White Paper
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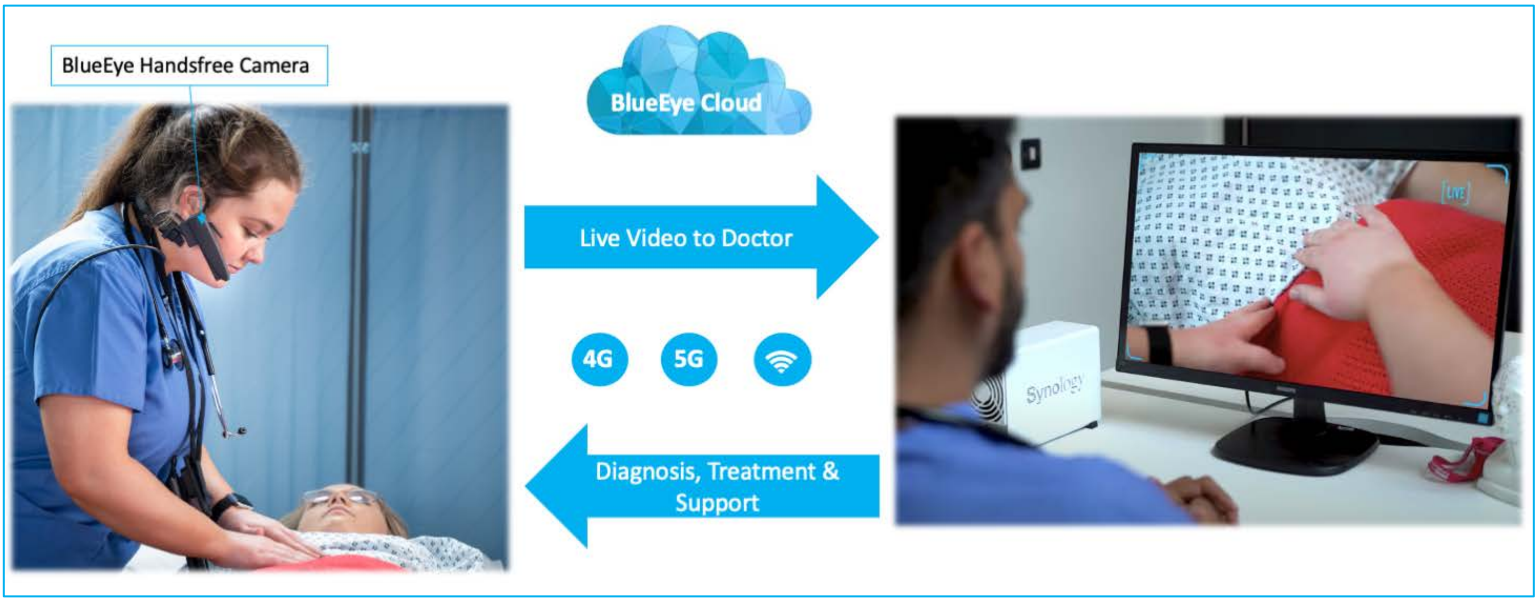
Using Mobile Video Telemedicine for Training and Consultation in Hospitals

A pilot of BlueEye wearable mobile telemedicine in Charité Hospital Berlin



Health5G

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1 EXECUTIVE SUMMARY

Telecommunications plays a critical role in supporting access to healthcare. Telemedicine continues to evolve and help improve healthcare. **5G** or fifth-generation wireless networks provides **faster speeds, lower latency and massive capacity** – making it ideal for video communications.

The **Health5G project** set out to test the usefulness of mobile wearable video for healthcare applications alongside the performance of 5G networks transmitting video data. Remote educational training was identified as a clinical need where video telemedicine could be piloted on 5G networks using a 5G campus network in hospital. The idea was to use mobile wearable video in a hospital setting to provide training to remote students. A second clinical use case remote emergency service support was further identified where an outdoor 5G testbed would be needed outside the hospital.

The **Technical University of Berlin (TUB)** and **Fraunhofer Institute** provided the private 5G networks for the project. A public 5G network was also available. **RedZinc Services** provided the *BlueEye wearable video*[1]. **Charité Hospital** provided clinical resources in the form of echocardiography education and consultation.

The project succeeded in the remote educational use case using the public 5G network and wearable video technology.

A combination of the Covid pandemic and GDPR issues in some hospitals means that further work is necessary to pilot a video use case within the hospital using the 5G campus network and to pilot the emergency services over the 5G outdoor testbed.

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[1] https://redzinc.net/blueeye/classroom/

2 INTRODUCTION

This paper is based on the work of some of the partners in the HEALTH-5G[2] CELTIC Plus project. *HEALTH-5G is a pan-European research and innovation project whose main goal is to devise and demonstrate health related use cases that utilise the benefits available via 5G*. HEALTH-5G has a total budget of over €7m and consists of 27 partners.

In this part of the project, several partners connected to the Cardiology Clinic in Charité Hospital in Berlin, collaborated to deliver an innovative 5G solution for medical support and training using ultrasound. RedZinc provided the BlueEye wearable video platform including BlueEye software, cloud services, camera headset and smartphone. Technical University Berlin provided 5G network support linked to the 5G testbed in Berlin. Fraunhofer Institut für Integrierte Schaltungen provided strategic advice on 5G applications, liaison with other hospitals in Germany, as well as a 5G campus portable testbed.

This white paper describes the pilot objectives, the mobile video technology, the educational use case, the pilot outcomes, and learnings from the pilot.

2.1 Motivation for Pilot

The objective of the pilot was to test if wearable mobile video can improve medical education by providing remote training with video, be a valuable learning tool and reduce the consultation time for cardiography.

2.2 Healthcare Challenges

According to the World Health Organization (WHO), eHealth can improve prevention, diagnosis, treatment, monitoring and management, and benefit the entire community by improving access to care and quality of care and by making the health sector more efficient. It includes information and data sharing between patients and health service providers, hospitals, health professionals and health information networks; electronic health records; telemedicine services; portable patient-monitoring devices, operating room scheduling software, robotized surgery and blue-sky research on the virtual physiological human[3].

The global telemedicine market has grown from $9.8 billion in 2010 to $11.6 billion in 2011, and continued to expand to $27.3 billion in 2016, representing a compound annual growth rate of 18.6%. The convergence between wireless communication technologies and healthcare devices and between health and social care is creating new businesses. Redesigning the delivery of care and the 'silver economy' are highly promising markets (eHealth Action Plan 2012-2020)4.

The COVID-19 pandemic has caused various difficulties in the global healthcare sector. In Germany, the lack and underdevelopment of digitalization in healthcare turned out to be vast, in comparison to other countries5. It became obvious during the pandemic that patient care had to change from in-person consultation to remote or tele medicine solutions, whenever possible.

Telemedicine solutions also involves training and the education of medical students. At Charité, students are usually on campus participating in rounds in the clinic or having face-to-face tutorials with patients and lecturers on the wards. Charité consists of four campuses in Berlin with over 3,000 inpatient beds and 100's of outpatient clinics. Currently Charité has 298 Professors with over 8,600 medical students. **Due to the increasing numbers of COVID-19 cases in Berlin and Germany from 2020, through 2021 and into 2022, Charité implemented escalation levels regarding different**

[2] https://www.celticnext.eu/project-health5g/

[3] eHealth definition, https://ec.europa.eu/health/ehealth/policy_en

[4] Benchmarking Deployment of eHealth among General Practitioners, (2013), https://ec.europa.eu/digital-single-market/en/news/benchmarking-deployment-ehealth-among-general-practitioners-2013-smart-20110033.

[5] Christina Arentz, Ines Läufer. (2021). Challenges for the German Healthcare System in the COVID-19 Pandemic and Beyond. 1. Retrieved 09.12.2021, from https://www.aicgs.org/2021/11/challenges-for-the-german-healthcare-system-in-the-COVID-19-pandemic-and-beyond/

procedural requirements on all campuses. The escalations forbade the usual student classes, limited overall clinical research activities involving participants coming to regular visits, restricted diverse workflows involving more than two members of staff in one examination room and categorically affected the clinical daily routine. In addition, consultation of doctors and professionals during examinations and clinical diagnostics needed a suitable telemedicine solution, when large numbers of consultants could be present at the campus. Furthermore, the request to work from home whenever possible meant some staff were not always on campus.

Learning to use RedZinc's mobile wearable video technology, BlueEye, at the Clinical Research Unit for Cardiology on the Virchow Klinik made a real difference.

Once fully implemented at Charité, it could be a long-term solution in telemedicine, student classes and clinical routines. The need for innovative solutions meant Charité wanted to take part in the pilot with RedZinc testing BlueEye video in a real life setting. It is used not only as a learning tool but also for real time feedback from Professor Edelmann, as he was at times not able to be on campus in person. The inspiration to complete such a pilot was driven by the rising COVID numbers and restrictions placed on the staff.

3 BLUEEYE MOBILE WEARABLE VIDEO TECHNOLOGY FOR REMOTE EDUCATION

Medical training often requires live demonstration of a medical action or procedure which requires a teaching professor and a group of students or trainee doctors in a hospital.
Groups of medical students and colleagues in hospitals present numerous challenges:

- Contagion risks
- Difficulties in accommodating large groups in small hospital rooms
- Disturbance and inconvenience to the patients or other hospital staff
- Unsatisfactory view of the procedure for the students

BlueEye technology addresses these challenges by enabling the medical educators to conduct live demonstrations for remote students using BlueEye wearable camera, BlueEye mobile app and BlueEye hot desk as shown in Figure 1.

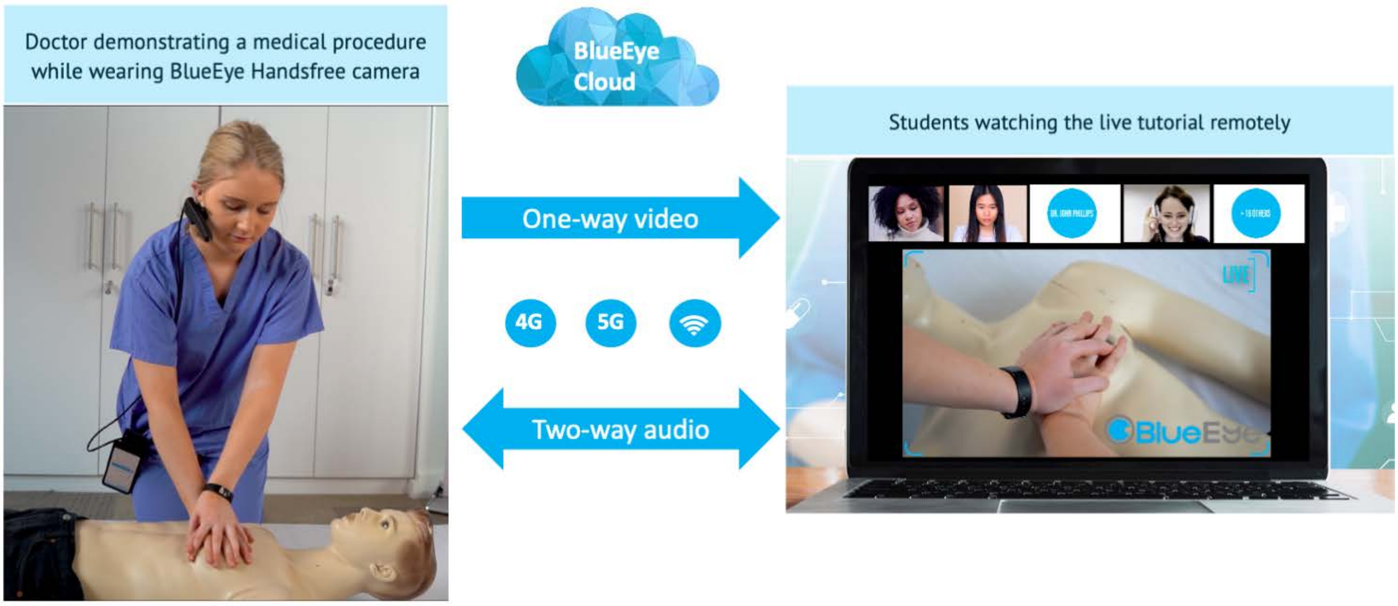

Figure 1 A medical professor giving a live demonstration of a medical procedure to remote students via BlueEye wearable video platform

Key features of BlueEye Classroom include

1. **2 Mega pixel** rotatable camera for optimum video quality
2. Narrow or Wide angle camera options
3. **No need for the students to download an app or software** to join the classes
4. High quality video and audio streaming using **prioritisation**
5. **One-way video** and **two-way audio** for uninterrupted and interactive video sessions
6. Supports local Wi-Fi as well as 4G/ 5G networks
7. Uses AES-256, TLS 1.2 and TLS 1.3 for data encryption
8. Supports multiple Operating Systems (MacOS, Windows), Web browsers (Google Chrome, Safari, Mozilla Firefox, Microsoft Edge) and device types (Laptop, Personal Computer, Tablet, Smartphone)
9. Complies with GDPR and Data Protection regulations

The wearable video solution supports an interactive and collaborative learning environment while facilitating *'You see what I see'* view of the medical procedure to many students.

4 5G AND 5G NETWORKS

5G provides an opportunity to deliver new services for healthcare. Many challenges in healthcare today could be helped by new digital technologies, such as:

COVID Pandemic: The pandemic has highlighted the need for increased digitalisation especially in video for reducing contagion.

Digital Transformation: Digital transformation is an ongoing process in many healthcare organisations and many organisations need support for new applications.

Shift Left, Stay Left. Health care is increasingly seeking to support patients' ex-hospital care. This means preventative care and improving pre-hospital and post-hospital support. 'Shift left' means support and keep patients at home and away from hospital.

Patient Outcome Improvement: Healthcare constantly strives to improve patient outcome. Healthcare providers seek evidence-based approaches to improving patient outcome.

Operational Efficiency: Healthcare operates from a fixed budget and society expects high performance from healthcare organisations. High expectations coupled with aging longer-living populations, places high demands on healthcare efficiency and CAPEX/OPEX.

These challenges can all be addressed, in part by new digital techniques, improving healthcare standard operational procedures.

5G promises fast mobile broadband, highly reliable networks with very low latency as well as a very high density of end devices.

eMBB (enhanced Mobile Broadband) offers higher speeds - up to 20 Gbit/s in the downlink (DL) and 10 Gbit/s in the uplink (UL). The extra speed can enable healthcare applications such as high-definition paramedic video, virtual ward rounds or live virtual reality. mMTC (massive Machine Type Communication) is intended to enable a high density of devices with the connection density of up to 1 million terminals per km^2. For healthcare this opens a wide range of possibilities for real time sensors for at home patients. Coupled with artificial intelligence there is a significant possibility to monitor health status and take action to improve patient outcome. URLLC (**Ultra-Reliable and Low-Latency Communication**) guarantees very reliable communication with very low latency (up to 1 millisecond) and thus a high availability for critical health care applications such as robotic surgery which requires fast response time.

With the help of 5G, the different requirements of modern future-oriented healthcare can be addressed.

- Significantly higher network performance in terms of transmission rates, reliability, and latency, but also a greater flexibility can, for instance, be of great value in providing a demand-oriented and personalized medicine of the future.
- 5G fulfils the prioritized requirements of healthcare, such as increased data security, a guaranteed Quality of Service (QoS) via network slicing and increased availability.
- Network slicing gives advantages for improved privacy and security.
- 5G gives improved performance compared to 4G in terms of better latency, lower costs per communications unit, reduced installation and maintenance costs and improve security.
- Compared to Wi-Fi, 5G gives better management and organization of wireless resources and reduces interference from other users and this is important for healthcare digital transformation.

4.1 Berlin testbed

Within project Health-5G, a 5G testbed was deployed in Berlin for the trials of various telemedicine scenarios in smart city context. The testbed incorporates the latest development and innovation of 5G mobile network and distributed cloud/fog computing technologies resulting from the project. Supporting demanding mobile healthcare services is the main motivation for the selection and development of core technologies in the testbed.

During project Health-5G, the German partners implement and trial telemedicine healthcare services for remote patients or emergency scenarios using smart city autonomous driving test bed Diginet-PS[6]. The testbed enables various connected and autonomous mobility (CAM) use cases for autonomous patient transport vehicles (PTV) in mixed and real traffic with traditional vehicles.

The clinical hub function is deployed using 5G and Multi-access Edge Computing technologies in the testbed. This provides a ubiquitous computing infrastructure to deploy eHealth service near to remote patients, for example, the BlueEye video server and other real-time analytics of medical sensor data.

The test area has full 5G coverage provided by both a commercial 5G network, and the campus 5G network based on OpenAir Interface software. The campus network allows advanced 5G technologies to be integrated to study unique requirements of eHealth applications.

Various use cases for eHealth developed by Charité Berlin incorporating eHealth services, such as, RedZinc's BlueEye HD streaming, are studied in the testbed infrastructure. This testbed can be used to support emergency services using mobile video for remote consultation and support.

4.2 Campus 5G testbed

Hospitals in Germany can apply for 5G licenses and thus become the network operator for their own 5G campus network, also called non-public network (NPN). This is known as **5G campus network.** Medical 5G campus network can be desirable for many reasons for meeting the demand of future-oriented medical use cases such as the ones below and others:

- on throughput of video- and data from medical diagnostic imaging systems
- connectivity of a big number of end devices and systems in a smart hospital
- real-time capability for telemedicine & patient monitoring
- on high security requirements, esp. data security for highly sensible medical and personal data

Fraunhofer IIS highly recommends 5G private campus networks to hospitals from the following five considerations:

i. **Independence from the public network** Private campus networks can be operated **completely autonomously** and do not require any interaction with external network components. The hospital IT departments can continue operation of the network in cases of a catastrophe or an environmental disaster through autonomous emergency power supply available in the hospitals. The use of a public network (for instance, a network slice in the public network) in such an emergency will not provide such independency and security. In an extreme situation of an earthquake or strong flood no network communication will be available to the hospital.

ii. **High security** Sensitive patient/hospital data remains isolated in a private hospital network.

[6] www.diginet-ps.de

iii. **Technological independence from the outside world** Configuration and maintenance of the hospital network is carried out by the hospital IT-department. The network can be customized for the big 5G use cases stated above: eMBB, mMTC and URLLC.

iv. **5G + MEC (Multiple Edge Computing) capability** The data gathered from diagnostic equipment such as X-ray, ultrasonic and MRI can be processed locally thanks to MEC. Besides traditional equipment, the use of artificial intelligence-based applications, such as machine-directed diagnostic tools, intelligent video endoscopes and many others, increases in hospitals. They all require extended processing capacity for analysing large amounts of imaging data. **MEC helps reduce the time between data collection and treatment by processing the data locally.** It delivers low-latency performance and accelerates diagnosis.

v. **Equipment Localization** *According to studies from some hospitals, medical staff spends up to 20% of its time searching for devices like syringe pumps and oxygen monitors, or even beds and patients.* With the large number of instruments and diagnostic devices in hospitals, equipment localization becomes a big issue. 5G campus network solves this problem by connecting communication and localization in one network. Tracking the sensor data of all devices, beds and patients in the hospital is possible. **Nurses and physicians can save a lot of time by locating equipment on their mobile device.**

Furthermore, hospitals will just need one single system for voice communication, data communication and localization which reduces complexity and streamlines operation.

4.3 Public 5G network

Hospitals in Germany can also procure 5G services from providers such as Deutsche Telekom. This is not a private network and does not have the same degree of customisation and security as detailed above.

5 GDPR AND DATA PROTECTION

Patient data protection is a complex area as it touches on privacy requirements, legal requirements and security issues as well as the more obvious structural and infrastructural problems. The exchange of clinical care information, radiology reports and medication lists, although improved slightly, remains an issue. The non-implementation of telemonitoring of outpatients, has gone from 89% non-implementation to 76% non-implementation between 2010 and 2012[7]. Telehealth is only implemented to a minor extent and is mostly available for holding consultations with other healthcare practitioners (31%).

However, when telehealth capabilities are implemented, they are mostly being used (usage in around 90% of the surveyed hospitals on average). This demonstrates that the capability offers genuine utility for healthcare professionals. European regulators have published high-level cybersecurity recommendations for industries including IoT (Internet of Things) medical devices.

Healthcare transformation needs to have policies to deal with patient privacy/permission for video. In practice, this means hospitals need to prepare and implement data protection policies when using video with patients. Firstly, a Data Protection Impact Assessment identifies and mitigates against any data protection related risks arising from a new project or technology in a hospital. Then a data processing agreement is signed off – this is a legally binding contract that states the rights and obligations of the hospital and the technology supplier concerning the protection of patient and hospital data.

As part of this project, three German hospitals were approached by the Health5G consortium to ask if they would pilot educational and emergency services healthcare use cases, based on the enabling technologies of RedZinc (BlueEye wearable video platform) and TU-Berlin and Fraunhofer IIS (5G infrastructure).

- Universitätsklinikum Erlangen (contact to Dr. Cornelia Erfurt-Berge, Dermatological clinic). The data protection team in Erlangen Hospital in Nurnberg needed more resources to evaluate video as a potential use case. Web-based patient contact continues to be evaluated by their data security team.
- Klinikum rechts der Isar in Munich (contacts to PD Dr. Michael Kranzfelder, Clinic and Polyclinic for Surgery and Isabelle Kirchbauer, Team Entwicklung & eLearning). Munich Hospital had GDPR concerns which could not be overcome in the timeframe of the project. Their approach was to obtain consent from each patient, which is very difficult to fulfill. Also, it was mentioned that the patients would not be aware of livestream implications, so it was difficult to legally cover everything in the patient consent form.
- Charité University Hospital Berlin (Medical clinic specializing in cardiology). The Charité GDPR group were satisfied that **data protection was not an issue by using manikins for the video instead of real patients and by not recording any patient data.**

Since the students take part on the patient examination remotely, our consortium prepared the following patient data protection measures for this use case:

- 5G private non-public campus network with the own user management.
- The educational platform is situated on the German data center and falls under the German data protection law. This means the video routers, media relays and other infrastructure is under EU GDPR and Germany data protection laws. The GDPR challenges of using hyperscale infrastructure does not exist as the data center has Germany corporate governance.

[7] (European Hospital Survey: Benchmarking Deployment of eHealth Services (2012-2013), https://ec.europa.eu/digital-single-market/en/news/european-hospital-survey-benchmarking-deployment-ehealth-services-2012-2013).

- Students agree upon and sign-up rules supporting the data protection agreement when they enter the class.
- Students receive a time sensitive onetime login with PIN get access the service on a browser for the class.
- The service does not include a record feature and students are prohibited by the rules from 'ripping' the video into a file or making screenshots.

The first service demonstration was very well received. Both doctors and clinic personnel involved in student teaching showed great enthusiasm about the implementation of the learning platform in the clinical environment and first trials. For instance, one participant involved in medical education commented that

"BlueEye wearable video platform is a very exciting product and an interesting approach from our consortium."

Unfortunately, the data security teams of the clinics in Munich and Erlangen were unable to sign off on the patient data protection measures prepared by consortium in time for the pilot.

Data protection regulation was a significant obstacle for the Health 5G consortium to offer essential technological support in the COVID-19 pandemic. Data processing regulation must be addressed by the German healthcare authorities and the hospitals themselves during digitalization to be more flexible and open for the new technologies.

The final outcome regarding GDPR and data protection was the pilot was accepted in Charité – Universitätsmedizin Berlin with mannikins/actors in the cardiac department. Furthermore, a sister 5G HEALTH pilot was accepted in Sweden. A data processing agreement was signed by RedZinc and the community nurse organization in Sweden.

To minimize or overcome any GDPR data protection obstacle to video telemedicine, the following terms were agreed

- No storage or recording of video
- No processing of patient name or other information
- No processing of patient record or other medical data records
- Inform the patient and show the benefits to the patient
- Use a Data Centre under Germany governance to keep all data local and secure

As a next stage we are providing a data processing agreement annex to the legal and IT department of Charité – Universitätsmedizin Berlin to establish that it meets their requirements. The annex includes: (i) list of data processed; (ii) list of data sub processors; (iii) security features (iv) data processing impact assessment.

There is further work to be done in getting data protection for the use of telemedicine. The benefits of improved patient outcomes and savings on costs are tangible benefits for the use of telemedicine which make this a worthwhile challenge to address at a government policy level. Strict security and data protection measures will ensure patient data privacy and build confidence of healthcare providers in the use of new technologies.

We are going to put more effort in the legal topics in the following, more user-oriented projects like EU SNS Stream D with the open cascade and many external users. Still, Germany with 80 million population, huge medical market and a lot of bureaucracy behind needs more time to adjust its legal system to the new digital technologies. The situation here is not comparable to that in Ireland with 5 million population.

6 PILOT OUTCOMES

The mobile wearable video was used for two use cases in Charité cardiac department

(a) for training or educational events
(b) for consultative or collegial support

Cardiac Department uses echocardiograms as part of its work. An echocardiogram, or ´echo´, is a diagnostic procedure using ultrasound to investigate the heart's movement, image the heart's chambers and the four heart valves throughout clinical routine to assess the physiological function. Additionally, Color Doppler and Doppler ultrasound are applied to evaluate and assess the specific blood flow through the corresponding valves. With the echo investigation, physicians and doctors are able to diagnose manifold structured heart diseases like valve diseases and diverse kinds of heart disease, but also follow diseases or structural changes over time. It is also a good indicator whether a certain treatment is working and has an actual effect. (Cleveland Clinic, 2019)

6.1 Training and Consultations Events for the Educational Use Case

A number of training events and consultations used mobile wearable video in Charité as follows

Resuscitation Training Event

Resuscitation training is annual required training for Charité staff including nurses, doctors, scientists and students. Due to COVID-19, it was impossible to host this training event with high number of participants. Thus, it was the first opportunity to try out BlueEye platform. The event was hosted in a large auditorium, having room for a certain amount of participants in consideration of COVID-19 restrictions. Seven participants were physically present, and four participants followed the training remotely through BlueEye.

Echocardiography Nurses Training

The second use of BlueEye combined the CRU´s and BIH´s (Berlin Institute of Health) regular echocardiography nurses training. Normally, around 5-10 nurses and 1-2 doctors take part in a course for several hours. The examination room has to be constantly dark in order to have the echocardiography pictures and recordings visible in high quality. Otherwise, it would be a source of errors and diagnostics would not be meaningful. Thus, the requirements regarding the camera features are of great importance. In this pilot, two nurses and one doctor were present in the examination room giving the training, whilst three nurses followed the course remotely through BlueEye Classroom.

Echocardiography consultation with Prof. Dr. Frank Edelmann (Charité)

When Prof. Dr. Edelmann was not on campus, BlueEye was used for remote consultation regarding different diagnostic examinations and echocardiography pictures and loops taken from patients as shown in Figure 2.

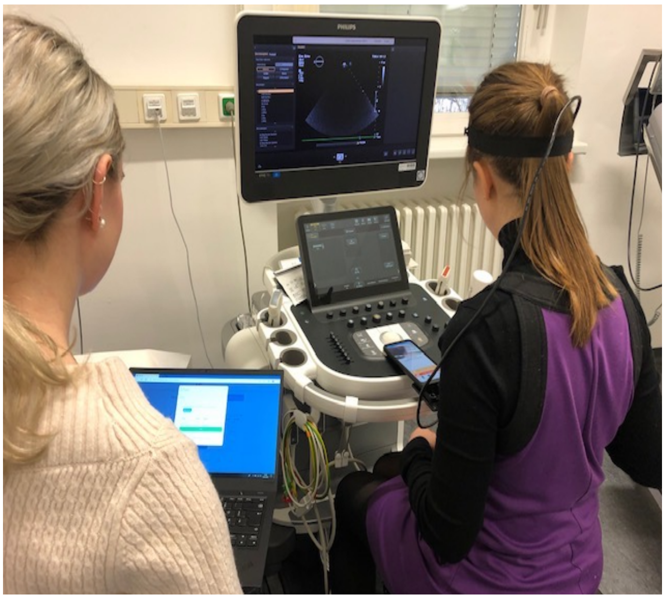

Figure 2 A doctor sending real-time video of an echocardiogram to remote Dr Edelmann using BlueEye camera and mobile app

Clinical Research Unit Team Meeting

BlueEye platform was used for weekly team meetings as a try-out. In these events, four study nurses and Prof. Dr Edelmann were present in one room, while two study nurses and two doctors participated remotely.

Echocardiography Examination Training
BlueEye was used in the Cardiac Clinical Research Unit for routine echocardiography training (six times to date).

6.2 Standard Operating Procedure for Echocardiogram Consultation Support

For an echocardiogram consultation, a patient is seen and an echocardiogram is performed by a qualified healthcare professional. **If there is any issue, the consultant is called in to review the patient and the echocardiogram. This means the consultant has to travel from nearby or distant locations to see the patient and the test results**. The use of live video changes the Standard Operating Procedure for a consultation as shown in Figure 3.

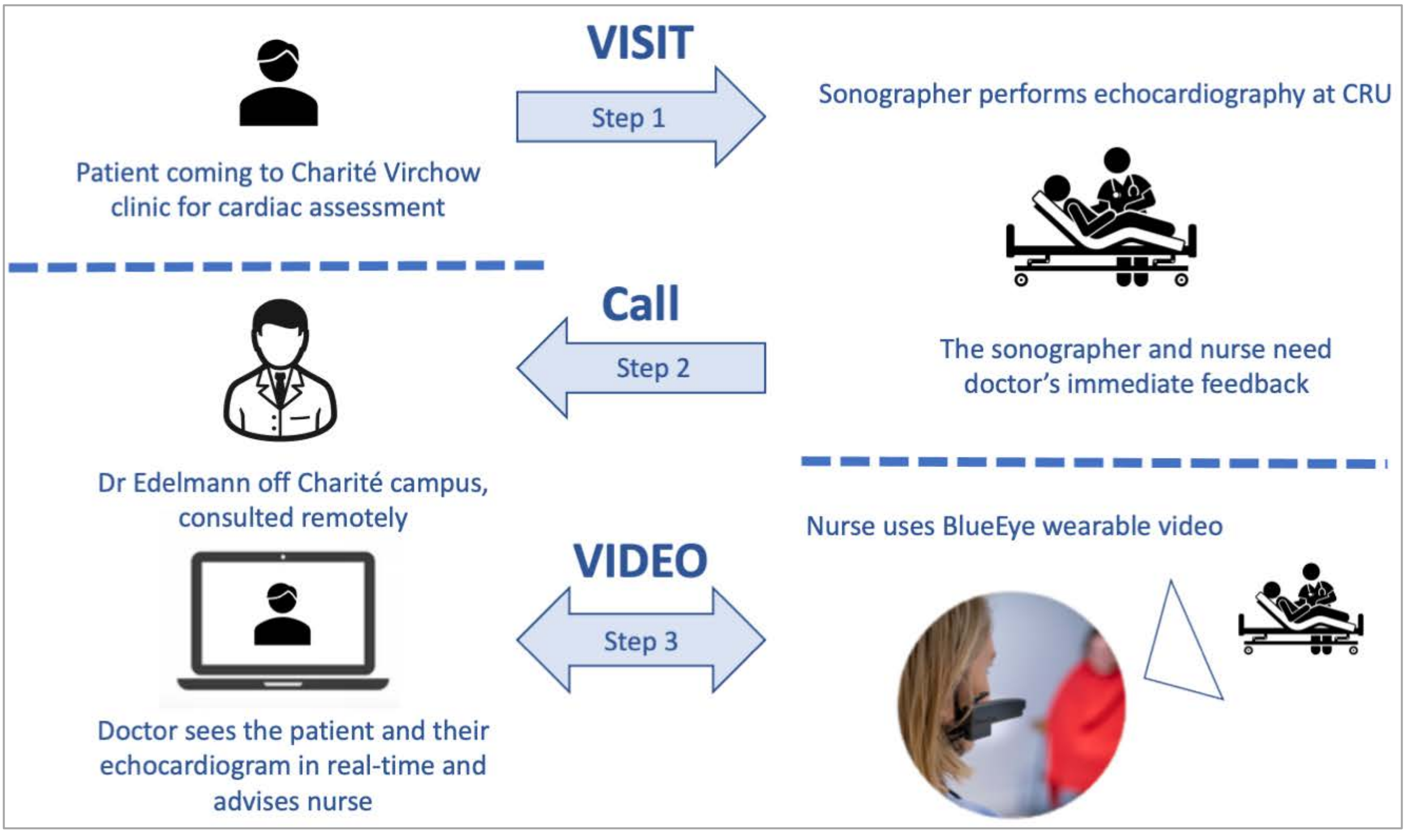

Figure 3 Cardiac Assessment Standard Operating Procedure with Video

BlueEye Classroom Remote Video Echocardiogram Consultation Support
Table 1 below describes the Standard Operating Procedure of Echocardiogram consultation with and without BlueEye video

	No video	**With video**
Situation	Consultant support is challenging due to location in hospital campus. Before corona see 5 to 7 patients daily. Consultant would come once per day. Save the images into hospital SAP patient record system (Doctors notes, patient records)	Consultant support can be instantaneous due to remote video
Task	Echocardiogram consultation support	Remote Echocardiogram consultation support

Action	Call Dr Edelman when there is a suspected problem (approx. once daily). Consultant comes over once daily to see complicated echocardiogram results and patients. Consultant receives full contextual info on patient including dialog on how patient is feeling, history of patient and current echocardiogram.	Video Call Dr Edelman when there is a suspected problem. Consultant can see patient remotely without travelling. Remote consultant can dialog and see patient and echocardiogram using BlueEye video and can access patient records remotely on SAP
Results	Consultant spends time in travel to give consultation support daily Possible delay in patient diagnosis treatment and follow up e.g., send patient to ward, start new medication, send to emergency room, further diagnosis	Faster patient care/treatment Optimum use of remote consultant time No need to travel

Table 1 BlueEye remote video echocardiogram SOP steps

6.3 Standard Operating Procedure for Echocardiogram Training

For echocardiogram training, an echocardiogram is performed by a qualified healthcare professional. The students are in the room beside the machine and ask questions. With video, the students can learn remotely. This is summarised in figure 4 below.

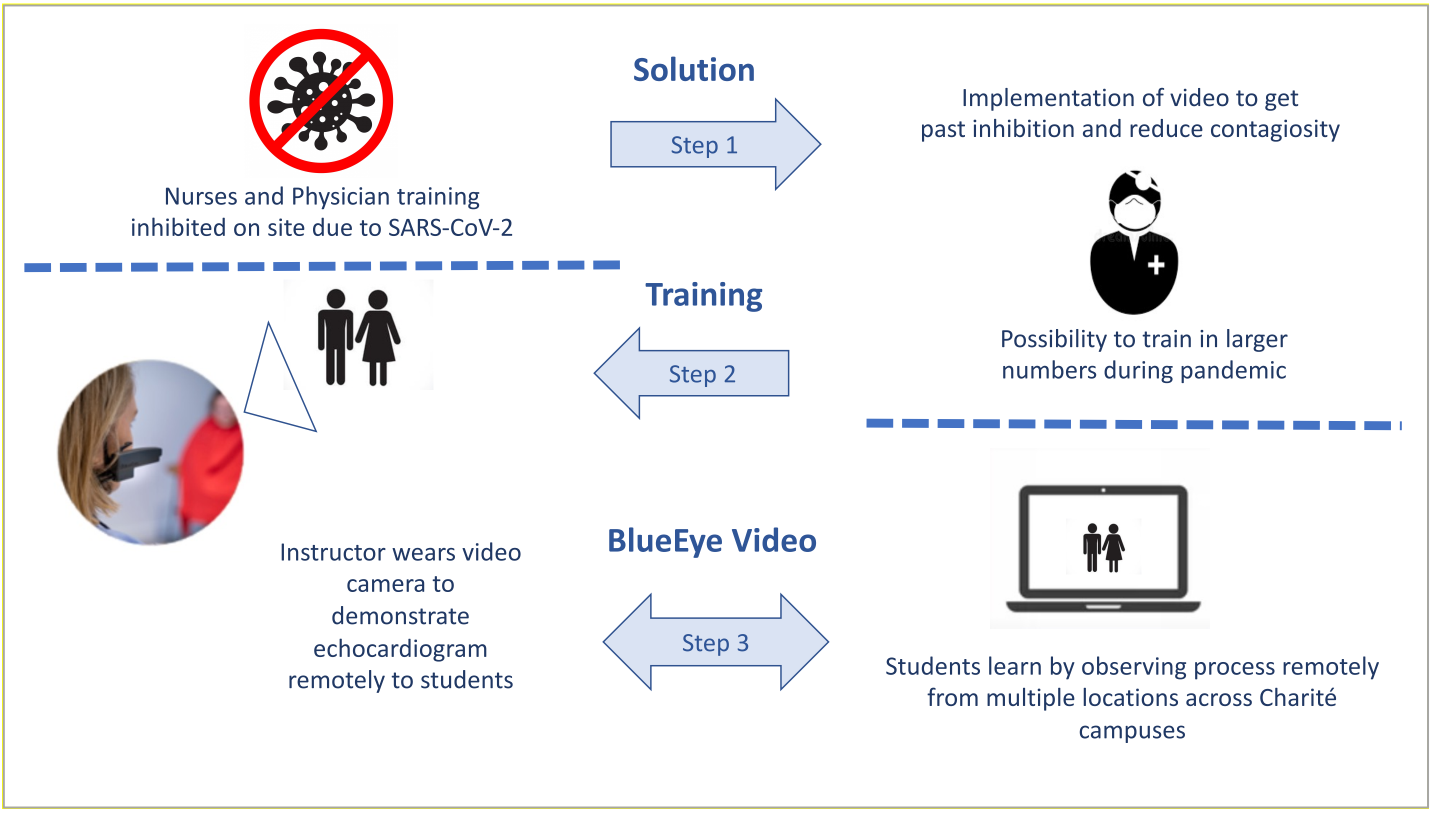

Figure 4 Echocardiogram Training Standard Operating Procedure with Video

BlueEye Classroom Remote Video Education/Training SOP

Table 2 below describes the Standard Operating Procedure of Remote Training with and without BlueEye video

	Current Procedure	New Procedure with video
Situation	Training was inhibited due to coronavirus	Addition of video to training process to get past the inhibition/reduce contagion risk
Task	Training in limited numbers at different points	Train larger numbers simultaneously
Action	1. Actor patient 2. Teacher expert in ultrasound demonstrates to echocardiogram to students 3. Students learn by observing process in same room	1. Actor patient 2. Teacher wears video camera and video is sent to remote students to demonstrate echocardiogram 3. Students learn by observing process remotely from multiple locations in Charité hospitals campuses
Results	Low volume (reduced from 5 to 10 students to 1 to 2 students during pandemic) Extra training sessions needed Backlog in training	Higher volume Fewer training sessions needed No backlog in training

Table 2 BlueEye Classroom Remote Video Education/Training SOP Steps

6.4 Software Challenges

As with most pilots, there are hurdles and obstacles that one must overcome in order to complete the project and with the Health 5G pilot, this was no exception. We encountered the following software related challenges during the project.

Logins and equipment

The staff had difficulties sometimes knowing exactly which log in to use for which task was to be performed. As well as the issue of knowing which device to use when sending out an invitation for a training session, the staff learned they needed to use a laptop that had video and audio capabilities before sending out the invitation.

RedZinc addressed this by implementing a new feature where user email addresses can be used for creating classroom and handsfree login ids. This will help to remove any login confusion. For device use, users can now change the device name in the app which will help them to identify which device to use for BlueEye classroom. In order to see if a laptop has video and audio capabilities RedZinc suggested to carry out a Test call on the laptop hot desk before using it for training sessions. It is always important to run a test call before the actual call.

Software Upgrades

Another technological issue identified was that the upgrades were not automatically installed. At the time of the session, when an educator tried to login, the system asked to update the app. This resulted in delay. A helpful automatic update or notification could be useful in such a scenario.

To address this, RedZinc have added automatic updates of BlueEye app to the product roadmap.

6.5 5G Network Challenges

5G network service

Another issue encountered during the project was the unavailability of 5G service with SIM cards. Working at a large hospital, there can be limitations to the purchase of a specific SIM card from a carrier that has the 5G capability. In order to get around this Charité hospital borrowed a SIM card from TU University Berlin in order to see the quality difference. Later on campus Wi-Fi was used. Charité was unable to purchase a 5G sim card from a provider that the university campus recognizes, due to numerous firewalls and data protection measures.

Hospitals should be able to receive 5G for faster transmittal of the video and sound, so that students and physicians get a clear picture and a good sound quality immediately or still framings. The quality of the video is highly important, especially during Echocardiography classes. The physicians need to be able to analyse the image and teach students about what they see and the position of the ultrasound device needs to be changed in order to see different parts of the heart at certain angles.

6.6 Hardware Challenges

Ergonomics

A key aspect of wearable camera is the comfort in wearing it, the first version of BlueEye camera was uncomfortable. It was stiff and the wearer felt uneasy, especially when wearing it for a long duration. RedZinc later provided a new headpiece which is very comfortable and easy to wear. The headband is flexible, can be worn for long durations and fits all types of heads.

RedZinc have introduced a new design of camera mounting with an adjustable elasticated headband mount.

Camera lens angle

The picture quality from the camera is good, but a better resolution is needed in some cases such as for direct visualisation of specific measurements needed for the Echocardiography. A zoom feature would be useful in such a scenario.

RedZinc has added zoom feature in the product roadmap.

6.7 Success Factors and User Experience

Success Factors

The objectives of the pilot were to test if mobile video can improve medical education and reduce consultation time necessary in the Cardiac Department. It was found that the **technology was a useful tool for remote learning especially when big groups could not be accommodated. It improved the ability of the consultant to give consultative support even when far away from the department. It was also useful for real-time feedback from the consultant during an echocardiogram.**

This shows that training sessions increased with video, the number of students being trained increased with video, there was a reduction in time for Dr Edelmann in travelling to the department and there was a time reduction for patient care due to the use of video.

The following table (Table 3) shows the metrics which were noted without and with video.

Metric	Without Video	With Video
Number of training sessions performed per week	1/week	3/week
Number of students being trained with/without video	1-2 students	5-6 students
Time reduction for Dr Edelmann in travelling to department	0	25- 30 minutes /consultation
Time reduction for patient care	0	25- 30 minutes /consultation

Table 3 Metrics comparing the medical training with and without video

User Experience

A number of questionnaires were filled out to get feedback on the video technology. These questionnaires were to do with the BlueEye Technology usability and comfort and can be summarised as follows (Table 4):

Features	Liked	Suggestion for improvement	Solution/Outcome
Camera	OK to adjust size	More comfortable mounting on head	Redesign of head mounting – Headband camera available now
		Zoom option	In product roadmap
		Different lens for close ups	Narrow and wide angle lens options available now
Smartphone	OK to clip on	Improve audio/echo Longer cable	Audio toggle switch between smartphone speaker and earphone Available
BlueEye App	Snapshot feature useful	Automatic updates	In product roadmap
BlueEye Hot desk	OK to use	Customisation	In product roadmap

Table 4 Suggestions to improve BlueEye wearable video solution

In general, the use of video in remote education and consultation in the Cardiac Department was found to be beneficial. Overall the backlog in training was reduced as training could be scheduled again with remote training available. Sometimes no training sessions were allowed during COVID-19 and this changed with the use of mobile video.

Hospitals using wearable video to send real-time video from a clinical scenario to a remote medical expert for support, can offer many benefits such as

- Accelerate treatment and learning through instant remote assistance/expert advice
- Improve patient outcomes
- Eliminate contagion risk
- Enhance operational efficiencies
- Enable remote training
- Enable point-of-view video transmission without impacting the wearer's vision
- Eliminate unnecessary travel savings cost and time
- Eliminate geographical barriers in getting support from medical expert(s)

7 CONCLUSION

The use of mobile video for education and consultation proved to be beneficial in **increasing the number of training sessions** and the numbers of students being trained. Video also gave the ability to get **remote support** from a colleague during ultrasound echocardiography investigation supporting **quicker decision-making.** Mobile video can provide remote support, real-time feedback and ultimately can improve patient treatment and save costs for the hospital. There was an established ability to train sonographers remotely. This remote training was necessary at the time due to COVID contagion risk but can be used in circumstances where students or trainers are remote from one another.

Wearable video has many applications in-hospital and pre- and post-hospital such as emergency situations and virtual ward rounds as well as in education and consultation.

An integrated mobile video service will help improve access to healthcare, increase quality of healthcare and reduce the cost of healthcare, while offering an easy-to-use solution for healthcare professionals.