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Standard operating procedure of image-guided intervention during the COVID-19 pandemic: a combined tertiary musculoskeletal oncology centre experience



R. Rajakulasingam^a, E.J. Da Silva^b, C. Azzopardi^c, T. Fernandez^d,
R. Botchu^{c,*}, R. Hargunani^a

^a Department of Radiology, Royal National Orthopaedic Hospital, Brockley Hill, Stanmore, Middlesex, London HA7 4LP, UK

^b Department of Anaesthetics, Royal Orthopaedic Hospital, The Woodlands, Bristol Road South, Birmingham B31 2AP, UK

^c Department of Radiology, Royal Orthopaedic Hospital, The Woodlands, Bristol Road South, Birmingham B31 2AP, UK

^d Department of Anaesthetics, Royal National Orthopaedic Hospital, Brockley Hill, Stanmore, Middlesex, London HA7 4LP, UK

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AIM: To evaluate the response measures in continuing an image-guided intervention service in two tertiary-level musculoskeletal oncology centres during the COVID-19 pandemic.

MATERIALS AND METHODS: This study was a retrospective review of all patients undergoing image-guided intervention in the computed tomography (CT) and normal ultrasound (US) rooms from 24 March 2020 to 24 May 2020 (during the COVID-19 pandemic peak) at Royal National Orthopaedic Hospital, London, and Royal Orthopaedic Hospital, Birmingham, UK. Measures were put in place to address air pressures, airflow direction, aerosol generation, and the safe utilisation of existing scanning rooms and work lists for interventional procedures.

RESULTS: Three hundred and thirty-one patients (164 at Royal National Orthopaedic Hospital and 167 at Royal Orthopaedic Hospital) underwent image-guided procedures at both sites in the CT and US rooms. At the Royal National Orthopaedic Hospital, 40% of all procedures were performed under general anaesthesia. These consisted of 47 CT biopsies, 7 CT radiofrequency ablations (RFAs), and 12 US biopsies. At the Royal Orthopaedic Hospital, 86% of all procedures were performed under local anaesthetic, with no general anaesthetic procedures. These consisted of 61 CT biopsies and 83 US biopsies. All 256 patients having procedures in the CT room had no post-procedural complications or COVID-19-related symptoms and morbidity on follow-up.

CONCLUSION: By adopting a pragmatic approach with meticulous planning, a limited, but fully functional image-guided interventional list can be run without any adverse patient outcomes.

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* Guarantor and correspondent: R. Botchu, Department of Radiology, Royal Orthopaedic Hospital, The Woodlands, Bristol Road South, Birmingham B31 2AP, UK.

E-mail address: rajesh.botchu@nhs.net (R. Botchu).

Introduction

The COVID-19 pandemic is unlike anything seen before in modern day medicine, placing enormous strains on healthcare systems worldwide. Although not seemingly frontline, radiology services have been greatly affected with a significant decline in imaging capacity.

Within this context, there has been a change to workload and working patterns in radiology departments across all National Health Service (NHS) hospitals, including curtailing all elective work, home reporting, and reduction of referrals and virtual attendance at multidisciplinary team (MDT) meetings. Despite this, essential imaging and procedures in the setting of a tertiary level musculoskeletal oncology service have still continued. The Royal College of Radiologists (RCR) has recently published guidance stating that urgent interventional procedures remain one of the patient categories for which services should continue.¹ Musculoskeletal-related soft-tissue and bone sarcoma patients referred to specialist centres remain a protected pathway throughout the pandemic, with a view to avoid treatment delay, which could have a detrimental effect on outcomes and survival for cancer patients.

Aerosol-generating procedures (AGP) have been defined by Public Health England (PHE) as procedures that may generate higher concentrations of infectious respiratory aerosols than coughing.² Endotracheal intubation, a component of general anaesthesia (GA) for many biopsy patients is considered an AGP.³ Clearly, if no precautions were taken, there would certainly be a higher probability of patients contracting COVID-19 with unforeseen consequences. Bearing this in mind, it was decided to assess the safety of the current set-up for image-guided intervention at the Royal National Orthopaedic Hospital and Royal Orthopaedic Hospital. The decisions made were reviewed retrospectively in order to continue a fully functional but somewhat limited sarcoma biopsy and intervention service across both sites.

This study outlines considerations related to airflow exchanges and the need for adequate extraction ventilation to involve. We will also briefly discuss changes to the biopsy worklist, workflow pattern, and personal protective equipment (PPE). The intricacies of GA induction will not be discussed. Finally, the number of cases performed at each site and any complications at follow-up are present. The aim of the present study was to evaluate and explain the rationale behind the approaches taken at both institutions to continue with urgent diagnostic interventional procedures, whilst ensuring low viral transmission risk to patients and staff.

Although most elective work has been halted across the country, the authors' combined experience demonstrates that it is possible to offer a safe image-guided intervention service as long as all the necessary precautions are taken.

COVID-19 testing

Throughout March, April, and May 2020, widespread hospital testing for COVID-19 was not available routinely for

staff or patients at either site. At the time, nasopharyngeal swabs would only be taken for symptomatic patients and staff according to the Department of Health (DOH) NHS guidance.⁴ If symptomatic, patients were advised to complete isolation for 2 weeks prior to having the procedure and await swab test results. Given the current testing policy at the time, it was possible that performing interventional procedures on asymptomatic patients could cause virus transmission. Both radiology departments adopted the policy of treating all patients as if they were COVID-19 positive. Thus, PPE as per DOH guidelines was used by the radiologist and anaesthetic team at all times.

PPE

At the Royal National Orthopaedic Hospital, three people would generally wear full PPE at all times: the anaesthetist, CT radiographer, and radiologist. These would be put on before the patient was brought inside the CT room where the intervention would take place. The second radiographer not wearing PPE would be in the control room where images showing the biopsy approach can be viewed. At the Royal Orthopaedic Hospital, three people would also wear full PPE at all times: the anaesthetist, operating department practitioner, and the radiologist. The radiographer would be in the control room at all times and assist with image viewing on the CT monitor.

For GA cases, full PPE was worn in the form of a filtering face piece respirator and eye protection in accordance with RCR guidelines.⁵ Anaesthetists followed their relevant Royal College-based guidelines, depending on the case type.^{6,7} Sedation according to PHE is, however, not considered AGP. Thus full PPE as mentioned above was not a requirement, and a surgical gown with facemask and gloves sufficed^{2,3}; however, the radiologist and anaesthetist carrying out the procedure often felt safer wearing full PPE, and so personal preference for sedation procedures was usually the deciding factor. This is understandable, as in theory, sedation cases could be upgraded to full GA and wearing full PPE avoided any potential problems removing and putting on new PPE.

CT biopsy work list changes

The potential for viral transmission brought about many logistical challenges that needed to be addressed. At both sites, consent would be routinely done on the ward, rather than in the imaging department itself. At the Royal National Orthopaedic Hospital, all CT-guided procedures were undertaken by one consultant radiologist. At the Royal Orthopaedic Hospital, a consultant or radiology fellow were present with preferably only one person in the room. A 45 minute to 1 h turnaround time slot was allocated between each patient. This ensured enough time for removal of any contaminated items and allowed a deep clean of the whole CT room.

The patient was taken back into the recovery room at the end of the procedure for extubation. In accordance with the Centers for Disease Control and Prevention (CDC)

guidelines, the room was also left empty for at least 21 minutes after the patient had left the department to ensure enough air exchanges had taken place.⁸ This was felt sufficient to remove 99.9% of any potential airborne contamination.

Given the time needed for deep cleaning and minimising potential viral transmission, the biopsy list was limited to a maximum of four GA cases at the Royal National Orthopaedic Hospital. At the Royal Orthopaedic Hospital, usually one sedation case per list was performed with roughly two to three local anaesthetic (LA) cases. The overall numbers were greatly reduced during the pandemic period; normally, eight to 10 cases would be listed on a fully functional list at either site. All cases to be listed were discussed the week before within a sarcoma MDT setting ensuring they were urgent and could not wait until after the COVID-19 pandemic peak. All non-urgent cases were deferred.

Air exchange and flow

The coronavirus is mainly transmitted by respiratory droplets with some evidence for airborne transmission.^{2,3} The act of airway securement itself does not produce aerosols, rather it is coughing during induction or extubation where viral transmission can occur.^{2,3} Aerosols could also be produced by other means during the peri-intubation period, such as delivering high-flow oxygen or suction. In general, intubation represents a very high-risk moment for contact or droplet transmission, and so, is regarded as a high-risk procedure.

The virus particles are too small (<5 µm) to be contained by even the best air filters. Thus unlike larger droplets, which may just evaporate within milliseconds, the coronavirus can remain suspended in air for up to 3 h within normal indoor conditions and on surfaces for a few days.⁹ If potential AGPs are required, ventilation systems should exist that permit extraction, increasing air-exchange rates, and allowing as much outside air circulation into the area of concern. The Health Technical Memorandums released by the DOH stated that operating rooms should have a minimum of 10, with the ability to increase to 15 air exchanges per hour (ACH) for high-risk patients.¹⁰ Interestingly, no specific guidance for radiology interventional suites is stated, but both departments agree that a minimum of 15 ACH should be used, as stated for minimal access interventions elsewhere.¹¹ The ACH is designed to supply a high rate of clean (filtered) air for interventional procedures reducing infectious risk. In addition, satisfactory 2 m distancing between all involved health professionals needed to be adhered to within the interventional room.

As well as appropriate air-exchange rates, a negative-pressure environment was ideally needed.¹² Although in principle a room with adequate air changes could quickly eliminate the virus, an adjacent negative pressure meant that all contaminated air was kept within the environment reducing dispersion. This in theory meant that health personnel were at increased risk of direct virus contact; hence, strict PPE adherence was required.

Materials and methods

A physical air-quality monitoring report was commissioned by The Royal National Orthopaedic Hospital and provided by the East and North Hertfordshire NHS Trust Quality and Control department after visiting the Royal National Orthopaedic Hospital scanning centre. The layout of the CT suite and neighbouring rooms with measured air pressures and ACH is illustrated in Fig 1. Unfortunately, the existing CT room did not have an extraction ventilation system and was deemed unsuitable for GA induction. Fortunately, the adjacent MRI preparation room across the corridor measured 21 ACH and could be used. Being the only adjacent room with the requisite ACH and pre-installed ventilation extraction system, a decision was made to carry out all GA inductions in that room. Outside air was introduced into the room, and room air was extracted through flap vents located throughout the ceiling.

There was also a requirement for the corridor immediately outside this preparation room to have a pressure of minimum -5 Pa,¹² this fortunately measured -6.5 Pa. Following consultation with the infection control team, it was deemed safe to transfer patients from the MRI preparation room, across the small corridor, and into the adjacent CT room. Fortunately, the natural pressure gradient already in the corridor meant that no further adaptation or installation was needed.

At the Royal Orthopaedic Hospital, the Estate and Facilities Department commissioned a company to undertake airflow tests in the CT room. Again, no extraction ventilation system was present with less than required minimum number of ACH; however, unlike the Royal National Orthopaedic Hospital, there was no neighbouring room with adequate ACH and no method of maintaining a negative pressure environment. Ultimately, a decision was made to stop performing all GA biopsy cases; however, the CT room was still deemed safe for LA, sedation, and regional anaesthesia. Cases suitable for sedation or regional anaesthesia would be fully discussed between the consultant radiologists and anaesthetists, usually after meeting the patient on the day of the procedure.

This retrospective study was approved by the Local Research and Innovation Centre of the Institute of Orthopaedics (IRAS 262826) as well as the Research Ethics Committee, with permission granted for patient telephone consultation. A search for all image-guided procedures in the CT and US rooms were carried out at both sites using the appropriate radiology information systems. A 2-month time period from 24 March to 24 May 2020 was used, with the chosen dates accurately reflecting changes in radiology practice during the peak of the COVID-19 pandemic. Procedures carried out in the CT room at the Royal National Orthopaedic Hospital included CT-guided biopsies, CT-guided radiofrequency ablation (RFA), and US-guided biopsies. In addition, CT-guided vertebroplasty was performed at the Royal Orthopaedic Hospital. Although the majority of biopsies performed were for bone and soft-tissue sarcoma, this was not exclusively the case.

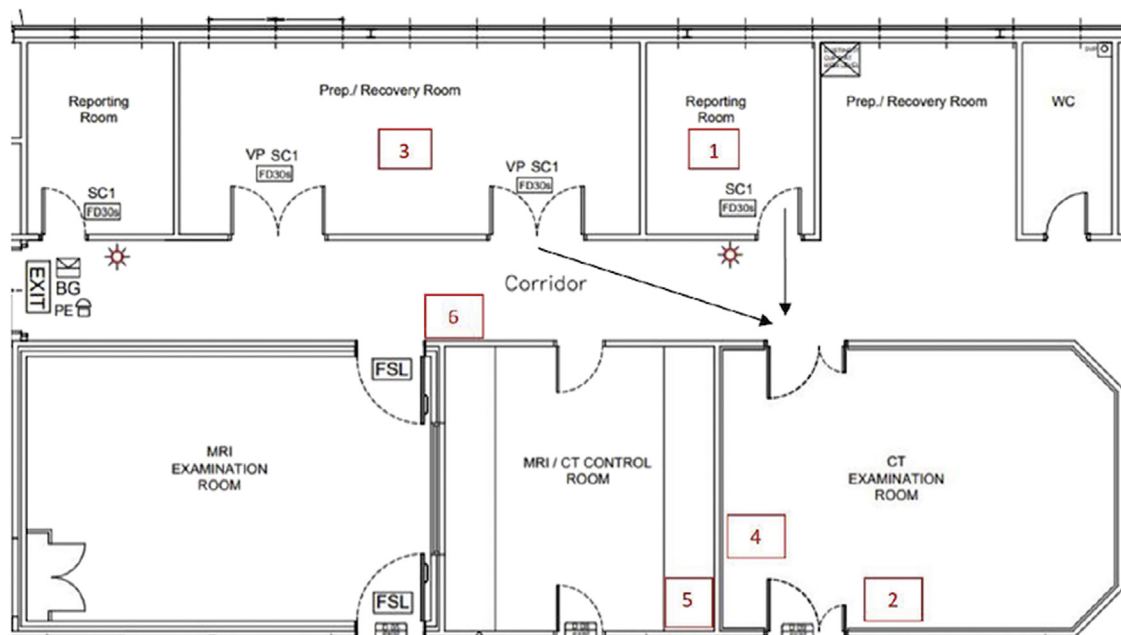


Figure 1 Schematic highlighting the layout and adaptations made to the Royal National Orthopaedic Hospital imaging department during the COVID-19 pandemic. Full anaesthetic PPE was donned at location 1 (old reporting room). The radiologist would don their PPE at location 2 in the scanning room where the sink is located on the side wall. Endotracheal intubation/extubation was performed in location 3 (preparation room) where ceiling extraction flap vents were pre-installed. This provided adequate air exchanges (21 ACH) and a -6.5 Pa pressure gradient relative to the adjacent corridor. If images needed to be viewed, a designated zone was set up in the control room for the scrubbed radiologist, location 5. The radiologist would remove their gown at location 4. Upon leaving the room, the facemask and visor would be disposed of at location 6 in accordance with PHE guidance.

Biopsies to exclude osteomyelitis and discitis were also carried out across both sites. It should be noted that image-guided steroid injections were not being performed at this time in accordance with recommendations set out by the British Society of Skeletal Radiologists.¹³ Patient data was reviewed by one radiology fellow at Royal National Orthopaedic Hospital and one consultant radiologist at Royal Orthopaedic Hospital. The hospital computer system and radiology information systems at both sites were used to check for any pre- or immediate post-procedure complications.

All patients having a procedure in the CT room at both sites were contacted at least 1 week after the procedure (average 2 weeks). This happened via direct telephone consultation at the Royal National Orthopaedic Hospital and normal orthopaedic/specialist nurse follow-up at the Royal Orthopaedic Hospital. Any COVID-19-related respiratory symptoms that the patient or immediate household family developed following the procedure were recorded. The questions used were taken from the COVID Symptom Study mobile application designed by Kings College, London.¹⁴

Results

A total of 331 patients underwent image-guided procedures at both sites from 24 March to 24 May 2020

inclusive, 164 at the Royal National Orthopaedic Hospital and 167 at the Royal Orthopaedic Hospital. At the Royal National Orthopaedic Hospital, 89 procedures were undertaken in the CT room (66 CT biopsies, seven CT RFAs, and 16 US biopsies), while 75 US-guided biopsies and an additional 148 purely diagnostic US studies were performed in the usual US room (Table 1). At the Royal Orthopaedic Hospital, all 167 procedures were undertaken in the CT and adjacent fluoroscopy room (77 CT biopsies, six CT RFAs, one CT vertebroplasty, and 83 US biopsies; Table 2). Ninety diagnostic US studies were performed at the Royal Orthopaedic Hospital during this time in the US suite.

Table 1

Details of the 164 total procedures performed at Royal National Orthopaedic Hospital.

Anaesthesia	CT biopsy (n=66)	CT RFA (n=7)	US biopsy- in CT room (n=16)	US biopsy- in usual US room (n=75)
GA	47	7	12	0
Sedation	12	0	2	0
Regional	0	0	0	0
LA	7 ^a	0	2 ^b	75 ^c

CT, computed tomography; RFA, radiofrequency ablation; US, ultrasound, GA, general anaesthesia; LA, local anaesthesia.

^a Four cases were converted from CT GA to CT LA.

^b Two cases were converted from US GA to US LA.

^c All cases performed in the normal US room. In addition, 148 diagnostic US studies were undertaken.

Table 2
Details of the 167 total procedures performed at Royal Orthopaedic Hospital.

Anaesthesia	CT biopsy (n=77)	CT RFA (n=6)	CT vertebroplasty (n=1)	US biopsy (n=83)
GA	0	1 ^a	0	0
Sedation	14	6 ^b	1	0
Regional	2	6 ^b	0	0
LA	61	0	0	83 ^c

CT, computed tomography; RFA, radiofrequency ablation; US, ultrasound, GA, general anaesthesia; LA, local anaesthesia.

^a In one RFA case, sedation and regional anaesthesia was inadequate and general anaesthesia undertaken.

^b All RFA cases had regional anaesthesia and sedation.

^c In addition, 90 diagnostic US studies were undertaken.

At the Royal National Orthopaedic Hospital, 40% ($n=66$) of all procedures were performed under GA. This consisted of 47 CT GA biopsies, seven CT RFA procedures, and 12 US GA biopsies. Fifty-one percent ($n=84$) of all procedures were done under LA, consisting of seven CT LA biopsies, two and 75 US biopsies in the imaging room and normal US room, respectively. Forty-six percent ($n=75$) of all procedures performed consisted of US LA biopsies performed in the normal US room, well away from the CT room. Fourteen cases under sedation were performed, 12 under CT and two under US. Four CT GA biopsies were converted to LA on the day of the procedure after reviewing the images and discussing with both the anaesthetist and patient. Two US GA biopsies were converted to US LA, also on the day of the procedure.

At the Royal Orthopaedic Hospital, 86% ($n=144$) of all procedures were performed under LA. This consisted of 61 CT LA biopsies and 83 US LA biopsies. Six CT-guided RFAs were carried out both under regional block anaesthesia and sedation. In one RFA case, sedation and regional block was not sufficient and full GA was required with endotracheal intubation.

Table 3 highlights the exact numbers and breakdown of cases performed during the 2-month period of the COVID-19 pandemic peak and the same dates in 2019. Of note, there was a 34% and 35% reduction in the number of CT biopsies performed during this period at the Royal National Orthopaedic Hospital and Royal Orthopaedic Hospital, respectively, compared with 2019. All 256 patients having biopsies or other procedures in the CT room were followed up at both sites. None of the patients had COVID-19-related morbidity.

Table 3
Comparison of numbers of procedures during COVID-19 pandemic and corresponding dates in 2019 at both sites (24 March to 24 May inclusive).

	Royal national orthopaedic hospital		Royal orthopaedic hospital	
	2020	2019	2020	2019
CT biopsy	66	100	77	118
CT RFA	7	12	6	9
CT vertebroplasty ^a	0	0	1	0
US biopsy	16	54	83	61

CT, computed tomography; RFA, radiofrequency ablation; US, ultrasound.

^a CT vertebroplasty is performed at Royal Orthopaedic Hospital only.

Discussion

The scope of interventional radiology has evolved dramatically in the past 50 years especially within a tertiary-level musculoskeletal oncology service. Image-guided biopsies in such centres are usually the main investigation performed to obtain a histological diagnosis for bone and soft-tissue sarcoma. Given its importance, it is surprising that ventilation systems in most CT rooms still lag behind those in operating theatres. This likely reflects the fact that the biopsies are done within the CT room itself rather than a true dedicated interventional suite. Moreover, bone sarcoma biopsies were traditionally performed under X-ray guidance and only more recently under CT.

The main source of potential coronavirus airborne contamination is the skin of personnel moving within the procedure room. In operating theatres, airborne virus particles can be diluted by supplied air, with air then flowing to less sensitive areas. In addition, studies have shown that the airborne microbe counts increase with the degree of movement and personnel numbers,¹⁵ supporting the decision to have only one radiologist and anaesthetist physically present in the scanning room. The principle of modern theatre ventilation is to remove airborne contamination generated in the room and to prevent the ingress of contaminated air from surrounding areas. A dedicated extraction system actively supplies relatively clean air into the room faster than excess air can be removed passively.

For minimal access interventions, guidelines state that the procedure room should be ventilated mechanically to achieve 10–15 ACH with a pressure differential of at least 5 Pa to maintain this condition.^{10,11} Although the CT room at the Royal National Orthopaedic Hospital provided insufficient air changes, the adjacent MRI preparation room had a pre-installed extraction system with a measured 20.9 ACH and pressure differential of –6.5 Pa relative to the corridor. Thus, GA induction could be performed here prior to CT room transfer. Once a breathing circuit filter had been placed to provide protection during disconnection of the airway circuit, the patient was transferred across into the scanning room where the biopsy itself was performed.

Similarly, at the Royal Orthopaedic Hospital, there was no dedicated ventilation system within the CT room and insufficient ACH. Furthermore, the adjacent rooms also had no appropriate extraction systems. Thus, a decision was made to stop performing all GA cases at Royal Orthopaedic Hospital, with only sedation and LA being utilised. It should be noted that sedation unlike endotracheal intubation is not an AGP and so deemed safe to proceed in the scanning room itself. Studies have shown how operating rooms can be adapted to obtain a negative pressure gradient but the time constraints and general set-up within the NHS meant this was not feasible.¹⁶

The differences in the available ventilation set-ups account for the main results across both sites. At the Royal Orthopaedic Hospital, only one sedation case per session would be performed with the majority of the list taken up with US LA cases. At the Royal National Orthopaedic

Hospital, the list mainly contained GA cases, a small minority of which would be converted to sedation or LA on the day itself. With a clear decision not to perform any GA cases at the Royal Orthopaedic Hospital, all outstanding cases were reviewed by the radiology team in the weekly sarcoma MDT and decided whether sedation or LA would be appropriate. The large number of CT LA cases at the Royal Orthopaedic Hospital reflects this approach, which was not necessary at the Royal National Orthopaedic Hospital given that a functional GA list (albeit with less capacity) could still be run. A similar number of sedation cases were done at both sites.

There was a concerted effort across both sites to convert some GA cases to sedation if at all possible to avoid intubation. In fact, certain radiologists and anaesthetists preferred this approach. CT RFA for osteoid osteoma was not undertaken initially, and was only slowly phased in during the last few weeks of May at both sites. This is understandable given that although it is potentially very symptomatic, it is not life threatening; however, the necessary PPE precautions and protocol changes had been fully established during the month of May. Moreover, both sites had a relatively low number of known COVID-19-positive cases meaning that with the necessary precautions, such cases could be performed. RFA should be performed under GA ideally, with one case at the Royal Orthopaedic Hospital converted from a regional block with sedation to GA. As routine practice, all RFA patients are contacted by telephone a few weeks after the procedure to highlight any change in symptoms. No COVID-19-related morbidity was detected.

One hundred and forty-eight diagnostic US studies were performed at the Royal National Orthopaedic Hospital and 90 at the Royal Orthopaedic Hospital. These all constituted imaging related to sarcoma patients, e.g., exclusion of deep vein thrombosis (DVT), skin marking of small tumours, assessing incidental findings, and primary tumours.

The number of procedures at both sites reflect a functional, but somewhat limited, service designed to only biopsy the most necessary and urgent cases. It should be noted that at the Royal National Orthopaedic Hospital, two extra sessions not usually timetabled were arranged to undertake a biopsy list. Despite travel restrictions during lock-down, performing urgent procedures at a specialist centre is considered best practice to increase the likelihood of a diagnostic biopsy. Thus, no urgent cases were referred back to the local hospital during this study period. Interestingly, when comparing data using the same study dates in 2019, there was a 34% and 35% reduction in the number of CT biopsies performed during this period at the Royal National Orthopaedic Hospital and the Royal Orthopaedic Hospital, respectively compared with 2019. Although this reflects the current reduced intervention service, the current workload demonstrates that a sizeable proportion of this vital patient pathway can be maintained. In addition to a curtailed list, differences in work output may be partially explained by patients not presenting via normal referral pathways due to the potential fear of contracting COVID-19. The exact impact of this is unknown. The reduction in numbers was also due to a concerted effort by the sarcoma

MDT to perform as many primary excisions as possible when clinically appropriate, particularly for smaller lesions, which has been shown to be safe practice.¹⁷ This no doubt assisted with the delivery of a reduced capacity but safe and functional intervention list. It also ensured that a large backlog of patients awaiting image-guided biopsy was avoided and all outstanding non-urgent cases could be dealt with swiftly post the peak of the pandemic. The importance of the MDT in facilitating this service cannot be overstated here. A dialogue between the sarcoma surgeons and radiologists is crucial in deciding which cases should be biopsied, with priority given to children, radiologically high-grade tumours or clinically urgent cases.

All patients undergoing a procedure in the CT room were contacted as part of follow-up. Typically, a 2-week interval was normally given from the procedure date to follow-up. As physical outpatient appointments were essentially halted, a telephone consultation was felt sufficient. No local procedure-related complications or COVID-19-related symptoms or morbidity were highlighted.

Given the lack of Trust-wide patient testing, it is unclear if performing procedures on definitive COVID-19 positive cases would have altered the outcomes. There is currently a wide sensitivity range (71–98%) for the COVID-19 swab test with no true reference standard.¹⁸ For the purpose of performing a biopsy and subsequent surgery, it is unclear how much value should be placed on an apparent positive or negative result, especially in asymptomatic individuals. Various measures have been proposed to tackle this dilemma including patient shielding for 14 days, repeated swab testing and even low-dose CT chest studies for selected surgical patients; however, in the setting of urgent sarcoma, waiting up to 1 week for additional swab tests and scan results was not felt to be appropriate. The authors' approach of treating all patients as "COVID-19 positive", ensuring appropriate PPE at all times minimises the risk of potential virus transfer whilst ensuring no delay in patient management. Although hospital-wide swab testing for patients is useful, in reality this does not alter current practice for the near future. Hospital-wide antibody testing is only currently available for staff at both sites.

This article is designed to illustrate that even though intervention lists at both sites were curtailed, they can still be carried out and performed safely. Although this mainly depends on the existing ventilation set up, the contrasting arrangements at Royal National Orthopaedic Hospital and Royal Orthopaedic Hospital shows that concerted effort can be made to adapt rather than outright halt all interventional lists. A MDT approach and discussion of all cases is advised. All relevant personnel should be flexible in modifying their normal practice, e.g., converting to LA or sedations, surgeons carrying out more biopsies in theatre, etc. In addition, attention to detail is crucial with staff willing to discuss the logistics required. This includes designating areas for PPE "donning and doffing", physically marking boundaries and safe zones, ensuring the correct number of personnel is present in the room, etc. A summary of the standard operating procedures for GA biopsy lists is highlighted in [Table 4](#). It will be interesting to note how clinical practice at both

Table 4
Summary of standard operating procedure for GA biopsy lists.

Pre-procedure	<ul style="list-style-type: none"> • Ensure designated intubation room has necessary requisites: ventilation system with adequate ACH (10–15), negative surrounding pressure (minimum –5 Pa) • Scanning room set-up: designated “donning” and “doffing” zones, designated image-viewing area • All patients to be consented on the ward • All procedures to be performed by one radiologist if possible
Aerosol generating	<ul style="list-style-type: none"> • Intubation to take place in designated room with ventilation system. Patient transfer across negative pressure environment if needed • Radiologist, anaesthetist, and CT radiographer to wear full PPE • “Don” and “doff” PPE as per RCR and PHE guidelines
Non-aerosol generating	<ul style="list-style-type: none"> • Try to convert as many GA procedures to LA/sedation if possible and safe. Dependant on anaesthetist and radiologist • Sedation induction can take place within the normal scanning room • Radiologist to wear surgical mask and gown in accordance with hospital policy; however, decision to wear full PPE (including FFP 3 mask) was left to personal choice
Post-procedure	<ul style="list-style-type: none"> • Patient brought back to recovery room for extubation • Scanning room to be empty for at least 21 min after the patient has left • Deep clean room after every case, allowing 45 min to 1 h time turn-around time for each patient

CT, computed tomography; RFA, radiofrequency ablation; US, ultrasound, PPE, personal protective equipment; RCR, Royal College of Radiologists; PHE, Public Health England; GA, general anaesthesia; LA, local anaesthesia.

sites after the COVID-19 pandemic alters, e.g., will as many biopsies under sedation or LA be performed or will there be a push to still do mainly GA biopsies?

Although the topic of steroid injection is certainly interesting, they were completely halted during the study period, and therefore, discussion was deemed beyond the scope of the current paper; however, certain steps have already been implemented to reintroduce steroid injections at both sites. At the Royal National Orthopaedic Hospital, an enhanced consent process specifically detailing potential lowered immunity to virus exposure is to be highlighted by clinicians at the time of requesting the procedure and then again by all radiologists. All referrals are on a consultant-to-consultant basis, with particular consideration for high-risk patients following individual risk analysis. At the Royal Orthopaedic Hospital, normal steroid injection lists have resumed since June 2020, but are only performed on a low-risk patient group, with a view to appropriately scale up to a wider patient population following audit review.

There is clearly a large amount of planning needed hospital-wide to ensure the safety of running image-guided intervention lists, and the relevant radiology clinical leads and service directors need to be at the heart of this. As of 4 June 2020, there are 10 and 14 outstanding urgent biopsies at the Royal National Orthopaedic Hospital and Royal Orthopaedic Hospital, respectively, waiting to be done. This highlights a great effort by all relevant teams to run almost daily interventional lists safely across both sites.

It is hoped that the authors’ approach to ventilation systems, workflow, and PPE can be emulated by other centres in the UK. This is clearly a dynamic process changing on an almost weekly basis. More modifications to current practice will be needed given that the next phase of reintroducing a fully functional interventional list slowly and safely is fast approaching.

Conflict of interest

The authors declare no conflict of interest.

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