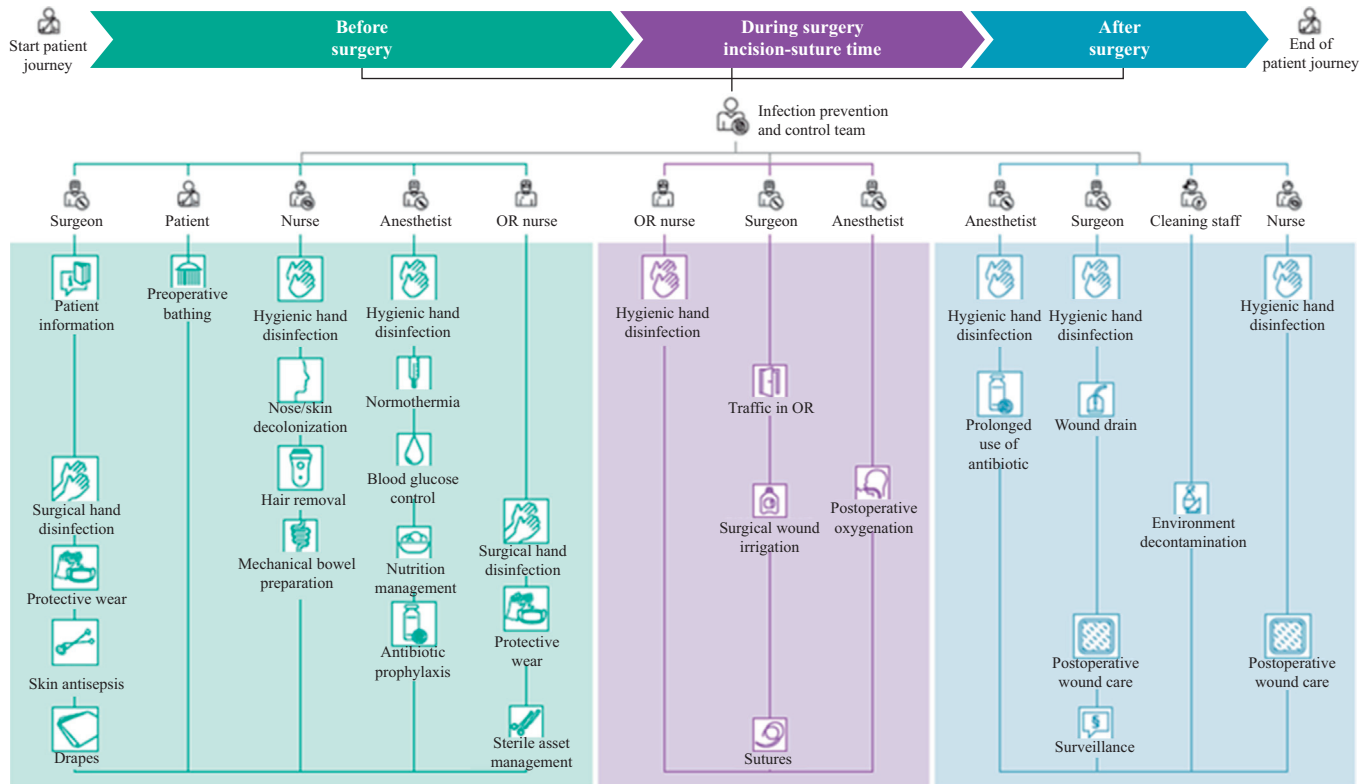


Figure 2. The surgical site infection pathway summarizes the measures to prevent surgical site infection.

- Decisions on the need for antivirals should be made, such as aqueous povidone-iodine–based formulations (according to the WHO April 2020 decision for inclusion of povidone-iodine-gargling solutions to the list of experimental treatments for COVID-19 [46], because gargle and mouthwash (PVP-I 1%) and throat spray (PVP-I 0.45%) are active against SARS-CoV-2 within 30 s [48].
- It is recommended, in regions with a high prevalence of COVID-19, that surgery on patients who have not been RT-PCR-tested for SARS-CoV-2, surgeons, and the entire surgical team who perform preoperative skin antiseptic and patient pre-operative draping, wear particulate filter respirators with an exhalation valve (filtering face piece FFP2, or FFP3). During intubation as well as extubation anaesthetists and anaesthetic nurses must wear an FFP3-respirator with exclusion of the surgical team.
- Once intubation or extubation are completed, the surgical team should wear class II surgical face masks and, if available, a face shield with a neck cover that wraps around the face with an extension which can be placed inside the gown, head protection and two pairs of gloves [48].

Behaviour in the ICU

- If using aerosol-generating procedures (including intubation, bronchoscopy, cardiopulmonary resuscitation, or suction), pre-procedural virucidal gargling and virucidal nasal antiseptics (spray) is recommended [35,47].
- Allow entry of essential staff only.

- Wear a particulate respirator (filtering face piece, FFP2 or FFP3) if available, together with gown, eye protection and gloves.

Postoperative Assessment

- Clean and disinfect personal/dedicated patient equipment between patients.
 - Remove any PPE (gloves, gown, mask, eye protection) using correct hand hygiene during any replacement. During the 2014 Ebola-outbreak, it became vitally clear to use a correct dress code, donning and doffing of PPE, to prevent infection.
 - It is recommended that members of the hygiene-team should be trained to use the dress/undress code of the PPE [32].
 - Dispose of viral-contaminated waste as clinical waste. Prevention of needle stick injury should involve use of suitable containers.

After discharge from hospital

- Provide instruction and materials to patients and caregivers on the continuous need for respiratory hygiene/cough etiquette, physical distancing as well as hand hygiene and mask-wearing principles.
- Provide advice on home isolation if necessary, infection control and limiting social contact, i.e. respect physical/social distancing.
- Record patient address and telephone number for traceability.

- All patients should wear an approved surgical mask class II postoperatively within the hospital.
- Include basic information about maintaining hygiene and monitoring incisional wounds as a routine part of discharge service.

Embedding protective measures to prevent SARS-CoV-2 transmission to surgical patients and the surgical team into the strategy of preventing SSI

All accepted measures for the prevention of SSI (the SSI-bundle approach) need to be undertaken consistently as usual, whether patients with confirmed or questionable COVID-19 infection are involved. This requires the implementation of general recommendations for the prevention of SSI provided by WHO, CDC, NHS and RKI [49–52], which are summarized in Figure 2.

Conclusions

The COVID-virus is here to stay. Different vaccines are available, but the protective effect is unclear, especially with the spread of new mutants. At present it is important to:

- avoid operating on any patient with COVID-19 (carrier, clinical suspicion or manifestly infected), if the situation allows
- prepare hospitals and staff for pandemic situations such as COVID-19 (emergency plans, training of nurses/doctors, establishment of isolated wards, etc.) – it is possible to provide safe surgical care for SARS-CoV-2-positive patients and to minimize nosocomial transmission [53–55].
- learn to live with and deal with COVID-19 without risking dramatic economic upsets.

Authors' contributions

O.A., D.L., N.T.M. and A.K. drafted the manuscript together with B.R. and M.G. M.G. has included experiences from a clinical 'hot spot-centre', C.K. from a surgical clinic.

Conflict of interest statement
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