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Telehealth in Multidisciplinary Target Delineation for Radiotherapy During the COVID-19 Pandemic. A Review and a Case

Kenneth Jensen, MD, PhD,* Rikke Beese Dalby, MD, PhD,† Kirsten Bouchelouche, MD, PhD,‡ Erik Morre Pedersen, MD, PhD,† and Stefan Kalmar, MSc§

Like all other medical specialties, radiotherapy has been deeply influenced by the COVID-19 pandemic. The pandemic has had severe influence on the entire patient trajectory in oncology, from diagnosis to treatment and follow-up. Many examples of how to deal with patient and staff safety, shortness of staff and other resources and the quest to continue high-quality, evidence-based treatment have been presented. The use of telemedicine and telehealth is frequently presented as a part of the solution to overcome these challenges. Some of the available presented solutions will only apply in an acute, local setting, whereas others might inspire the community to improve quality and cost-effectiveness of radiotherapy as well as knowledge sharing in the future.

Some of the unresolved issues in many of the available technical solutions are related to data security and public regulation, for example, GDPR (General Data Protection Regulation) in the EU and HIPAA compliance (Health Insurance Portability and Accountability Act) in the USA. Using a solution that involves a supplier's server in a non-EU country is problematic within the EU.

In this paper we shortly review the influence of COVID-19 on radiotherapy. We describe some of the possible solutions for telehealth in target delineation − a crucial part of high-quality radiotherapy, which often requires multidisciplinary effort, hands-on corporation, and high-quality multimodal imaging. Hereafter, our own technical solution will be presented as a case.

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Background

Like other medical specialities, radiation oncology has been forced to deal with the consequences of the COVID-19 pandemic. Patients undergoing radiotherapy, receive extended treatment, lasting weeks, with repeated close-contact encounters with staff for immobilization, scanning, positioning, clinical evaluation and often concomitant treatment with drugs which might compromise their immune response. Furthermore, the patients are at a greater risk of serious complications from a COVID-19 infection, largely due to comorbidities [1] and recent treatment may be a risk factor for a severe course of COVID-19.[2, 3] Due to staffing challenges and risk of disease transmissions, radiotherapy treatments have been postponed, interrupted, shortened using hypo-fractionation or even cancelled.[4-9] The impact of the pandemic, of course, depending on the regional effect of the pandemic. In several countries an unexpectedly low number of patients have been diagnosed with cancer during the spring of 2020.[10-12] and if this, as one must fear, is an indicator of delayed diagnosis this may have direct consequences for patient survival.[13] Also patient inclusion in protocols,[14-16] continuous funding for research,[17] and sharing of new knowledge and networking has suffered with the numerous cancelled meetings and congresses.

*Danish Center for Particle Therapy, Aarhus University Hospital, Denmark.
†Department of Radiology, Aarhus University Hospital, Denmark.
‡Department of Nuclear Medicine & PET-Centre, Aarhus University Hospital, Denmark.
§Department of IT, Central Denmark Region, Denmark.
Address reprint requests to: Kenneth Jensen MD, PhD, Danish Center for Particle Therapy, Aarhus University Hospital, Palle Juul Jensens Boulevard 99, 8200 Aarhus N, Denmark E-mail: Kenneth.jensen@auh.rm.dk

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These external factors have put great resource strain on all departments and put focus on maintaining high-quality treatment with optimal use of available resources as well as a secure working environment for the involved staff. Telehealth and teleconferencing have been widely used, also in radiation oncology. As radiology and nuclear medicine, radiotherapy is a technology-driven medical specialty. Information is therefore digitized to a large extend, making most processes available for remote execution or evaluation.[18]

Defining targets for radiotherapy with the best possible accuracy is one of the major challenges in radiation oncology.[19] Target delineation comprises both gross tumor volume (GTV) and clinical target volume (GTV). Recurrences may arise inside the high dose volume, in the margins or more distant from the bulk of the tumour.[20] If a tumor manifestation, such as a lymph node, located some distance away from the bulk, is not defined in the original target, no extra radiation margin or systemic treatment will prevent recurrence. Furthermore, there is a high degree of correlation between irradiated tissue volume and side effects of which some may have severe consequences for the patient, and even a few mm reduction in added margins around tumors will decrease the risk of side effects.[21] Unfortunately, the process of target delineation is associated with far greater uncertainties and inter-observer variation than the other steps of radiotherapy.[22]

Radiation oncology requires dedicated imaging protocols for therapy planning as well as a multidisciplinary collaboration between experts in oncology and medical imaging.[23, 24] In our country, radiation oncology is performed in hospital radiotherapy centers by specialists in clinical oncology, that is, oncologists without specialist level training in imaging. Therefore, target delineation is assisted by radiologists and nuclear medicine specialists at multidisciplinary conferences. A typical setting involves subspecialists from all three medical specialties gathered in front of a target delineation system, flanked by imaging workstations, and slice by slice agreeing on the definition of tumor volume, often combining multiple imaging modalities. This setting exploits the cumulated experience of imaging experts and clinical knowledge. Inconsistencies or disagreements are solved on-site. This setup, however, is challenged with the COVID-19 pandemic, in large hospitals with geographically distant departments and with increasing demands for subspecialised day-to-day radiation therapy planning.

Early experience with teleconferencing in radiotherapy target delineation has been described by.[27-29] Below we describe some of the possibilities with contemporary technology.

Description of available technologies

Introduction

There are different technical options available that in principal can be used as platforms for diagnosing and working together remotely. The different technical platforms each present their advantages and disadvantages in terms of diagnosing-regulations, IT security, data protection, image quality and price.

A remote and collaborative diagnosing session requires two IT-technologies:

1. Monitor, keyboard and mouse sharing. The ability to collaborate on the same PC with colleagues from a distance.
2. Videoconference. The ability to view, hear and talk to clinical colleagues from a distance.

1. Monitor, keyboard and mouse sharing

Below we present three major technical platforms (A-C) for monitor, keyboard and mouse sharing.

A: Remote Desktop PC (RDP)

Products such as TeamViewer, Microsoft Remote desktop etc. are software-based ways of connecting to and controlling other PCs, Macs and servers.

Some RDP products are "lossless" and without compression of the image quality, or at least give the user the option of lossless data-flow. Others have a notable image compression that will be an issue for the physician in the diagnostic session who is not present locally and therefore will not be viewing the patient images with the same image quality/resolution as the physician sitting locally.

The data traffic from the local PC to the user sitting remotely is usually passed through the supplier's servers (eg, TeamViewer). This presents an IT security issue since the data traffic is not 100% controlled by the hospital. It also presents a data protection issue. Hospitals in the EU will, due to GDPR regulations, have to establish a data processor agreement with the supplying company. The situation is also challenged by the fact that some suppliers (eg, Microsoft) have RDP servers outside of the EU. This requires even stricter data processor agreements for EU based hospitals.

Some suppliers (eg, ConnectWise, Anydesk) give customers the option of creating their own RDP server. This option solves the data protection issue since data is then contained on the hospital network.

Even though many of the products can be used free of charge, as a private-home-license, they are not free when using them as a hospital organization.

Conclusion: Most RDP products are not suited for remote and collaborative diagnosing, due to mainly data protection and IT security reasons. Image quality and compression rates can with some products be configured to an acceptable level. It is possible that some suppliers of RDP are able to fulfil all requirements for remote and collaborative diagnosing. This has to be further evaluated.

B: Screen Sharing via Videoconference Systems

Most videoconference systems, like Google Hangout, Cisco, Facebook Messenger etc. have built-in monitor sharing options. However, the monitor sharing is primarily a viewing function where one user has the keyboard and mouse controls, and the user who is connected remotely only has viewing options.

Some software tools, such as Cisco Webex also incorporate keyboard and mouse sharing with all the connected users. This option, however, requires an .EXE/MSI file to be installed on every user's PC at the beginning of every conference call. The installation of this file presents a practical and an IT security issue for many hospitals. Many European hospitals run their IT in major enterprise solutions where users are not allowed to install software or execute files that are not whitelisted on the PCs.

Image quality in most screen sharing products is highly compressed, rendering these products useless in diagnostic sessions.

Roy et al. [30] describes an example of a screen sharing solution via videoconference systems for remote target delineation, using Zoom. They concluded that the setup was feasible and that it will remain an integral component of their future setup. However, the authors did not comment on the image-quality and image-compression that happens with screen sharing, nor if they qualitatively or quantitatively ensured that this did not pose an issue for the physician in the receiving end. Neither did they comment on the HIPAA compliance (Health Insurance Portability and Accountability Act) of Zoom. Companies are not HIPAA certified by an official body. HIPAA compliance is a title that companies bestow upon themselves based on a periodic technical and non-technical evaluation form provided by the United States Department of Health and Human Services, meaning that individual hospitals' IT-security department may still reject the use of a given screen sharing provider, if they feel that it doesn't meet their IT security standards.

Monitor sharing via videoconference systems also presents the same data protection issue as RDP, since data traffic flows through the supplier's servers.

Conclusion: Screen sharing via videoconference systems are not suited for remote and collaborative diagnosing. Image compression is too high and IT security/data protection issues need to be addressed.

C: Keyboard, Video & Mouse (KVM)

KVM is a technology that is often used to let a user with one set of keyboard, video and mouse, connect with several PCs/Macs or servers (one unit at a time). The KVM connection is either established locally or via IP (internet/network).

When establishing an IP-KVM connection a user has monitor, keyboard, and mouse control over a PC/Mac/server located at another location.

Certain IP-connected KVM-switches can also be set up to work in combination with the locally controlled PC. In this case a PC can be controlled both by the user sitting physically next to it, with the directly connected keyboard and mouse — but also at the same time by a user sitting remotely connected via the IP-KVM. In this way two people are in control, at the same time, of the keyboard and mouse of a given PC. The two users also view the same monitor output for the PC.

Many KVM-suppliers have IP-KVM switches that transmit data lossless. This is important when dealing with patient images that need to be of the same quality for all viewers in a remote diagnostic session. IP-KVMs can also be setup to only broadcast on the hospital network, thereby containing the data traffic. Though suppliers of IP-KVM state that their solution is data-lossless, it is still possible to test differences at least using stress-tests. See below.

Conclusion: IP-KVM products that can broadcast data-lossless are suited for monitor, keyboard and mouse sharing during a remote and collaborative diagnosing session.

General Comments

EU GDPR and national patient data regulations from many EU countries require user-logging when viewing patient data. When using any of the above technologies clinicians have to be aware that, in principal, all participants of a remote collaborative diagnosing session have to be logged as having viewed the given patient data. This is usually dealt with by making a note on the patients record in the hospital's Electronic Medical Journal, stating which staff members have viewed the patient data, apart from the user that is logged in.

In all of the above mentioned technologies, the person sitting next to the PC that is being shared, has the responsibility of making sure that all viewers are disconnected after the remote diagnosing session. This is a practical IT security issue that with some of the technologies can only be dealt with manually. Most hospital IT security departments will require well-defined, informed and enforced protocols for this manual shot-down-action.

2. Videoconference

The videoconference addition to the remote setup, enables the clinicians to have a conversation over video while sharing the monitor/mouse/keyboard and conducting a target delineation conference. There are many videoconference solutions on the market.

When using a videoconference system for diagnosing and discussing patients it is important that the videoconference system does not send video-data-traffic, containing patient data, through a supplier's server (eg, Microsoft server in the USA). Videoconference data traffic has to be contained on the hospitals network, and the hospital needs to ensure that non-essential staff members cannot tap into the video conversation without permission.

Conclusion: Videoconference solutions that can contain data traffic on the hospitals network are suited for remote diagnosing sessions.

Our Case of a Secure, Hands-on and Resource-Efficient Solution

A new Danish Center for Particle Therapy (DCPT) opened in 2019 at Aarhus University Hospital. The center serves the

Figure 1 Aarhus University Hospital. Blue: Danish center for Particle therapy. Purple: Department of Radiology, Section of Abdominal and Oncoradiology. Yellow: Department of Nuclear Medicine and PET-Centre. Red: Department of Radiology, Section of Neuroradiology. Green: Department of Radiology, Section of Thoracic, Female and Pediatric Radiology. Photo: Aarhus University Hospital.

entire country with proton radiotherapy, and therefore patients are referred nationwide. Our hospital is among the biggest in Europe and houses 44 departments and a total of 1,150 beds. The hospital area covers 500,000 m^2 and the walking distance from the most distant part of the Department of Radiology (Section of Neuroradiology) and the Department of Nuclear Medicine & PET-Centre to the DCPT is around 15 minutes (Fig. 1). From the planning phase of the DCPT, it was a clear aim to maintain a high quality in target delineation, despite the logistic challenges outlined above. In addition, we experienced a need for more frequent target delineation conferences in order to reduce planning time for new patients, as patients most often start their treatment trajectory at the local departments of oncology, and from there, they are referred to the DCPT, if proton therapy is considered beneficial.

With these factors in mind we wanted to test the well-known concept of interactive video conferencing – see for example,[25] – in a large hospital multidisciplinary setting with the possibility of hands-on target delineation. Our aim was to establish a user-friendly technical setup that allows for secure, fully interactive target delineation with optimal imaging quality[26] and easy access to subspecialised experts in different locations with no excess time spent on transport.[25]

Development and Evaluation

Specialists from the Departments of Radiology, Nuclear Medicine & PET-Centre, IT and the DCPT specified individual wishes and basic requirements for the system setup. An external hardware vendor presented possible technical solutions, using Black Box® (Black Box, Lawrence, PA, USA) Emerald SE transmitters and receivers, see below. In order to assess the image quality of MR-images transmitted via the Emerald SE solution, we established a blinded setup with two standard PACS monitors. One monitor showed the images coming directly from the PACS system, and the other monitor received the same images but via the Emerald SE transmitter and/or receiver from the first monitor. The transmitting monitor was connected via the hospitals LAN-network, using a router and RJ45 cables and the Emerald SE to the receiving monitor. The medico engineers detected that there was a slight loss of image data. This loss of image data was only visible in a technical stress-test with technical images created to stress the connection. Thereafter, two experienced radiologists representing experience within both neuro- and onco-radiology and two medico engineers were told to point out the monitor with original images, and the monitor with the images transmitted via the Emerald SE solution, over the LAN-network, and then assess the images on both monitors to see if they could identify loss of image quality on the receiving end. The assessment was divided into two parts. In the first part PACS monitor 1 acted as the original, and in the second part PACS monitor 2 acted as the original – with the other monitor as the receiving monitor. A series of images from different body parts were compared during the two parts of the assessment. The radiologists and the medico engineers could not identify the original monitor and they could not identify any loss in image quality. It was unanimously concluded by both radiologist and medico engineers that the image quality on the receiving end of the Emerald SE for all body parts was sufficient for target delineation.

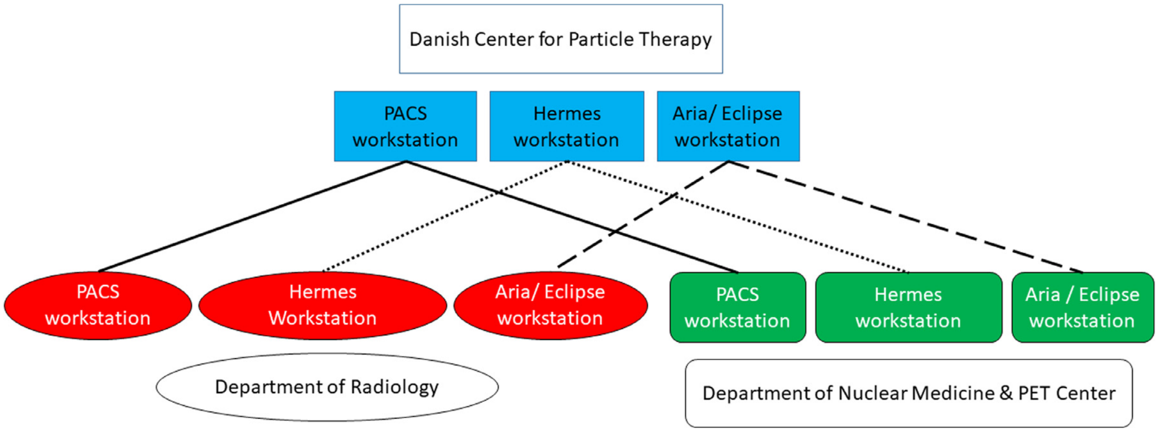

Figure 2 Technical setup. The screen signal from the Danish Center for Particle Therapy is split to the other departments for full interaction.

Final Technical Solution

Three central PCs located at the DCPT split their respective screen signals to three different locations (DCPT, Department of Radiology and Department of Nuclear Medicine & PET-Centre), see Figure 2. Signal transmission is handled by three Black Emerald SE transmitters Box (Black Box, Lawrence, PA, USA), that transmit the three PC screen signals, and two corresponding Black Box Emerald SE receivers located at the Departments of Radiology and Nuclear Medicine & PET-Centre, respectively, that receive the signals. A KVM switch enables the participating locations to interact and control the mouse and keyboard of the transmitting PCs in cooperation with the other locations, thus creating the possibility of working, pointing and delineating together in real-time. The solution is PACS vendor independent.

For data security purposes our technical solution also involves an administration unit, Boxilla, which is a centralized KVM / AV manager that connects and manages multiple extension solutions and enables remote access to an unlimited number of endpoints from one access point. When using the Boxilla administration unit the setup can be locked to an enclosed group of selected transmitters and receivers, thus creating a safe environment where the sharing of patient data and images is restricted to the relevant participants of the target delineation conference.

User Experience

Our video-based target delineation conference system has now been in use for 18 months. The system has been very reliable with few technical issues. A short user manual placed at each workstation has eliminated most start-up troubles, for example, when using the switch boxes.

We experienced non-consistent technical issues when transmitting images from the image diagnostic workstations (IDW), used for PACS images. One example is that the IDW content was shown with one half on one screen and the other half on the other screen. We suspect that when transmitting the content of a certified IDW screen to a receiving end that does not have an IDW screen this can create nonconsistent and randomly occurring errors in how the content is shown. The graphic card on the PC of the Black Box transmitter can see the graphic card on the receiving end. This might be part of the reason for the issues mentioned.

A major benefit from the video conference setup is the valuable time saved per patient case on staff logistics between the different hospital departments, especially when only a few patients are discussed at a given conference.

By chance, our target delineation setup coincided with the need for social distancing due to the COVID-19 pandemic, and allowed us to continue target delineation at an unaltered pace and sustained quality.

Discussion

There are other technical solutions on the market from different vendors, apart from the Black Box Emerald SE that we describe here, that can create similar screen and image sharing setups. When dealing with image-based diagnostics, it is important that images are transmitted with no significant loss in quality. Other vendors have solutions that significantly compress images in order to gain faster network transmission. With the present solution, no notable differences between the transmitting and receiving end were observed.

Data Security

Due to the COVID-19 pandemic, Medicare has halted the use of penalties for the use of HIPAA (Health Insurance Portability and Accountability Act) noncompliant technologies (eg, Zoom, Skype, and FaceTime) to provide telemedicine solution, but this is of course a temporary solution due to data security reasons.[15] This is one example that COVID-19 has stimulated a productive use of technology, but that security issues have to be resolved.

The General Data Protection Regulation (GDPR) and other patient data legislation proved to be a challenge in designing our solution. Current patient data legislation calls for audit logging of patient data and relevant user administration. When conducting a target delineation conference over the network with our current Black Box solution, only the physician who is logged on to the transmitting PC is audit-logged in regards to the patient data. This physician is still legally required to note who else reviewed the patient data during the conference — just as it is current practice with other electronic patient record systems in conference settings.

The Black Box solution does not have Microsoft Active Directory integration. This means that we cannot use single-sign-on with the hospital's own regular ID-profiles. The solution has its own user administration through the Boxilla administration unit.

When designing our solution, the Boxilla unit proved to be the defining element of the security process that resulted in permission to use the setup from our Department of IT-security. This was due to the Boxilla's ability to enclose the network communication to the three specific locations. The Black Box Emerald solution can be used via a local VLAN, a local network based on several VLANs or over the internet. However, without an administration unit such as the Boxilla the transmitters may transmit content indiscriminately to everyone on the internet with an Emerald receiver as long as they know the IP address.

We find our solution ideal for a setup where the involved PCs and screens are dedicated solely to the target delineation conference. But due to financial and practical issues, the screens on the receiving end are also used for other purposes when not engaged in the target delineation conference. We have solved this by adding local KVM switches on the receiving end, which gives the clinical staff the opportunity to work on local PCs and switch to the target delineation conference screen when needed. This, however, is both a security issue and a practical issue, because the users of the PC on the transmitting end (in our case at the DCPT) are transmitting the content of their screen to two other locations, in principle not knowing who is watching at the receiving end. In addition, the clinical staff working on the receiving end should always be aware if they are working on the local PC or on the conference PC at the transmitting end (here the DCPT).

In conclusion, the system has been very reliable, saved a considerable amount of transportation time and allowed for a very short time spend on conferences and the planning phase of radiotherapy treatment. We believe our technical solutions and experiences could have implications for other institutions with similar demands or setups with even greater geographical challenges. Furthermore, the solution allows for "social distancing" without compromising target delineation quality, even in a time with constraints on physical conferences. The solution can easily be expanded to more locations at a relatively low price allowing for more subspecialised participation when needed.

We hope that the COVID-19 pandemic will eventually stimulate similar technical solutions to other practical issues, as well as help distribute knowledge, education and high quality treatment in a broader long term perspective.[31-32]

Declaration of Competing Interest

We have no experience with other vendors, and this report can therefore not serve as a comparison between vendors. No funding has been received from the vendors and the vendors have not had any influence on the conceptualisation or writing of the manuscript.

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