

The Impact of the COVID-19 Pandemic on the Radiology Research Enterprise: *Radiology*

Scientific Expert Panel

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ABSTRACT

The current COVID-19 crisis continues to grow and has resulted in marked changes to clinical operations. In parallel with clinical preparedness, universities have shut down the majority of scientific research activities. Radiology researchers are currently grappling with these challenges that will continue to affect current and future imaging research. The purpose of this article is to describe the collective experiences of a diverse international group of academic radiology research programs in managing their response to the COVID-19 pandemic. The acute response at six distinct institutions will first be described, exploring common themes, challenges, priorities, and practices. This will be followed by reflections about the future of radiology research in the wake of the COVID-19 pandemic.

INTRODUCTION

The COVID-19 pandemic has led to major changes in the clinical operations of radiology departments world-wide.¹ In parallel with clinical preparedness activities, academic medical centers and universities have rushed to shut down scientific research activities to maximize social distancing and minimize the spread of infection to research staff and others with whom they might have contact. The definition of “essential” research-related activities narrowed rather quickly, until *very few research personnel are now on site in radiology departments*. The rapid suspension of radiology research operations has created numerous challenges with both short-term and long-term implications.

The purpose of this article is to describe the collective experiences of a diverse international group of academic radiology research programs in managing their response to the COVID-19 pandemic. In addition, the authors assess the future of Radiology research in the wake of the COVID-19 pandemic.

University of Cincinnati

Research at the University of Cincinnati (UC) Department of Radiology is centered around four institutes, devoted to neuroscience, cancer, cardiovascular disease, and diabetes and obesity, respectively and is predominantly concentrated on clinical trials. UC also hosts the national coordinating center for the NIH/NINDS Stroke NET, supporting a robust infrastructure of approximately 400 clinical performance sites, and managing large Phase II and Phase III stroke trials.

COVID-19 response: As the pandemic gained momentum in our area, we prepared for an imminent and sustained reduction in on-campus research. A day after the state of Ohio issued a ‘stay at home’ order, we transitioned to a ‘level 1’ research status, wherein only approved critical research activities on campus were allowed. These activities were predominantly limited either to a) COVID-19-related research or b) medical research that, if discontinued, would endanger the

lives of participating human subjects. *We discontinued all human subjects research studies involving in-person interactions except those programs with explicit institutional and Internal Review Board (IRB) approval to continue (Table 1).*

Safety of research personnel and participants: Our top priority has been the safety of our research team members and the participants in our research studies. Our secondary priority is to preserve the scientific integrity of our research protocols. We put in place guidelines for study enrollment including screening for COVID-19 symptoms, particularly for studies involving direct contact with human subjects. To achieve social distancing, we transitioned all research staff to work from home, provided contact information for all research team members, and updated the research group with clear communications. We gave research team members remote access to lab computers, files, data and software systems and maintained Health Insurance Portability and Accountability Act (HIPAA) compliance and data control assurances.

Continuing productivity during the discontinuation of research programs: We expect significant disruptions to research operations, facility access and staff availability for at least the next three months. Therefore, we have developed a continuity-of-operations plan for our research program. This includes setting up imaging infrastructures for upcoming new trials such as building imaging charters, central reading manuals and case report forms. We instructed research staff to devote time to productive off-site alternative research activities, such as writing grant proposals and manuscripts, reviewing articles, compiling data, conducting data analysis, and synthesizing literature. We are encouraging staff to learn new skill sets, start online writing groups and maintain weekly progress trackers. Some research coordinators have been redeployed to support clinical needs (e.g., rescheduling of non-urgent imaging). We have also joined in COVID-related research activities and working with colleagues in medicine and engineering to 3D print components for face shields, N95 masks, nasal-based PCR tests, ventilator splitting apparatus, and touchless door handle openers.

Wellness of Research Personnel: In these times of uncertainty, it is particularly critical to attend to physical and mental wellbeing (Table 2). We continually circulate wellness resources for research staff and promote morale-building activities such as virtual water-cooler conversations, virtual fitness challenges and mindful movement sessions. Our ongoing goal has been to maintain both individual and team morale in the midst of what promises to be an extended crisis.

University of Wisconsin

The University of Wisconsin (UW) Department of Radiology has centralized many of its research operations at a single large facility encompassing basic and translation imaging research in MRI, CT, PET and radiopharmaceuticals and ultrasound. Over 350 imaging researchers, including faculty, staff scientists, post-doctoral fellows, graduate students, research staff, and research administrative staff are located in our primary imaging research center, which is attached directly to the main UW hospital and clinics. In our radiology research operations, we instituted a rapid response to the COVID-19 pandemic:

Health and safety of employees and research subjects: The safety and welfare of employees, trainees and research subjects has been our highest priority. We initiated an urgent effort to halt non-essential on-campus research activities. All employees and trainees not engaged in essential research activities were instructed to go home, bringing necessary materials and equipment such as laptop computers to enable them to work from home for an extended period.

Restricted access and exceptions for essential research: 24/7 key card access was initiated to restrict access our primary imaging research center. All non-essential on-campus research was discontinued, including all face-to-face human subject interactions. Exceptions to continue research requires permission of departmental leadership and the office of the medical school Dean. Examples of essential research include *“research that has the potential to address the COVID-19 crisis, human subjects research that would endanger research participant lives if stopped, or projects where termination of the research would lead to loss of long-running*

experimental data, critical time-series, or time-sensitive data, loss of equipment, or to the loss of life of critical research-related organisms.” Researchers engaged in essential research are instructed to maximize social distancing practices, minimize the number of staff present, and use personal protective equipment (PPE) where appropriate. Care for animals and maintenance of research equipment is considered to be essential. When feasible, urgent standard-of-care clinical research imaging examinations have been migrated from our research center to the hospital. For essential imaging research in our research facility, we have implemented our hospital’s policies for COVID-19 protection of staff and patients, including social distancing, PPE and siloing.

Frequent communication and wellness: Research supervisors have devised individualized approaches to research team engagement. We encourage principal investigators to continue remote research activities using videoconferencing software. We are also encouraging frequent team-based communication, which has helped to maintain social connections and provide emotional support for employees and trainees. In order to promote transparency and flexibility, we maintain daily communication among research leadership, disseminating new policies and addressing new issues as they arose. Continued efforts are ongoing to provide remote computer access for researchers, while ensuring that appropriate HIPAA protections are maintained for human subjects research. Even with remote access to computer systems, the lack of access to imaging equipment has, of course, presented a major challenge for technical development.

Vulnerable groups: We have paid special attention to the wellness of all of our staff and students, via frequent one-on-one communications, virtual video-based social gatherings, and online yoga sessions (Table 3). Information on accessing campus resources provided by employee health services (including mental health services) has been disseminated to all staff and trainees. We are developing policies that will accommodate delays in graduate degree programs for radiology researchers. UW has initiated a tenure clock extension for junior faculty, and strategies for bridge funding are being formulated within radiology and on campus.

New York University

When COVID-19 arrived on our doorstep, the Department of Radiology at New York University (NYU) Langone Health was performing more than two million imaging examinations per year. The diverse activities of our 150-person research team, made up of PhD principal investigators, clinical researchers, research scientists, fellows, students, and research administrators, were concentrated in two centers and a few satellite facilities. All research activities at these facilities have now ceased in response to COVID-19.

COVID-19 response: In early March 2020, our medical center began an orderly and rapid shutdown of normal research operations. We cancelled human research imaging examinations except for research with an important contribution to the care of individual patients, and only if additional staff were not required. We checked helium levels on our research MRI scanners in preparation for long unattended intervals. We instructed the managers of core facilities in animal imaging and radiochemistry to devise contingency plans involving minimal or no staff. At the time of this writing, all our researchers are in isolation at home. Our radiology research priorities have adapted to various stages of the rapidly advancing pandemic.

Protecting our research teams: As infection rates kept rising, our key priority was to get our people home. We shared centralized telework resources (VPN–virtual private network, videoconferencing access, etc), and encouraged all research staff to prepare to work from home for an extended period, with computers and other equipment taken as needed from the office or purchased anew. Within a week, our research offices were empty, and entry was off limits to anyone without explicit permission from research leadership.

Promoting wellness in during the COVID-19 pandemic. This forced diaspora of our research team placed a new premium on communication. Our research leadership team, which met frequently online, began sending out daily updates. We established a weekly online meeting for all research staff, as a clearinghouse for questions and ideas. With coronavirus-related

information flowing in from all sides, these communications were targeted at the interests and concerns of researchers. This included the current policies for nonessential staff, the latest notices from the National Institutes of Health (NIH), reimbursement of meeting cancellation expenses, tenure clock extensions, and resources for mental health and wellness. Our researchers are also organizing virtual coffee hours, social networking channels, targeted research group meetings, and other modes of connecting.

Contribution of radiology research to fighting the pandemic: Our research teams have convened around helping to mitigate the COVID-19 crisis. Our 3D printers are being used to print face shields for emergency clinical use. Our department's collaboration with Facebook has been redirected to develop machine learning models for COVID-19 diagnosis, as well as prediction of disease course and severity, based on chest X-ray and other clinical data. We are participating in COVID-19 data-sharing consortia with other medical centers and imaging societies. Our researchers are developing projects in response to COVID-19-related NIH requests for proposals. Our research staff is also preparing educational lecture series on imaging research for trainees and clinical staff. While our research teams actively pursue ways to contribute to defeating the pandemic, we are also working with clinical teams to increase imaging efficiency, in order to meet increased demand when backlogged elective imaging studies resume at the conclusion of the current pandemic crisis.

Johns Hopkins University

Research faculty in the Russell H. Morgan Department of Radiology and Radiological Science are integrated within 8 clinical divisions, and 3 dedicated research divisions. The department houses two service centers for human research, one service center for large animal research, two service centers for preclinical small animal imaging and basic research, and one service center for *ex vivo* tissue imaging.

Radiology research preparedness: Institutional initiatives on research preparedness for COVID-19 focused on having adequate research supplies, ensuring adequate space for emergency transfer and storage of reagents and samples, establishing centralized communication for research groups, developing plans for shutdown of laboratory functions and establishing policies for studies involving human participants. A maximum of three essential personnel have been designated within each research group. PPE such as masks, gowns and gloves, as well as reagents, swabs and tubes for COVID-19 tests that were available in radiology research areas were consolidated and repurposed to support clinical needs. For human subjects research, only studies related to COVID-19 research or protocols in which serious or immediate harm could be caused to the research participants if stopped are allowed. For animal research, a contingency plan for the care of animals has been implemented to allow faculty to completely ramp down their animal research. Only essential personnel are allowed to complete critical ongoing studies and to maintain essential lab resources such as animals, freezers, liquid nitrogen tanks, and equipment. No new studies or continuations of ongoing research projects are allowed except for COVID-19-related projects. For all nonessential research personnel, we have implemented a work-from-home policy.

Wellness of research staff: We have actively encouraged research staff to interact through electronic media and networks. Research PIs have been engaging their groups with weekly remote meetings, and encouraging lab members to write pending manuscripts, analyze data, and think about new research ideas. Our aims have been not only to continue but also to grow the research mission, while also providing valuable structure to our research staff during the work-from-home period. Administrative staff have continued to assist faculty with grant submissions, scheduling of meetings, and other tasks requiring support. Our School of Medicine maintains a dedicated website that includes contact information for obtaining emotional support, referrals for child or elder care, and legal and financial assistance. To protect our vulnerable team members still further, we have established a Radiology Research Support Network consisting of 20

volunteers drawn from faculty, fellows and administrative staff. This network of volunteers assists individuals who may have to self-quarantine, or who are at high risk, with delivery of essential supplies. This is especially important for our fellows or junior faculty who have recently arrived in our areas and do not yet have a support network of their own.

Emory University

Research in the Department of Radiology at Emory University is multi-disciplinary; thus, labs are distributed throughout the main hospital and additional separate research facilities. Our research operations began to undergo a major transition due to the COVID-19 pandemic, focused on putting non-critical projects on hold and maintaining key imaging core operations for essential studies.

Faculty, staff and trainee safety: We quickly developed a 'Research Slowdown Planning Tool' to help identify all functions essential to research continuity. A 'Checklist to Ramp-Down Non-Essential Laboratory Research,' a FAQ page, and a definition of critical and essential research and personnel were developed to guide decisions regarding work-at-home transitions. Student and trainee health and safety was highlighted, with no undergraduate, medical or graduate students being allowed to come to work on site, and with postdoctoral fellows and other trainees only permitted onsite to perform essential functions. All buildings were changed to 24/7 badge access only.

Communication and updates: Dedicated telecommuting forms were required for those working at home, detailing resources, expectations, reporting plans, hours etc. Administration, department and division level websites were set up and updated regularly as information changed based on the evolving situation. We established a "Friday at Four" virtual series to help faculty understand current guidance from the University and from research sponsors. Additional topics covered in these sessions include research continuity, methods for staying connected, tools for remote collaboration, ramping up after the crisis, and resources for wellness.

Imaging and other integrated core facilities: The first phase of COVID-19 response for our multiple core facilities involved settling on a definition of what core activities were truly essential. Phase two involved limiting onsite core staff to support only these essential activities. For the Imaging Core, this meant working with Principal Investigators in Radiology and other departments to determine if ongoing clinical trials could continue in a limited fashion. Any trials not yet initiated were automatically placed on hold. Face-to-face research visits are allowed only if it is deemed to be essential to the health and/or well-being of the subject. Some essential trials, plus certain clinical scans, required that personnel associated with cyclotron and radiochemistry operation come into work periodically (following all standard safety and social distancing precautions). Ongoing animal trials are allowed to continue to the point where they can feasibly be put on hold. Those associated with newly developed animal trials are allowed to commence with proper approvals in place. Research faculty have contributed any extra PPE (e.g., masks or goggles) or related resources to our hospital facilities.

Research personnel wellness: While physical wellness is foremost on everyone's mind during the current crisis, we have also sought to support the mental and emotional wellness of our research staff. We have encouraged our teams to keep things as 'normal' as possible, with regularly-scheduled lab calls (preferably including video), regular work hours, and other simple expedients, such as changing clothes for work hours, scheduling physical activity (especially if that activity can involve family), and virtual coffee breaks. We have encouraged supervisors to keep information flowing, and to make themselves available to their teams as much as possible.

King's College London

The Department of Radiology at King's College London is affiliated with the School of Biomedical Engineering and Imaging Sciences, within the Faculty of Life Sciences and Medicine. Our research labs (including imaging chemistry, computational sciences, medical engineering, robotics and surgical intervention) and research imaging facilities (including cyclotron and

radiopharmaceutical production facilities) are directly connected to patients and their care. We have more than 600 imaging researchers on site and also host a National Institute for Health Research (NIHR) integrated academic training program in Radiology.

COVID-19 response: As the United Kingdom (UK) national response moved from 'containment' to 'delaying transmission,' the National Health Service (NHS) focused on preparing for a rapid rise in symptomatic patients and increasing critical care capacity nationally. It became apparent that arrangements had to be put in place to pause research activity. Our research response included a rapid transition through multiple steps. Communications focused initially on the need to pause all non-essential research activity across the hospital and the university. A premium was placed on wrapping up existing on-campus experiments promptly for an unknown but extended period of up to 6 months. We enabled teams to close down research labs, put in place safety procedures and other contingency measures, maintain the integrity of essential research equipment, and ensure the adequate care of animals. Research addressing the COVID-19 crisis, including clinical trials, have now been prioritized. Also, projects in which termination of human subjects research would endanger the lives of research participants have been allowed to continue, with required NHS permission and adherence to COVID-related protocols. We implemented a work-from-home policy for non-clinical researchers and all students to ensure their safety. We provided laptops and remote access to university and hospital networks as needed.

Supporting clinical care: Academic researchers with clinical credentials were released back to full-time clinical care to support the NHS. We paused our NIHR integrated training, to enable radiology residents to shift to full-time clinical activity and redeployed our research nurses to clinical care or to support essential research. Research imaging scanners are being used for clinical activity only.

Engaging with grant funders and degree programs: The NIHR and other UK grant funders fully supported the cessation of planned research activity. Our university worked to make sure

that trainees and faculty would not be disadvantaged by anticipated delays in the completion of graduate degree programs, or additional time elapsed on the tenure track. We are formulating bridge funding for PhD students who are within 6 months of completion of their degrees but who may be delayed due to the current COVID crisis.

Wellbeing of the research team: We have encouraged PIs to continue online research activities using conferencing software such as Microsoft Teams, in order to maintain social connections and support of junior researchers. Ongoing daily communication, in the form of newsletters and open forums with the senior research leadership, has been effective in raising awareness of new policies and address new issues that may arise. We have devoted special attention to staff wellness. We are disseminating information on current hospital and university online wellness initiatives and counselling access to all staff. Further, we have asked personal tutors to check in regularly with undergraduate students.

IMAGING RESEARCH AFTER THE COVID-19 PANDEMIC

We anticipate important negative sequelae on radiology research programs after the conclusion of the COVID-19 pandemic (Table 4). *If not specifically addressed, the current disruption of imaging research will have adverse ramifications for productivity, funding, and scientific progress in the future.* A shutdown of 3-4 months will likely result in as much as 1-2 years of lost scientific productivity. For example, when clinical trials resume, investigators will have to deal with missed visits, and protocol deviations (although a significant amount of groundwork can be carried out now to jumpstart activities once re-initiated). Further, we anticipate challenges with re-engaging existing subjects and recruitment of new subjects, including possible reticence of subjects to visit medical environments. Missing data will greatly impact trial results and interpretation, possibly stopping some trials altogether. Another example of disruption is the current suspension of the national IRB process in the UK, which will inevitably result in significant backlog and delays after

submission reopens. Many US IRBs are only reviewing COVID-related studies, creating potential for future delays as well.

Radiology research funding will also be a central challenge. Departmental and institutional budgets will undoubtedly be constrained in the wake of the pandemic. This may lead to significant retrenching of research expenditures in radiology departments. Clinical revenue typically offsets the costs of imaging research funded through extramural support. Radiology departments are currently experiencing an abrupt drop in clinical revenues due to sharp declines in non-urgent imaging volume. As a result, departments may be forced to make difficult decisions regarding research support in subsequent budget cycles. Imaging research could potentially be devalued during the post-COVID-19 period, when departments are focused on recovery of clinical operations and revenues. This effect may persist for many years and there is a real risk that some imaging research programs may never fully recover.

In addition, research equipment purchases will be delayed or cancelled with shrinkage of capital budgets. National funding organizations, such as the NIH in the US or the NIHR in the UK, are offering flexibility in the conduct of projects affected by the crisis, and there may be benefit in the short term from COVID-related stimulus packages. However, the emerging worldwide economic downturn is certain to impact long term national research budgets. The impact on industry partners is also likely to be significant, not just those supporting clinical trials, but those with whom institutions have master research agreements that support research, equipment purchases and many other related activities. This may be especially impactful for smaller companies and those developed by our more entrepreneurial faculty.

Another challenge will be the ability to publish research and submit grants without access to laboratories and imaging equipment, which are necessary to generate essential preliminary data. In light of our current “work at home” paradigm, we call on journals and funding organizations

to accommodate publication of manuscripts and review of grant submissions without the level of laboratory-based data required under normal circumstances.

The disposition of research hiring is also a matter of concern. Given anticipated funding constraints, uncertainties about future travel, and potential restrictions in immigration policies, many institutions are already imposing hiring freezes. Staff retention is also precarious, particularly those funded by clinical or departmental funds. Loss of highly trained academic research personnel is anticipated, either due to lack of work with accompanying furloughs or layoffs, or through loss to industry. Recovery from the loss of highly experienced personnel may take decades, if ever, and will place considerable additional pressure on our remaining research work force. Similarly, imaging service centers and cores that rely on revenue to maintain expert staff are also at risk. These service centers will require varying degrees of financial assistance to recover revenue and to continue to function once the demand for research services begins to ramp up. Junior faculty, fellows and students may struggle to meet deadlines for promotion or graduation, which may in turn negatively impact future job prospects.

Meanwhile, interruption in the exchange of scientific ideas due to cancellation or postponement of annual meetings of major scientific societies will significantly impact global scientific progress. Imaging societies that host meetings and maintain other key connective activities are under existential pressure from current and future lost revenues. Larger and financially solvent societies will simply delay or cancel their annual meeting for ~1 year, while smaller or less financially viable societies may be impacted more severely. This will be compounded by reduced professional development expenditures provided by radiology departments to their personnel, who will ultimately attend fewer society meetings.

What can the radiology and imaging research communities do to ensure that we not only survive but also manage to thrive under such uncertain conditions? We believe that future of radiology research should be reconsidered. Even as the artificial intelligence (AI) tsunami has

rolled through Radiology, we have been slow as a field to create platforms for broad-based image and data sharing. The COVID-19 pandemic has highlighted, with shocking urgency, the importance of data sharing and rapid mobilization of disseminated research teams. RSNA recently announced the COVID-19 Imaging Data Repository initiative which will allow image hosting, annotation and analysis framework for researchers.² Additional disease specific imaging biobanks linked to other biorepositories would need to be disseminated widely. Lobbying for additional funding for imaging and health informatics, has never been more important.

Nursing staff, emergency physicians, and critical care specialists are clearly on the front lines of our current battle against the coronavirus. Even though radiologists, particularly in non-pulmonary and non-emergency subspecialties, may not be in the public eye right now, the tools that radiology offers continue to offer key insights, and imaging research after COVID-19 will be more important than ever for human health. Dedicated advocacy efforts through organizations such as American College of Radiology (ACR) and Academy for Radiology & Biomedical Imaging Research will be essential to inform the public and policy makers on the importance of continuing innovative imaging research. It is up to us to continue to innovate and create new opportunities to advance imaging research.

CONCLUSION

Common challenges and strategies (Table 1), mechanisms for maintaining morale and wellness in research personnel (Table 2). special groups in research team to consider (Table 3) are a priority for radiology research programs. As our priorities shift from emergency response to the eventual resumption of imaging research, we will have to face numerous challenges. We will be called upon to rethink some of our accustomed processes. We will have to engage with leaders, funding agencies and the general public as we navigate the post-coronavirus world. The actions we take now, and the plans we put in place, have the potential to change the shape of imaging research for many years to come.

Table 1: Challenges and strategies pursued across academic Radiology research programs in response to the COVID-19 pandemic

Challenges	Strategies/Actions
Maintaining physical health and safety of research personnel and participants	<p>Discontinue all non-essential on-campus research.</p> <p>Institute work at home procedures and policies</p> <p>Minimize on-site personnel</p> <p>Practice social distancing for any essential on-campus research</p>
Continuing essential research activities on campus	<p>Define essential research</p> <p>Create process for rapid request and approval of essential on-campus research activities</p> <p>Consider separate shifts for research work force in case of prolonged shut down</p>
Continuing off campus research activities to minimize the short and long-term implications, including extramural funding	<p>Provide remote HIPPA-compliant computer access</p> <p>Begin video-based communication among teams to maintain productivity and social contact</p> <p>Centralize web-based COVID-related resources including links to federal institutions e.g. https://grants.nih.gov/policy/natural-disasters/coronavirus.htm,³ https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/covid-19⁴</p>
Contributing to broader clinical care to our communities	<p>Support innovative engineering solutions such as 3D printing to construct new personal protective equipment (PPE) and ventilator equipment</p> <p>Donate personal protective equipment (PPE) from laboratories to local medical facilities</p>

Table 2: Maintaining Wellness of the Research Team

<i>Purpose</i>	<i>Mechanisms</i>
Research Team Morale and Effective Communication	Frequent team-based communication to maintain social connections and provide emotional support of employees and trainees. Engaging virtually: Virtual water cooler, virtual fitness challenges and mindful movement sessions. Continue remote research activities using video conferencing software. Daily communication from research leadership to disseminate new policies and address new issues. Expansion of remote networking capabilities. Weekly 'Coronavirus hero' announcement. Dedicated website and resources with contact information for obtaining emotional support, referrals for child or elder care, and legal and financial assistance.
Protecting vulnerable groups	Tenure clock extension for junior faculty, and strategies for bridge funding Financial support for research imaging service centers that depend on users for revenue. Strategize to accommodate delays in graduate degree programs. Radiology Research Support Network consisting of volunteers from faculty, fellows and administrative staff to assist individuals under self-quarantine, or immune compromised or other high-risk individuals, with delivering essential supplies.

Table 3: Considerations for specific members of the research enterprise

Group	Considerations & Recommendations
Undergraduate & medical students	Generally deemed non-essential Research activities discontinued Urged to remain active remotely as feasible & communicating with project lead/PI Paid as feasible per project lead/PI funding sources
Graduate Students and postdoctoral fellows	Same as undergraduate students; stipends typically still paid Mitigate impact on academic progress as feasible by delaying/flexing key milestones such as prelims/qualifying exams & virtual oral examinations
Junior faculty tenure-track	Consider extension of the tenure clock by at 1 year or more
Emeritus/Partially retired faculty/staff	Likely to be high risk for COVID-19 (older, existing conditions) Urged to stay at home
Research nurses, staff (e.g., radiochemists) and coordinators	Determine if essential to work according to institutional definitions
Individuals with special medical conditions and risk factors	Urged to stay at home

Table 4: Long term impact of COVID-19 on radiology research

If not specifically addressed, disruption of imaging research will have adverse ramifications for radiology and imaging sciences:

A 3-4 month pandemic shutdown is estimated to result in up to 1-2 years of lost research productivity

Potential for reduced radiology research funding due to economic impacts of the pandemic on universities

Potential for delay in equipment purchases with reduced capital budgets, otherwise necessary for state-of-the-art research programs in radiology

Potential for reduced innovation and publishing in imaging research due to lack of access to imaging equipment and research labs

Potential for negative impact on research staff retention and hiring

Interruption in the exchange of scientific ideas due to cancellation or postponement of scientific meetings

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