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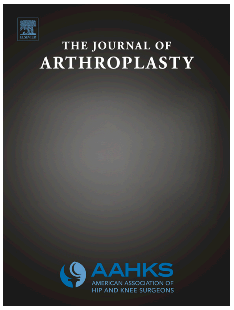

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Introduction

The date was September 28th, 1918. 200,000 Philadelphia and Pennsylvania citizens united to celebrate the end of World War I. It was the day of the Liberty Loan Parade, a government initiative to promote the new bonds being issued to pay for war-associated cost. Most of the city's population joyfully attended the event. Three days later, 635 of attendees of the event fell ill to what was assumed to be common flu. By six months, over 16,000 of the event participants had died, and a half million more were infected in Pennsylvania. [1–3] Such was the power and impact of the 'Spanish Flu' (H1N1) which remains one of the worst pandemics in our history. Based on some estimations, it killed over 50 million people around the globe [1]. Ironically, and within the context of current pandemic 102 years later, some lessons are being re-learnt.

While the outbreak of COVID-19, caused by SARS-CoV-2, does not appear to be on the same scale as the pandemic of 1918, it does share some of the same signatures of the "Spanish-flu" and, for that matter, some more recent pandemics. All of these pandemics were caused by a virus originating from an animal source and spreading amongst humans by droplets and/or contact with bodily fluids. [4]. The SARS-Cov-1 epidemic during 2002-2004, which started in China , was also caused by a coronavirus and killed 774 people with a 9% fatality rate [5]. In 2009, the H1N1 pandemic spread across the globe and killed over 18,000 people in the United States alone [6,7]. Then, in 2012, another fatal coronavirus, known as Middle East Respiratory Syndrome (MERS), hit the Arabic peninsula[8]. All of these outbreaks were similar to what we face today but occurred on a much smaller scale. The major difference between the current pandemic, caused by SARS-CoV-2, and those before it is that the current virus appears to be highly contagious. In fact, COVID-19 has already caused ten-times as many cases as SARS in a quarter of the time [9]. The SARS-CoV-2 virus can also infect some people without causing many, or any, symptoms and is capable of surviving on surfaces for a relatively long period of time. The aforementioned qualities of SARS-CoV-2 makes the current COVID-19 pandemic a truly challenging one to manage. Especially when considering that we live in an increasingly connected world that appears ideally suited for the rapid spread of diseases across countries and continents.

The medical community has been mindful of infection origination and pathogen transfer for centuries. As surgeons, we meticulously exercise the necessary steps to decrease the possibility of pathogen transfer and are acutely aware of the consequences of infection affecting our patients. Societies also have considerable knowledge regarding the importance of "breaking the chain of pathogen transfer". In the middle of 19th century, Ignac Semmelweis, known as the Saviour of Mothers, [10] recognized the personal chain of pathogen transfer and mandated hand-washing to disrupt this process. Quarantines have an even more remote history, dating back to 14th century[11]. In an effort to protect the coastal cities from diseases arriving on incoming boats, passengers were placed in isolation for a period of time and monitored for the presence of disease before being allowed to interact with the local community. All of the measures implemented to address the COVID-19 pandemic, which have been in practice in the medical and surgical community for centuries, are intended to break the chain of pathogen transfer. There is no doubt that this pandemic shall also pass and we will return to our "normal" lives. Many, however, believe that the new normalcy will have different features than what was present prior to COVID-19. Our profession will also witness changes in everyday routines that will be necessary to overcome the issues with the current pandemic and diminish the scale and gravity of future epidemic/pandemics. As we prepare to emerge from this pandemic and contemplate resuming our practices, we are faced with the ever-pertinent question of what changes will we need to implement in our daily routines. This article is written, with reliance on available evidence from the past and the current events, to provide some guidance on strategies that may need to be implemented to disrupt the chain of pathogen transfer. These strategies may also translate to a reduction in the rate of surgical site infections in the future.

Resuming Elective Arthroplasty

There will come a day, hopefully in not so distant of a future, when the current pandemic subsides and elective surgical procedures are resumed. The decision of when to re-start elective procedures will be a complicated one being affected by societal, political, geographic, economic and health related factors. Once such normalcy resumes, we have to entertain the major question of what changes we will need to introduce in our practices to prevent the spread of SARS-CoV-2 from infected hosts to others. We will also need to be cognizant of the potential for re-infection with the virus and the emergence of a second wave.

While any discussion regarding a SARS-CoV-2 'reinfection' remains theoretical, a few recent articles have raised this possibility [12,13]. If such a phenomenon is indeed possible, three distinct explanations exist. First, patients who contract the disease do not develop lasting immunity against the virus and are just as vulnerable as those without a prior infection in contracting the disease. Second, there are issues with the accuracy of the test, with false positives and false negatives existing. So, it is possible that some of these presumed reinfections are a result of the re-test being a false negative result which was incorrectly interpreted as **the** individual being declared as "cured". Finally, it is plausible, and indeed scientifically proven [14–17], that viruses undergo marked genetic mutations, even during an active pandemic. Hence those infected with the virus develop partial immunity and are still vulnerable for infection with the 'new' mutated version of the virus [14–17]. We are familiar with the concept of partial immunity as it relates to the flu-vaccine, as it affords only 60-70% immunity against the disease in any given year [18]. Based on scientific data, the genetic footprint of the initial SARS-CoV-2 affecting individuals in Wuhan is different than the RNA sequence of the virus affecting people in other countries [19]. The virus has certainly undergone mutation. In fact, these mutations likely explain why some epidemics come to an abrupt end as the continued viral alterations may revoke the virulence of the pathogen.

So, without an effective vaccine against the virus, and without an absolute test for detection of the disease, we need to assume that every patient under our care, and for that matter healthcare personnel around us in the hospitals, are potential carriers of the virus and capable of spreading the infection. The latter does not imply that we should not insist on large scale testing of every individual who comes out of social isolation and enters the society. The medical profession is aware of the importance of "screening" patients for a condition or a disease. Identifying carriers of a pathogen is critical step in disruption of the chain of transfer.

Disrupting the chain of pathogen transfer

Infection, either viral, bacterial or fungal, can be transferred from one individual to another through air (droplets), direct contact with skin or bodily fluids or contact with a surface harboring the pathogens. Here, we summarize the importance of good practices that are known to be effective in disrupting the chain of pathogen transfer. We are aware that there remains many unknowns regarding COVID-19 and excited that the scientific discoveries and innovations arising from the current pandemic will serve the society in general, and healthcare profession in particular, for years to come.

Patient screening.

To determine the risk of a patient being infected with SARS-COV-2, all patients scheduled for elective surgery should be screened for symptoms and exposure. Symptoms of infection include fever, sore throat, cough, and anosmia are common with a COVID-19 infection. Patients should also be asked if they have been exposed to anyone with known COVID-19 infection or anyone with symptoms of COVID-19 to determine the risk. Furthermore, the rate of infection in the community will be important as well as a patient's history of travel from a region with known high rates of COVID-19 infection.

Routine screening of nasopharyngeal swabs or throat swabs by PCR (polymerase chain reaction) to detect viral genetic material is subject to false positive and false negative results, and is therefore not indicated in low-risk patients. Serological tests for IgG and IgM are not currently widely available but may become useful tools to determine the patient's status. There is limited data on their accuracy and they are not regulated in the same manner as more standard antibody tests at this time so enthusiasm for these tests need to be tempered. All of these tests will undergo further refinements as we continue to expand our knowledge regarding immunity to COVID-19. We believe that questions regarding who should be screened and what screening should be in place is a pertinent one. Most, if not all, institutions will need to have access to a rapid turnaround test for COVID-19. A point of care test is currently available and should be utilized for emergency cases. Industry has also been able to develop special swabs that can be used to detect the presence of SARS-CoV-2 in the oral cavity, eliminating the need for more invasive nasopharyngeal swabs for testing.

Prevention of transfer through direct contact

Direct contact with an infected host is also a major pathway for the spread of pathogens. Thus, wearing protective gloves and gowns by all in the OR should be routine. Furthermore, scrub changes should be frequent throughout the day. Again, without a widespread screening mechanism in place for COVID-19, it is impossible for us to determine who is 'safe.' Another mechanism to glean information about the status of a patient would be the use of an antibody testing to identify those who had contracted the disease and developed immunity.

Prevention of spread in the air

Aerosolized particles have proven to be a mechanism of spread of SARS-CoV-2[20]. Aerosolization of virus particles usually does not occur with breathing or talking but some procedures in the operating room may cause aerosolization of virus particles. Droplets are expelled during talking and breathing but these usually do not become aerosolized and land on surfaces within a few minutes. Patients undergoing elective arthroplasty should be supplied with a simple surgical mask that will prevent the spread of droplets carrying the virus. Personal protection equipment (PPE) should be available to all the healthcare workers and should focus on masks that are able to filter any pathogen, while allowing for enough comfort to be worn for a substantial length of time. We, as surgeons, and healthcare workers in general, should also be fitted with such masks.

It is fortunate that the majority of arthroplasties are performed under regional anesthesia. Intubation of patient can cause aerosolization of a large number of particles in the upper airways and particular caution should be taken with this procedure when there is a risk that the patient may be carrying SARS-COV-2. Anesthesia teams dealing with patients who require general anesthesia and airway management should be fitted with secure personal protection equipment (PPE). As orthopaedic surgeons, we use power tools (drills, saws, etc.) that releases aerosolized material [21] containing blood, bone and fat tissue. The amount **of** virus particles in these tissues **is** not known but these instruments could potentially aerosolize virus particles in the operating room. In patients who are positive for the virus, when surgery cannot be delayed, the power settings should be as low as possible, and suction devices should be carefully handled to remove any aerosol formation [22]. This may include suction fitted to electrocautery devices or sterile towels dropped over cutting surfaces to potentially decrease the amount of aerosolized.

In cases of known SARS-CoV-2 positive patients, surgeons and other healthcare workers should also have ventilation systems that are able to filter and capture SARS-CoV-2, as well as other bacteria and fungi. These systems can be used outside of the operating area but should be present in every operating room. Given that coronaviruses are approximately 0.125 mm (125 um) in diameter [23] high-efficiency particulate air (HEPA) filters might be one possible solution. [24] Thus, filtration of the operating room with devices that intake the air and remove the micro-organisms may be preferable to the positive pressure laminar flow settings. Negative pressure operating rooms will reduce the risk of virus particles being forced out of the room into the corridors.

The current surgical helmets (by Stryker and Zimmer-Biomet, for example) are not protective against spread of virus, as learnt during the 2012 SARS epidemic. They are designed to protect the user against splash back and can actually pull and condense sub-micron particles within the hood system [25]. All reusable material should also be sanitized or sterilized at the conclusion of each procedure. Tests on the proper length of use for each mask and eventual reusing, should be performed to provide evidence-based guidelines to medical staff. Many questions remains: How long we should wear the mask?; How often should we change the masks?; Can the masks be sterilized and safely reused? And many others still remain unanswered. Further data is needed in order to provide evidence-based recommendations on these issues.

Decontamination of Surfaces

Every pathogen is capable of surviving on inanimate surfaces for a period of time [26]. We have come to understand that SARS-CoV-2 is a robust virus capable of surviving on the surfaces of metal and plastic for up to a few days and is not easily removed by standard air filtration systems [20,27,28]. Thus, another approach to disrupt the chain of pathogen transfer needs to concentrate on the decontamination and sanitization of inanimate and skin surfaces. One agent that has been demonstrated to be viricidal, including activity against coronaviruses, is dilute povidone iodine [29–31]. Dilute povidone iodine was tested against SARS, MERS and Ebola and found to have absolute efficacy. Other agents with potential activity against viruses, as well as bacterial and fungal pathogens, includes hypochlorite and high-concentration alcohol. Thus, it is crucial that all reusable material in the OR, that includes helmets, lead aprons, tourniquets, X-ray machines, navigation consoles, keyboards, screens and robots be sanitized and decontaminated routinely. The current sterilization systems in the hospitals for instruments and trays are effective in eliminating viruses and may not need to be altered. We may, however, need to implement a practice that requires these instruments to be placed in a bath of antiseptic solution during the procedure to prevent potential contamination. We must also be aware that there is a wide variation in the terminal cleaning of the operating rooms across the globe. Effective infection prevention and viricidal protocols need to be implemented in every operating room and arguably in every patient room after discharge.

Conclusion

The current pandemic has taken us into uncharted territories. The economic and health impact of this pandemic may be irreversible and will be felt for years to come. While we mourn the loss of lives to this pandemic, society needs to prepare for the eventual lift of social isolation and attempt to return to normalcy. As our knowledge of this pathogen expands and we continue to work towards an effective vaccine and potential treatments for SARS-CoV-2, further strategies for the disruption of the chain of pathogen transfer needs to implemented. We have attempted to highlight some of the changes that arthroplasty surgeons will need to instigate now and when elective arthroplasties are resumed (**table 1**). While SARS-CoV-2 may be a novel pathogen, the actions needed to protect ourselves and our patients against the pathogen are not. The medical community and, more specifically, orthopedic surgeons have been acutely aware of the devastating impact of infections for centuries. We, as **a** medical community, have always been in the forefront of developing infection prevention protocols and implementing evidence-based strategies to combat these pathogens. Our fight against the COVID-19 will be no different. The ultimate changes that we implement as a result of this pandemic stand to serve our patients and the society well for years to come and help us all safely return to caring for our patients.

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SURGICAL STEP	SUGGESTED ACTION
WAITING ROOM	These should not be used. Family members can be called when the surgery is complete and should not enter or wait within the hospital unnecessarily.
CHECK-IN	A form of 'mobile' check-in would be preferable where the patient can call the desk and, when the staff is ready, be escorted directly to their pre-operative holding area room and provided a mask. Patients would ideally not stop at a 'front desk.'
PRE-OPERATIVE HOLDING AREA	Registration would ideally take place here before each patient prepared for surgery. All beds should be adequately spaced. If curtains separate beds, they should be cleaned after each patient.
OPERATING ROOMS	Each operating room would ideally have its own air-handling system to minimize air-based contamination and consider using high-efficiency particulate air (HEPA) filters. Minimize the number of people in the room. Minimize non-sterile equipment such as X-ray machines, navigation consoles and robots as virus may last up to 72 hours on these surfaces.
ANESTHESIA	Spinal anesthesia should be used preferentially over general anesthesia to decrease aerosolized particles from each patient within the operating room.
SURGICAL HOODS/HELMETS	Surgical helmets/hoods should be modified for increased protection against viruses for those wearing these systems. Alternatively, operating room personnel can eschew the helmets/hoods and use a N-95 mask and face shield in their place.
FORCED-AIR WARMING SYSTEM	These devices should be used with caution as they may increase the distribution of aerosolized particles during the case. Blankets may be more effective at decreasing particulate generation and distribution.
SCRUBS	Scrubs should be changed frequently, potentially after each patient.
ROOM TURNOVER	Each room should be cleaned between cases with solutions such as dilute povidone-iodine and alcohol that are effective against viruses and other pathogens.
POST-ANESTHESIA CARE UNIT	All beds should be adequately spaced. If curtains separate beds, they should be cleaned after each patient. Patients who are not going home on the same day should be brought to their hospital room expeditiously.
HOSPITAL STAY	If patients can be safely discharged on the same day as their surgery, they should be sent home. Protocols should be in place to facilitate this process and patients and their families should be educated of this policy prior to undergoing their total joint arthroplasty.
'ROUNDS'	Telemedicine should be used to 'round' on the patients post-operatively to limit direct contact.

Table 1: Common steps for the surgical procedure and recommendations for decreasing the potential viral load for each step.