CAN SMART PHONES BE USED IN A TELERADIOLOGY SETTING FOR EVALUATING LUNG CANCER THERAPY RESPONSE?

by

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Date: ______________________________

ABSTRACT

CAN SMART PHONES BE USED IN A TELERADIOLOGY SETTING FOR EVALUATING LUNG CANCER THERAPY RESPONSE?

Works to be done daily can be done with mobile technology in more practical, flexible times, in desired environments. With this study, it is aimed to increase productivity for radiologists by the use of some techniques to improve the performance of mobile displays at normal conditions. It was chosen a mobile dicom viewer which is called Medfilm in the Iphone 6S model smartphone. As a DICOM viewer in the computer, Radiant Dicom Viewer Version 4.1.16 was executed to examine the images in the Viewsonic VA2410-mh model monitor. For case analysis, nodules in lung CT images were examined. Data was taken from TCIA collection [4]. 271 cases were included in the study.It was used Bland-Altman analysis, which is the most accurate method used to describe the harmony between the two measurements. According to Bland-Altman test with 95 % confidence interval, the difference between observer 1 and 2 were calculated as 0,6740,39 mm and 0,660,387 mm respectively. If the differences are normally distributed, we would expect 95% of the nodule measurement differences to lie between -0.095 mm and 1.443. It can be said that nearly all pairs of measurements by the two methods will be closer together than these extreme values, which we call 95% limits of agreement. The difference between observer 1 and observer 2 for smartphone and monitor measurement were calculated as -0,190,662 mm and -0,1620,55 mm respectively. If the differences are normally distributed, we would expect 95% of the nodule measurement differences to lie between -1.5 mm and 1.12 mm for observer 1 ; -1.25 mm and 1.12 mm for observer 2. The encouraging results show that smart phones can potentially be used in tele-radiology for evaluating therapy response in lung cancer during clinical trials or actual therapy for large tumors.

Keywords: Digital Radiology, Teleradiology, mHealth, Dicom Images, Mobile App.

ÖZET

AKILLI TELEFONLAR İLE AKCİĞER KANSERİ TEDAVİSİ DEĞERLENDİRMESİ TELERADİYOLOJİ DE KULLANILABİLİR Mİ ?

Günlük yapılması gerekenler mobil teknolojiyle daha pratik, esnek zamanlarda istenen ortamlarda yapılabilir. Bu çalışma ile normal koşullarda telefon ekranlarının kullanımı ile radyologlar için verimliliğin arttırılması amaçlanmaktadır. Medfilm denilen bir mobil dicom görüntüleyici seçildi. Medfilm, DICOM PACS istasyonunun ve tıbbi araştırmaların aynı anda görüntülenmesine uygun bir görüntü işleme yazılımı olarak kabul edilir. Olgu analizlerinde akciğer CT görüntülerindeki nodüller incelendi [4]. Bu çalışmanın amacı, farklı radyolog deneyim düzeyleriyle aynı koşullarda taşınabilir ve mobil cihazlarda kullanılan ekranların performansını değerlendirmektir. Gözlemci 1 için PACS istatsyonunda yapılan ölçüm ile telefondan yapılan ölçüm farkı ortalama 0,6740,39 mm olarak hesaplanmış olup istatistiksel olarak anlamlıdır ($p<0,0001$). Elde edilen Bland-Altman grafiğinde olguların %99,6'sında nodül boyut farkı -0,095 ile 1,443 mm aralığındadır. Gözlemci 2 için PACS istasyonunda yapılan ölçüm ile telefondan yapılan ölçüm farkı ortalama 0,660,387 mm olarak hesaplanmış olup istatistiksel olarak anlamlıdır ($p<0,0001$). Elde edilen Bland-Altman grafiğinde olguların %96,11'inde nodül boyut farkı -0,107 ile 1,426 mm aralığındadır.PACS istasyonunda yapılan ölçümlerde gözlemci 1 ile gözlemci 2 arasında ölçüm farkı ortalama -0,1620,55 mm olarak hesaplanmış olup istatistiksel olarak anlamlıdır ($p<0,0001$). Elde edilen Bland-Altman grafiğinde olguların %92,83'ünde nodül boyut farkı -1,25 ile 0,926 mm aralığındadır.Telefonda yapılan ölçümlerde gözlemci 1 ile gözlemci 2 arasında ölçüm farkı ortalama -0,190,662 mm olarak hesaplanmış olup istatistiksel olarak anlamlıdır ($p<0,0001$). Elde edilen Bland-Altman grafiğinde olguların %98,35'inde nodül boyut farkı -1,5 ile 1,12 mm aralığındadır. Bu sonuçlar gösteriyorki, telefon akciğer kanseri nodül boyutu ölçümüyle tedavi derğerlendirmesinde kullanılabilir.

Anahtar Sözcükler: Dijital Radyoloji, Teleradyoloji, mHealth, Dicom Görüntüleri, Mobil uygulama.

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LIST OF ABBREVIATIONS

ACR	American College of Radiology
CT	Computed Tomography
DICOM	Digital Imaging in Communication in Medicine
GE	General Electric
GUI	Graphical User Interface
HIS	Hospital Information System
HL7	Health Level 7
HTTP	HyperText Transfer Protocol
MRI	Magnetic Resonance Imaging
PACS	Picture Archive and Communication Systems

1. INTRODUCTION

Developments in technology affect all sectors as well as health sector and transforms business processes. In developed countries, this situation is higher, but this situation is less in underdeveloped and developing countries. Although the position of developing countries from Turkey to adopt the technology, said to be the adaptation and use of high performance. This is still the case in the context of the health sector. As a matter of fact, the institutions and organizations operating in the health sector in our country use the latest technologies by integrating them in the system. One of the newest technologies is e-health applications. E-health, m-health, tele-health etc. concepts are also widespread in the world. Significant steps are being taken in our country regarding the use of these technologies in the health sector. Starting by integrating them into the said technologies healthcare institutions, should health be performed both of the logistics activities in service delivery due process experienced say costs could be used as effective tools in reducing all the improvements possible considering.

Advances in health systems have led to the emergence of new concepts. One of the most important of these concepts is Telemedicine. Diagnosis using information and communication technologies in remote centers, treatment, follow-up evaluation with the aim of sending physiological signal, storing and healthcare delivery to telemedicine is called [1, 2].

Imaging methods are an indispensable tool in modern medicine. One of the biggest problems in this area is the increasing number of investigations. Therefore, radiologists cannot allocate enough time for analysis. Because despite the increase in annual imaging methods, the number of radiologists remains limited. When the current conditions are met, it can be said that the most effective method of dealing with this problem will be tele-radiology. Tele-radiology, radiologists serve by allowing patients found nowhere is contributing to the development and sustainability of health services provided [1].

This study was carried out by using Medfilm mobile application. Because Medfilm is a workstation-like software. As a DICOM viewer in the computer, Radiant

Dicom Viewer Version 4.1.16 was executed to examine the images. It is possible to perform all operations with this software which provides simple and effective interpretation of the analysis and images equipped with special methods. Thus, it can be concluded that the interpretation of medical images with mobile technologies could be used in diagnosis and treatment for clinicians.

2. LITERATURE REVIEW

2.1 Telemedicine

New developments in technology provide more accurate diagnosis and treatment opportunities in medicine, but also provide better communication opportunities between doctors and patients. The dissemination of communication technology in every area of ââour lives and the easier access to information have led to the widespread use of technology in diagnosis and treatment in the field of medicine as well as in patient-doctor communication and even in the regulation of clinical applications in most branches. Tele-health applications are common in many developed countries today because of the advantages of the physician to gain access to patient information more quickly, easily and more frequently even if they do not replace classical physical examination and patient follow-up. It is seen that it can open a new horizon in daily medical practice.

Telemedicine methods include clinical applications of tele-health services and use in treatment and patient follow-up. Today, tele-health networks are established all over the world and remote health services have been started and clinical and pharmacoeconomic studies are conducted. Tele-medicine applications are increasingly used in science, such as endocrinology and oncology where chronic disease is frequently followed.

Tele-medicine applications are examined in 3 categories: store and forward services where information is stored and then evaluated, remote control and interactive services.

2.1.1 Telemedicine History

The beginning of telemedicine applications dates back to the 1960s. In 1964, a 180-kilometer closed-circuit television system was installed between the Nebraska Psychiatry Institute in Omaha and the State Mental Hospital in Norfolk [6]. This system enables interactive consultation between experts. In these years, special lines were established and telemedicine applications were started in North America to provide health services to rural areas without specialist physicians. In 1968, the video connection between Massachusetts Hospital and Boston Airport eliminated the need to have a permanent physician at the airport [7]. In 1968, through the INTERACT program, consultation and training from specialist physicians were provided in rural areas using telemedicine [5]. With the development of satellite communication techniques in the 1970s and 1980s, many projects have been started to establish connections with clinics located at far distances. In particular, U.S. Pat. and in Canada several telemedicine projects have been initiated. Most of these projects could not be continued due to high costs. In Germany, 30 hospitals in the framework of Medkom have been working with video conferencing since 1986. In a study conducted between the United States and China, doctors in the United States in the treatment of patients in the diagnosis and treatment of medicine has been provided [8]. Nowadays, telemedicine applications are increasing in parallel with the developments in the communication and communication sectors. America, Canada, Australia, the UK and Germany are the leading countries in telemedicine applications [9].

2.1.2 Telemedicine Uses

Telemedicine is used not only in hospitals but also in military field, in space researches and in prisons for remote consultation. Remote patient monitoring; in order to be transmitted over long distances, patient data is collected using various electronic devices and sent to the monitoring center for evaluation. For example, data such as heart rate, the oxygen in the blood, the amount of carbon dioxide in the astronauts in space can be monitored from around the world by various methods. Again, the medical data of patients working in distant places or away from hospitals can be monitored remotely by telemedicine [10].

Disease diagnosis and treatment; In case of difficulty in diagnosing the disease, the information and examinations of the patient are sent to other centers via the communication and communication tools. Diagnosis can be made, and treatment can be arranged through the experts or centers. Medical education and research; Access to databases and special seminars provide medical education and research for health personnel and patients far away from medical centers [10].

Mobile communication technologies, short and long-distance usage, power con-

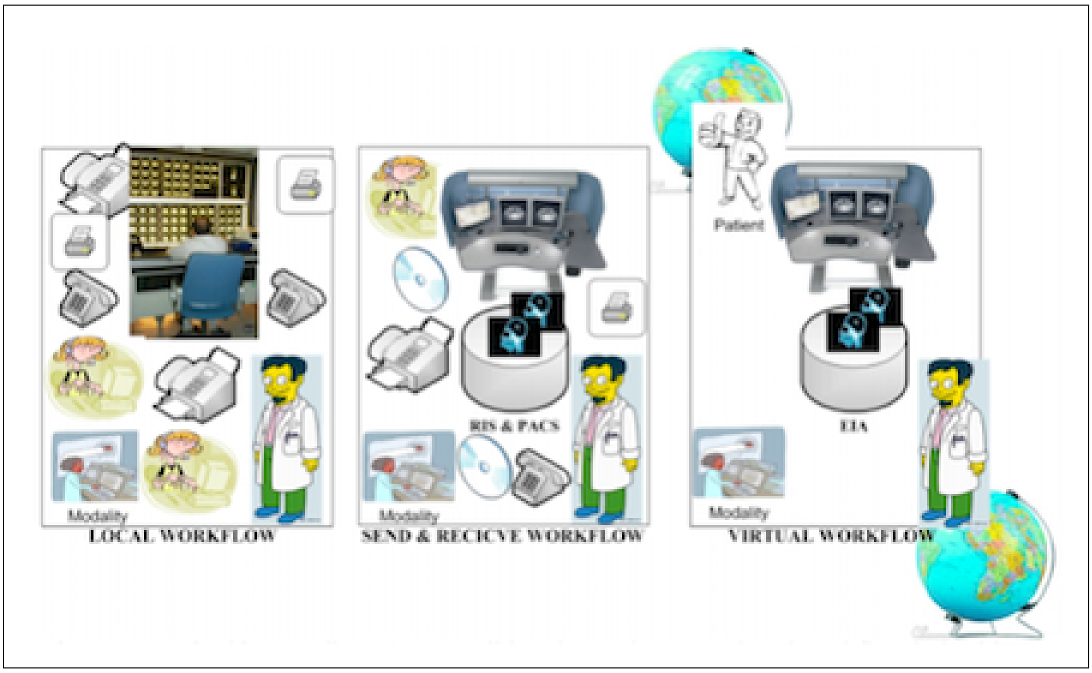

Figure 2.1 Describing the road map to virtual workflow in healthcare [10].

sumption, data transfer rates are different. However, the problems with their interoperability, the inadequacy of the devices supporting these technologies and the additional cost of transition to these technologies are among the most important problems that restrict the use of mobile communication technologies in health systems. However, with telemedicine, hospitals are becoming a place of intervention rather than a place of intervention. Electromagnetic wave and similar effects caused by the devices used in the continuous monitoring of the patient independently from time and place with telemedicine are among the side effects of this method. With these impacts, various expectations have emerged from mobile health systems [11]. Some of these expectations are as follows;

- Being a system where specialist doctors can access from their home, gather patient and specialist doctor between remote centers for the purpose of disease monitoring, use innovations brought by mobile communication technologies and eliminate time and space.
- To help patients make more effective decisions about the treatment of disease by obtaining statistical data by continuously monitoring the various physiological signs taken when patients go to hospital,
- Intelligent life support system working on the server located in the remote center to prevent the patient from predicting the crisis and prevent it,
- Being an assistant between physician and patient,
- Informing patients and raising awareness,
- To improve the quality of life of patients,
- To reduce treatment and follow-up costs [12].

2.2 Mobile Health Applications in Access to Health Services

Individuals need to have equal access to health care in order to live independently. This situation should be considered more important for disabled people. Disability, temporary or permanent loss of labor, loss of hearing or eyesight, temporary or permanent damage caused by accidents in childhood cause people to live a life connected with others. The design of technologies to be developed in this context in consideration of this situation is important for the inclusion of health technology. New generation smart devices have the ability to send voice messages, the ability to voice the actions performed on the screen and so on. These characteristics represent a great potential for visually impaired individuals.

In order to reduce waiting times in health institutions and organizations, it is necessary to make use of information technologies that make life easier. In order to decrease the waiting times of the patient, it is very important that the patient comes to the hospital by appointment, select the hospital and the physician, perform his/her operations remotely and perform the results remotely. Mobility has isolated the health institutions and organizations from time and space dimension and has a more autonomous structure [13]. The use of mobile applications reduces the medical error by 30% compared to the manual ones [14]. This is a noteworthy development in terms of preventing the loss of personal negligence and inaccuracies.

In this sense, mobile health has taken its place as an indispensable element in health services. Reduction of waiting times in hospitals, people to perform all operations on the smart device before coming to the hospital, makes people more autonomous. The person measures his own blood sugar, blood pressure, pulse and calories so that he has the opportunity to change his life style behavior. One of the objectives of using information technologies in the provision of mobile health services is to ensure that people are the determinants of their own health status, to be a family of conscious and healthy individuals, thus creating a healthier society.

Developments in information technologies create new opportunities for health care and provide new insights into future-oriented health services. Electronic tools and applications are widely used in health care services in developing and developing countries to reduce transaction costs and provide higher quality healthcare services. With the development of information networks, intra-hospital and inter-hospital networks transform the health system into a more transparent, patient-centered and accountable structure. Electronic systems, increased use of information and communication technologies, e-health, electronic health, integrated health, m-health has led to the formation of concepts such as. From the past to the present, these concepts have been used to express the change in the health system, to indicate the link between information science and health services. The emergence of network structures connects lives in the virtual world. Mobile, electronic, wireless networks have changed people's lifestyles with small technologies. As in some areas, most technological products have been used in health care [15].

Extensive technological possibilities are important for storing, analyzing and drawing projections for the future. It is important to enable voice communication between patient and health worker, visualize data for patient and health worker, allow place notifications, and obtain regional disease profiles. For the cost-effective delivery of health services, it is necessary to determine the health profiles of the regions, and to determine which region the health demands come from which region will inspire the health investments on a regional and national basis.

The use of mobile healthcare applications in the health care industry has become an issue that has been emphasized and discussed. The provision of health services effectively for hospitals. Hospitals want to offer quality health services to their patients at the lowest cost. In terms of patients, patients want to improve their health status in the most favorable conditions. It is the basic desire of the patients to get the highest quality health services at the most affordable prices. Patients want to manage their own health status with the latest applications. In terms of suppliers, such as pharmaceutical or medical companies, they want to enter into long-term relationships with health institutions and organizations and patients and to increase their own benefits.

2.2.1 Factors Affecting the Success of Mobile Health Applications

In terms of the necessity of disseminating mobile health, the possibility for better health care delivery wherever there is a mobile signal. This situation is considered to be the high inclusion of mobile health and the possibility that everyone can benefit from the service equally. Mobile health practices aim at protecting and improving human health. The success of these programs is necessary for improving public health. In order for mobile health programs to be successful, some conditions need to be met and are listed below [16]:

- Strong cooperation needs to be established. The projects required to be implemented should be supported by different sectors. The inclusion of different stakeholders in the project is important in terms of synergy and success to enable a more dynamic network.

- Accessible activities should be performed. It is stated that the projects realized by taking the demographic structure of the society into consideration can be successful. For example, it is stated that if the language used or the age range addressed is not taken into consideration, the studies will not yield results. Since the expectations of young and old people are different, all details should be considered in order to appeal to everyone with a single application.

- For whom the project is to be done, it should only be done by paying attention to the characteristics of that group and focusing on the availability of available practices. Steps should be taken by considering the contributions and expectations of the users in the applications to be developed.

- A long-term resource plan is required. If a significant project is to be carried out for a particular audience or public health, lack of resource problems is necessary for the results of the studies. Planning should be done well in terms of both financing and human resources.

- Measurable targets are required.

- Collaboration with mobile health application developers should be pursued and practitioners who are good in the field should be followed.

2.2.2 The Future of Mobile Health Applications

In the changing and developing world, there are significant differences in economic level among countries, as well as cultural differences such as the availability of technical structures, creation and dissemination of networks, and literacy. Although all these differences are found among countries, mobile health will probably become a shining area without notice [17]. Studies on the delivery of mobile health services have the potential to greatly affect the health and lives of people living in developing countries. Today, long-term research is carried out on whether mobile health is an effective tool in service and cost points and the findings are shared. In future, it is necessary to implement pilot projects and work on specific issues covering the whole country in each country. In these studies, it is necessary to use the health technology of the day and to support the acceptability and availability of these tools by providing the health services required by the majority. As treatment services require excessive costs to be incurred, it is necessary to increase the health expenditures in the USA and European countries mentioned in the developed countries, to take care of preventive health services in the subsequent processes, and to develop preventive health services so that developing countries do not fall into this health cost trap. Mobile health is seen as a key solution for the realization of these services [17]. There is not only the issue of inequality of health status among countries; there are also inequalities in the number of staff providing health care. There is an unequal distribution of health personnel between countries and regions. Mobile health will be able to play a key role in coping with all these adversities and enable the provision of better quality health services at low cost, comprehensive and real-time problem solving points. Emerging technologies, wimax technologies, wearable sensors, the widespread use of wireless networks, the increasing use of smart mobile devices enhance mobile health and demonstrate the need to address different perspectives. 4.5 G technology in use in many countries including Turkey, this will strengthen the mobile health issues to be cost-effective tool. 4.5 G technology that supports high-speed data transfer will further advance the health services offered through mobile technologies. With the increasing use of smartphones, people's mobile application usage levels are increasing. This will help control chronic diseases, prevent the spread of infectious diseases through short messages, and help patients live independently in their lives. Mobile health, which allows for remote monitoring of patients, will provide the national and perhaps international level to derive the health service from the local and regional level. Voice calls and camera features on smartphones reinforce communication between patient and health care workers. Mobile devices will trigger economic growth and health care development in all countries, including in developing countries. Mobile health, which changes the health service delivery model, will help citizens to be more conscious individuals, to control their own health, to select the best health institution, physician and the most economical option when a negative situation occurs. The new and emerging mobile healthcare technology is a part of everyday life, and thus creates a wide network. With the use of these technologies, it will be easier to establish the health profile of the country. This will enable governments to spend more effectively on the budget they spend on health care. In other words, mobile health technologies are of great importance in eliminating interregional health inequalities [17].

It would be useful to establish networks based on communication technologies at the local level to control the infectious diseases that adversely affect public health. Establishing the wireless network infrastructure covering the whole region in the identification and monitoring of diseases occurring in rural areas and enabling remote monitoring at the local level, conducting studies for introducing and using the devices to be developed to the public, cooperating with software companies to develop the application, training will be effective in raising health status. With the creation of the mobile health service model, citizens in the country will be able to connect to the internet via wireless networks with the applications in their smart phones and obtain the health information or health services they need.

2.2.3 Benefits of Mobile Health Applications

The following are some of the benefits that are expected to be achieved as a result of mobile health practices [11]:

- Availability of mobile healthcare applications in health care facilities
- Increased productivity of the doctor using the technology
- Increased satisfaction of patient and patient relatives
- Increased health information of patient and patient relatives
- A reimbursement section can be added to the service provided so that healthcare costs can be reduced and financed.
- Ensuring privacy, security and privacy, and obtaining permanent solutions.

Mobile health has an important role in increasing the effectiveness and efficiency of health services as well as creating a socio-economic impact. It is possible to see this in four ways [18]:

- Diagnosis: Early diagnosis of diseases and thus reducing the severity of the disease in individuals, and in later processes, to save both the patient and the hospital from more expensive costs. Wearable technologies can be achieved by the integration of medical sensors and mobile smart devices.
- Treatment and Observation: Patients can be monitored remotely with mobile communication technologies and patients visiting the hospital can be reduced.
- Stronger healthcare system: Clinical decision making can be improved, and physical and human resources can be maximized.

With the use of mobile health applications, regional disparities in access to health services can be reduced. The limitation here is that regional literacy rates and technology use vary regionally. Mobile health can be said to be based on empowering individuals. The frequency of going to the hospital is reduced and people will only apply to the hospital in cases of acute development and surgery. In addition to mobile health applications, the health care provider and the patient are able to get instant access to the information they want and the physician can transmit the necessary information to the patient at high transfer rate and low cost through the device connected to the software.

It is stated that mobile health applications take an increasing place in health

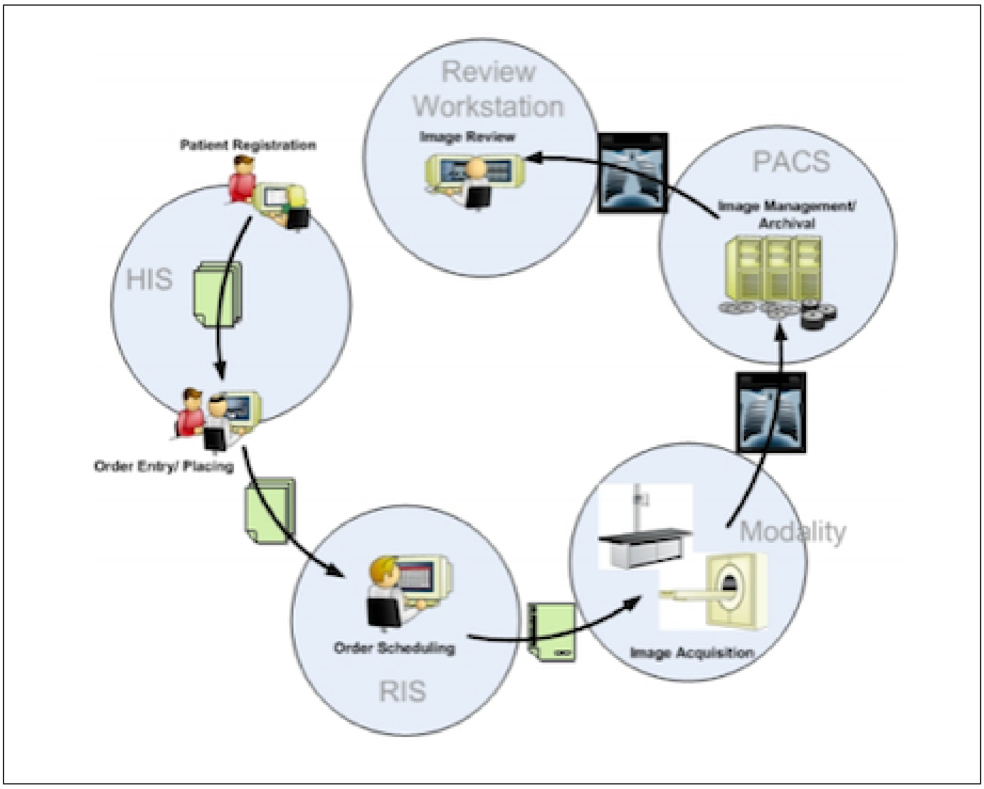

Figure 2.2 Imaging Workflow [7].

services applications. These practices may include smoking, weight management and sporting activities, diabetes and long-term management of disease, and message delivery for health education. Mobile applications can be used effectively in the management of long-term chronic diseases such as smoking cessation, weight management, diabetes, hypertension, cancer, change of some behaviors, observation of patients after surgical procedures.

2.2.4 Mobile Health Applications in Turkey

Hospitals can no longer be a diagnostic center and can only become a place of intervention by telemedicine. According to the Health Statistics Annual Report 2013 a person in Turkey in 2013 was 4.9 times the average admitted to any health institution [19]. The applied health institutions are 1st and 2nd level health services under the Ministry of Health. This figure, which is expressed as the average, varies according to the regions but has increased compared to the previous years. These increases have led to an increase in the workload of health facilities, excessive resource utilization and consequently an irregular increase in costs. Therefore, it can be argued that using mobile communication technologies in health services will be an effective tool for solving these problems.

Costs cannot be managed and cannot be measured, and that the costs need to be measured, the need to provide equal health services to all, and the fact that individuals can endure very little health expenditure, and they make suggestions for unit-level measurements. In addition, the weak cost methods are a disadvantage for hospitals, however, it is important to determine how much cost each patient has for the hospital. In this context, it is thought that mobile payment system to be established with mobile applications can provide calculation of cost of patient. People will pay a certain price to the service they receive. This situation is predicted to play a big role in the increase of the computability of the indeterminable indirect expenses.

It is thought that mobile health applications will contribute to the reduction of transactions and improvement of processes in health institutions. Mobile applications that will be designed and developed in order to reduce waiting times and improve the quality of the service will be able to contribute to the field of health and will be able to control the costs and get rid of the time constraints of the personnel who meet the patients. Mobile health applications can be said to be among the latest trends in the health care industry in terms of the control and minimization of transactions resulting from excessive workloads and the associated transaction costs [19].

Developing countries and Turkey, in coping with health problems, the country's health status of the development, a cause of the health needs of the population, which tends to aging community in the fight against chronic disease and lowering of costs incurred should benefit from the opportunities offered by the mobile communication technologies and effective solutions that offer these technologies configure the local level at the national level improve their applications [19].

In addition, telemedicine is used to manage real-time patient from remote center, decision support, remote sensing, collaborative working environment [4]. Factors such as increasing the cost of health services together with the population, decreasing the frequency of coming to the hospital, making more effective use of specialist doctors, obtaining more effective treatment methods for reaching the long-term statistical information about the disease have led to the onset of telemedicine applications. Some advantages of telemedicine applications are explained below.

The first advantage is the elimination of regional differences in the disease diagnosis and treatment process. Patients away from health centers can also benefit from health services through telemedicine. The second advantage is efficiency. Remote monitoring of patients saves time as well as reducing hospital costs. Patient data can be monitored by specialists, no matter where the patient is. Another advantage is that patient and patient information can be obtained immediately upon request. Following new developments or consulting other experts provides fast, accurate and effective decision-making in the diagnosis and treatment of diseases [19].

2.3 Radiology

Radiology has undergone a major change in the diagnostic contribution in the last 20-30 years due to the enrichment of the methods used and developments in parallel with technology. In addition, the expansion of therapeutic interventions in imaging has led to the emergence of a therapeutic character by altering the axis of radiology. Patients encounter radiologists in many periods of their illness. This situation increases the burden and responsibility of radiology as a clinical branch.

It is common for radiologists to be held legally and ethically accountable because of the individual defects of the radiologists and the defects of other clinical departments. The responsibility of the radiologists is not to stop and interpret.

Nowadays, the number of patients who have an active role in medical care decisions is increasing. Both hospital systems and physicians tend to enter into a more las patient-centered approach [5]. Over time, questions and problems change as well as expectations, efforts to increase the quality of services are also included in radiology. While efforts are underway to improve reporting practices, on the other hand, approaches such as the involvement of radiologists in more active roles in the stage of sharing the results with the patient are being raised [20]. Radiologists are aware of the importance of both the physician who requested the examination and the progress in their communication with the patient in terms of medicolegal and patient satisfaction [21].

The diagnosis of the disease is a prerequisite for treatment. Radiological imaging methods are one of the diagnostic methods. Regardless of the type of examination, the interpretation of the radiologist should be presented as a written document. The radiologist should report the radiological conviction and possible diagnoses in its report. The radiologist may suggest a radiological algorithm for a preliminary diagnosis or a possible diagnosis if necessary [21]. From the selection of the examination to the writing of the examination until the writing of the report, to supervise the examination as necessary, to perform additional examination, to apply the contrast agent, to protect the patient from the harmful effects of radiation, to make a comparative evaluation by reaching the patient's clinical information or examinations. It is also obliged to discuss with clinicians, to have educational and administrative functions [21]. The radiological

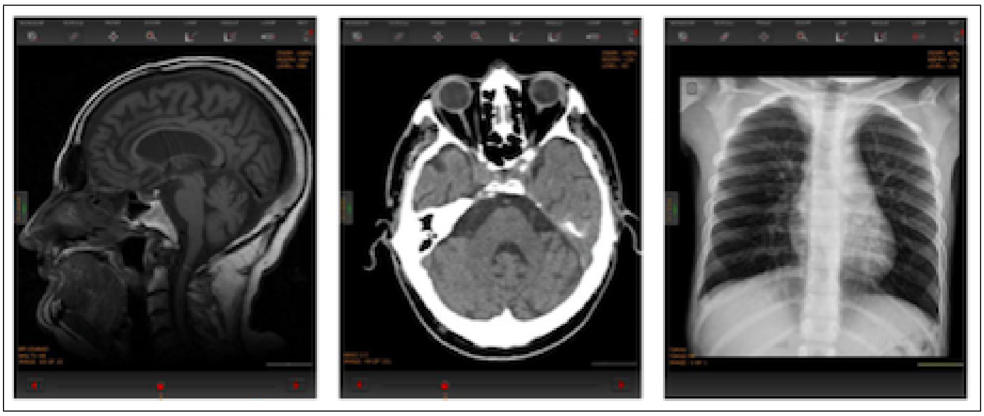

Figure 2.3 Examples of the application interface for 3 exams: MRI (left), CT (center)and conventional radiography (right).

report, an intermediate product in this process, cannot be considered separately from other functions [21].

2.4 IT Systems in Radiology

The two major types of IT systems developed to take care of the digital workflow in a radiology department are Radiology Information Systems and Picture Archive and Communication Systems [22]. The RIS system was developed to help the departments with administrative tasks, such as scheduling, billing and logistics. Today, the RIS also handles request and report information as well as communication with PACS and other electronic patient record systems in use in healthcare. Diagnostic reading applications available for smartphones and tablets support raw data and also allow for basic manipulation of images such as zooming, windowing, rotation, distance measurement and contrast and brightness alteration. Its main disadvantage is that it is difficult to perform measurements using fingers on the small screen and display the image data of the current and previous scans side by side. Monitoring such a small screen can be challenging for the eyes, so the FDA said that these applications cannot replace private workstations, and that mobile devices will only be used for reading when there are no workstations in your hands (Table 2. 1) [23].

Table 2.1
Mobile Dicom Viewer Applications [17].

MedFilm (iOS- free) http://chestradiologists.org/directory/medfilm/
eFilm Mobile (iOS â 9.99 USD) https://www.merge.com/na/estore/efilmmobile/index.aspx
OsiriX (iOS- free) (iOS â 29.99 USD) http://www.osirix-viewer.com/Downloads.html
iClarity (iOS â 9.99 USD) http://www.icrcompany.com/RSNA/iclarity.html
Mobile MIM (iOS â free) http://www.mimsoftware.com/products/iphone
ResolutionMD (iOS â free) http://www.calgaryscientific.com/index.php?id=5
CoActiv (iOS â 19.99 USD) http://www.coactiv.com/press releases.htm
ImageVis3D (iOS â free) http://www.sci.utah.edu/cibc/software/41-imagevis3d.html
DICOM Droid (Android â free) https://market.android.com/details? id=be.ac.ulb.lisa.idot.android.dicomviewer feature=search result
Centricity Radiology Mobile Access 2.0 (iOS â free) http://itunes. apple.com/us/app/centricity-radiology-mobile/id501936750?mt=8
Siemens syngoÂ® via WebViewer (iOS â free) http://itunes.apple.com/ us/app/siemens-syngo-.via-webviewer/id410836437?mt=8
iPaxera (iOS â 4.99 USD) http://itunes.apple.com/us/app/ipaxera/id432861550?mt=8

MedFilm is a fast dicom viewer. MedFilm can query and retrieve DICOM images from any DICOM compatible software and PACS through some DICOM network protocols: C-Find SCU, C-GET SCU, WADO. MedFilm can display all kinds of image modalities, such as US, CT, MRI, PET and etc. .

The radiologist first plans the examination of the patient, who comes with a written request, with appropriate technical and safety protocols, and then prepares the report according to the principles of radiological writing to give to the patient or the clinician by using his / her knowledge and experience . These reports are sent to the relevant physician via the radiology information system (RIS) or if there is a physician working in another institution, the written report is expected to be delivered to the physician through the patient or relative. However, if the patient does not apply to the physician, the physician may not know the result.

Figure 2.4 MedFilm on App Store- I Tunes .

The field of radiology, which stands out with the use of advanced technology and variety of devices, is also an area where the composition of skills is transformed by technological development. Medical imaging has made significant progress in the last 30 years with the development of new techniques such as computed tomography, digital radiography, magnetic resonance (MR) and ultrasonography [22]. The effects of this development on qualification are variable. A noticeable increase in the educational levels of radiographs is considered as an indicator for qualification. An undeniable reality is the dramatic reduction in processing times with new devices. However, the increased demand for imaging studies does not reduce the workload. On the other hand, with the new devices, the radiation dose to which employees and patients are exposed, the possibility of error has decreased [22].

The rapid change in imaging devices has led technicians into a continuous learning process. Each new device requires new information, especially computer use, for effective and safe use. It can be argued that this situation leads to qualification. However, some devices, such as MRI, require more complex and diverse procedures, while devices such as digital radiographs require simpler and more routine procedures. With the increase in the number of patients, repeated repetition of the same procedures, with the same device throughout the day, will turn the technicians into an extension of the device and de-qualified.

The developments such as digitalization in the field of radiology and the archiving and transfer of the image in computer environment have dramatically transformed

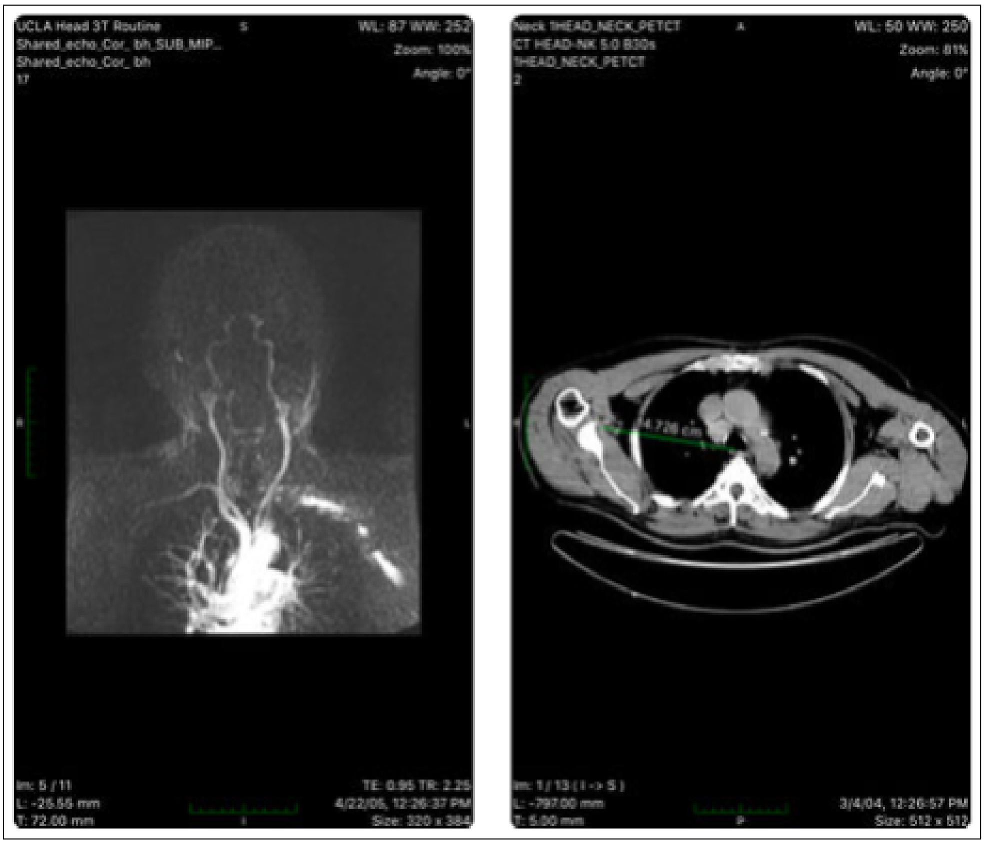

Figure 2.5 MedFilm viewer interface [12].

the way the radiologists work. This situation made the radiologist's work an ordinary commercial property, while freeing the process of interpretation and reporting of radiology examinations. For example, it has become possible to access many discounted MRI, tomography report advertisements from a leading online sales site such as e-bay. Many radiologists remotely interpret examinations through tele-radiology in the hours after work. This can lead to a reduction in the cost of radiologist labor by purchasing services from countries where physician labor is relatively cheap. This process, which allows spatial segregation of radiology services from other health services, suggests that radiologists are not far from the days when they are employed by large radiology firms to provide external services.

Tele-radiology has been one of the subjects that medical experts and researchers have been working on both hardware and software in recent years [24]. Immediately after the discovery of the X-rays by W. Conrad Rontgen in 1895, Pierre and Marie Curie discovered Radium in 1896 and laid the foundations of today's radiology. The first example of modern teleradiology supported by speed and technological progress

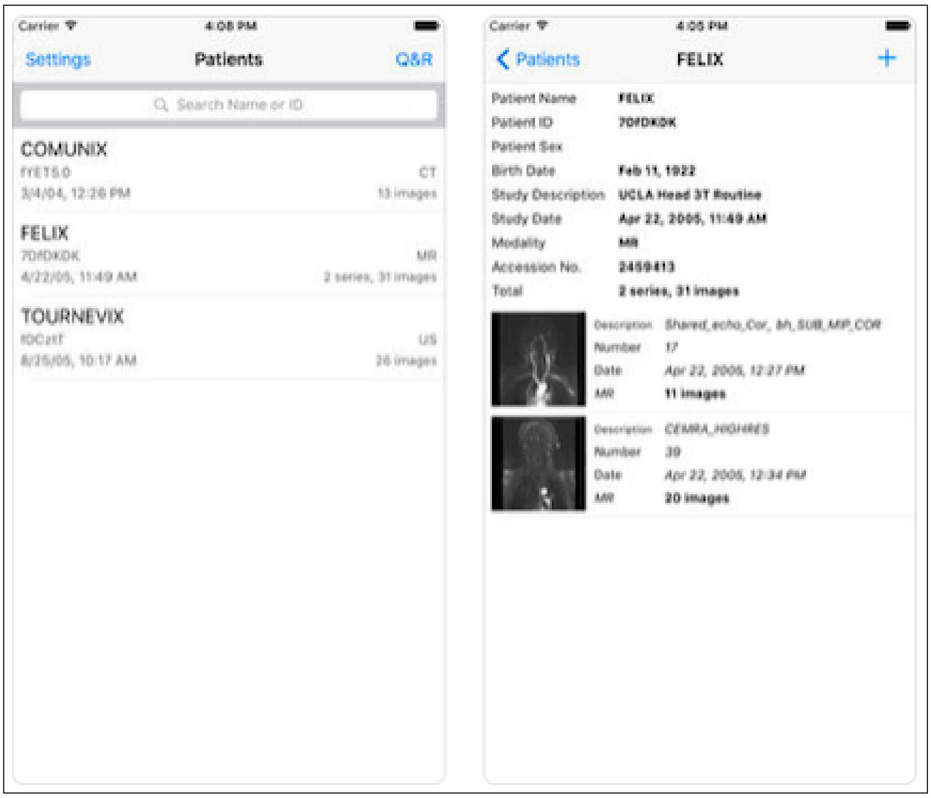

Figure 2.6 MedFilm patients information interface .

was in 1994 with a link between Massachusetts General Hospital (MGH) and the hospital in Riyadh, Saudi Arabia [24]. The cost of the system, which consists of all special hardware and software, is over $ 100,000 [24].

In the early days, physicians did not find the tele radiology applications very meaningful. However, with the developing communication network, the introduction of new technologies that emerged in the general consumer market in a way that facilitates image and data communication in medical and clinical settings has highlighted the effectiveness of tele-radiology. For example, in the study of Peter De Maio et al., Magnetic Resonance (MR) images were compared with both traditional radiology workstation and a mobile device for the diagnosis of intra-articular knee pathology. Sensitivity and precision of IPhone and workstation interpretations were performed using knee arthroscopy as standard reference. In diagnostic performance, no statistically significant difference was found between the two devices for each paired comparison [24]. Also evaluated the potential for teleconference in emergency radiology by comparing CT and MRI multiple-images in PACS workstations and iPad tablet computers with similar methods and tools. Obtained results have been performed specifically in emergency situations encountered in CT and MRI [24].

Using PACS workstations with tablet computers can help in diagnosis using a good fit [4]. This suggests that tele-radiology can be used as an alternative to the traditional method. When the studies in the field of telemedicine are examined, the studies of physicians and engineers can be evaluated separately.

One of the most important factors affecting the performance of tele-radiology is the software used. At this point, image archiving and communication software (PACS: Picture Archiving Communication System) is important for both diagnostics and other utilities. Many companies have both licensed and open source software for different operating systems for use in medical applications. MedFilm, 3D Slicer, MedINRIA, MITK 3M3, VolView, VR Render, OsiriX are some of them.

2.4.1 Coloring in Medical Images

Coloring is the process of adding color information by using computer support to visual information (black and white photography or video) that plays an important role in human perception [25]. Coloring also means replacing the brightness value in each pixel of a monochrome image with a multidimensional color vector [25].

Existing radiological imaging methods provide only gray-level images. Limiting the image to grayscale allows only the differences in brightness and texture to be used as a hint to recognize the shape within the image. However, color can be a significant and meaningful sign in perceiving shapes and objects. By enhancing the detection capability, the recognition of the object recognition and diagnostic accuracy allows the radiologist to interpret images in more detail. Optimally colored images can be distinguished by an observer at different levels of 250-1000, while the average of the gray image scale can only detect 140 levels [25]. Therefore, the level of perception of image properties between 2-7 floors is increased [25]. Medical image coloring can be used for a variety of diagnostic purposes that serve as a versatile imaging tool.

In the Medfilm application which is used as mobile dicom viewer in this study, there is a coloring option for images.

2.5 Lung Anatomy

The lungs are a pair of organs in the thoracic cavity where the gas exchange between the blood vessels and the breathing air at the sides of the heart occurs. The lungs are called the right lung (pulmo dexter) and the left lung (pulmo sinister). There are mediastinum cavities between the two lungs, including the heart, esophagus, trachea and large vessels. Thus, two lungs are separated from each other by mediastinum space.

There is always some air in healthy lungs. Therefore, the lung is floating when the amount is cut and placed in water. When crushed between the fingers, the sounds of the alveoli are heard, so the sounds of the creaking are felt [25].

The lungs are quite soft, spongy and elastic. The surfaces are covered by a double layer serous membrane called the pleura. The average weight of the lungs is 1200-1300 grams [25]. The top of the lungs, which are conical, are called apex pulmonaryis, and the base is called pulmonary artery. Apex pulmonaryis is round and blunt [25]. At the front level is 2.5-5 cm above the sternal end of the clavicle and at the back is the first collum costae level. The base of the lungs, which are broad and concave, are withstand the convex part of the diaphragm [25]. The lungs are also adjacent to the liver, the fundus portion of the stomach and the spleen. The weights of the lungs differ in both males and females, and in both of them the right lung is heavier than the left lung. The right lung is slightly above the liver due to the swelling [25].

The lungs are divided into lobes with deep clefts. The right lung is separated from each other by two deep fissures. These are called fissura obliqua and fissura horizantalis. There are three lobes in the right lung through these slits. Upper lobe (lobus superior), middle lobe (lobus medius) and lower lobe (lobus inferior) is called [25].

The left lung consists of two lobes. The upper lobe (lobus superior) is called the lower lobe (lobus inferior). Slits between the lobes allow the lobes to slide over

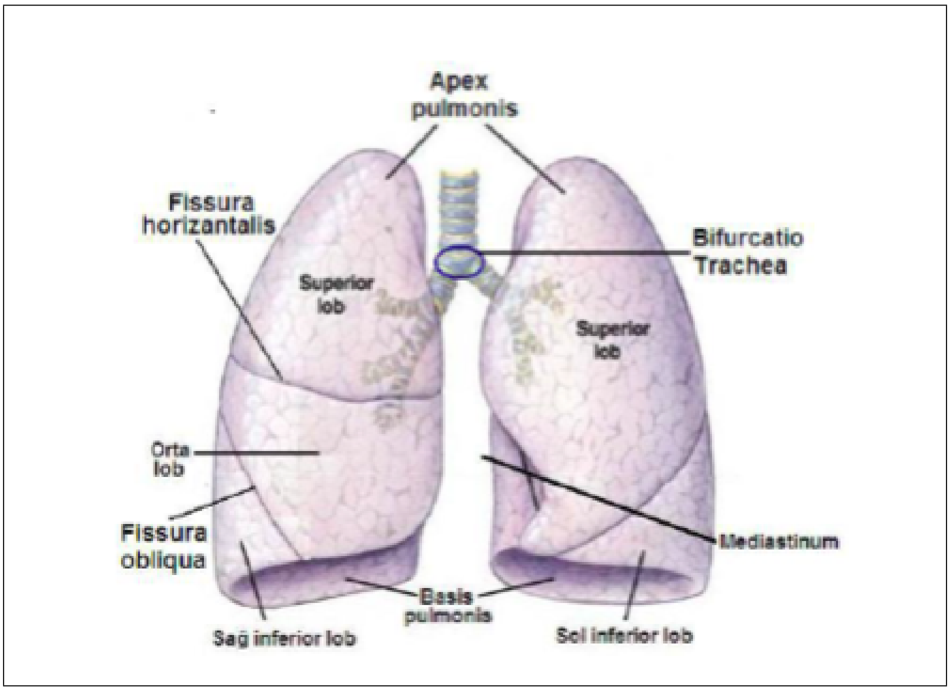

Figure 2.7 Lungs Anatomy [16].

each other. Lung lobes are composed of lobes. The inner side faces (medial face) of the lungs are light pits. The lung tissue enters the bronchus, the artery, and the nerves near the middle of the medial face. In the lung tissue vena pulmonary and lymphatic vessels are removed. The entrance to the lungs and exits is called the ide lung hub (hilus pulmonis). Radix pulmonaryis is also known as the lung stem and the hilum is connected to the pulmonary. The veins of the lungs are also pulmonary artery and vena pulmonary artery [25].

2.5.1 Tasks of Lungs

The most important task of the lungs is to take the outside air and to allow oxygen in the air to pass into the capillary blood vessels around the alveoli. The second main task is to take the carbon dioxide from the organs with dirty blood into the alveoli and to let it out. The surfactant substance is synthesized and used in the lung alveoli. The lungs also function as metabolic organs, such as a portion of the alcohol, anesthetic agents, and the like. Some important substances are destroyed by lung tissue (eg, bradykinin, serotonin, etc.) ensures that the pH of the body is kept in balance [25].

2.5.2 Lung Cancer

Lung cancer is a rare disease at the beginning of the 20th century, and its incidence has increased significantly since 1950 and it has been one of the most common cancers in men and women today [25]. Lung cancer is one of the most important health problems in the world with an estimated 1.2 million new cases every year and a significant increase is observed in incidence and mortality. Every year, 200,000 new cases of lung cancer are diagnosed in the European Union. In our country, lung cancer is the most common type of cancer in males and it ranks 7th in females in terms of frequency [25]. Lung cancer is the leading cause of cancer-related death. 31% of cancer-related deaths in males and 25% of females in lung cancer. The percentage of deaths due to lung cancer is greater than the total of deaths due to colon, breast and prostate cancer [25]. Lung cancer is a disease in which a number of factors play a role in the etiology. Environmental factors such as smoking, air pollution; occupational factors, diet, viral infections, past lung diseases; genetic and immunological factors are mainly etiologic factors [6]. Smoking is the etiological factor responsible for cancer development in 85-94% of patients with lung cancer. The risk of developing lung cancer is 24-36 times higher in smokers than non-smokers. In passive smoking, this risk is 3.5% [25]. Occupational and environmental contact with various organic and inorganic substances is known to increase the risk of lung cancer. Diet is another factor in lung cancer development. Diseases that can lead to scarring in the lungs increase the risk of developing lung cancer. This risk increases in the presence of chronic obstructive pulmonary disease (COPD) [25]. The idea of ââscreening for risky groups with the aim of detecting patients with lung cancer at an early stage was put forward. However, investigators and consensus reports do not suggest screening for lung cancer by using these methods to people who are not close to them [26]. Epidemiological studies also emphasize that family history of lung cancer may be important. The risk of lung cancer was found to be 2.6-fold higher in the first-degree relatives of patients with lung cancer [26]. Lung cancer is a preventable disease. It is estimated that 85-100% development can be prevented when the known risk factors are eliminated. The most important step in this respect is to take measures to minimize the use of cigarettes or even eliminate them [26].

2.5.3 Histological Classification

The World Health Organization updated the classification of lung cancer by histological findings in 2011 [26]. Growth rate, distribution, timing of metastasis, chemotherapy and response to radiotherapy were collected under two main headings, mainly non-small cell and small cell. Approximately 83% of all lung cancers consist of non-small cell lung cancer and 16% small cell lung cancer [26]. Only 36% of lung cancers are treated with surgery, 11% with radiotherapy, 23% with combined therapies and 9% with supportive therapies [26].

2.5.4 Statistics of Lung Cancer

Lung cancer is the most common type of cancer worldwide and one of the most common causes of cancer-related deaths. World Health Organization (WHO) reported that lung cancer was 12.9% of all cancers in 2012 with a total of 1.8 million new cases [26].

Lung cancer is the most common cancer in men worldwide (1.2 million new cases per year, 16.7% in all cancers). The expected incidence rates in women are generally lower (583,000 new cases per year, 8.7% of all cancers) [26].

Lung cancer is an important public health problem not only because it is a common cancer but also because of the mortality burden it causes. According to WHO data, the highest rate of cancer-related deaths worldwide is related to lung cancer, which is responsible for 1 out of every 5 cancer-related deaths (1.59 million deaths, 19.4% of total cancer-related deaths) [26].

Lung cancer is the most common and the most common cause of death in our country as well as all over the world. According to the 2012 data of the Ministry of Health of the Ministry of Health, lung cancer is the most common type of cancer in our country and the most common type in men. and fifth in women. 21.8% of all cancers and 4.9% of females in males. age standardized incidence rates of lung cancer in Turkey is 60.4 per 100,000 in men, while in women is reported to be 9.3 per 100,000 [26]. The frequency of lung cancer is higher in our western regions than in other regions. The most common type of non-squamous cell is the adenocarcinoma most frequently seen in young population under 45 years of age and in women. At the time of diagnosis, 47% of the cases were in the metastatic phase, 37% in the local advanced stage, and 16% in the appropriate stage of operation [26].

When mortality data due to lung cancer in Turkey evaluated, cancer, cardiovascular constitutes the second most common cause of mortality after the system disease, the most common cause of death in the cancer is lung cancer. According to Ministry of Health data 2013 41.129 lung cancer patients were admitted to health institutions and Turkey Statistical Institute (TSI) 2013 22.158 patients died of lung cancer deaths, according to statistics. New cases were 2/3 (66%) of total cases, and 44% of all cases died in 2013 [27].

2.5.5 Lung Nodule Imaging

Radiological examination methods used to evaluate single lung nodule are chest x-ray, CT and functional imaging methods. Nowadays, most of the single lung nodules are incidentally detected by CT because of the widespread use of CT. The features of the nodule can be partially understood by chest radiography, but the internal structure is best evaluated by CT. The size increase is best understood by comparison with previous radiological examinations. It is preferred to perform computed tomography with a thin and adjacent section (1 mm), volumetric, low dose technique [3]. It is not always necessary to use contrast media. Computed tomography features of a nodule can be used to differentiate malignant / benign characteristics, edge, calcification, density and growth characteristics.

Increased risk of malignancy has been shown to increase. For example, the

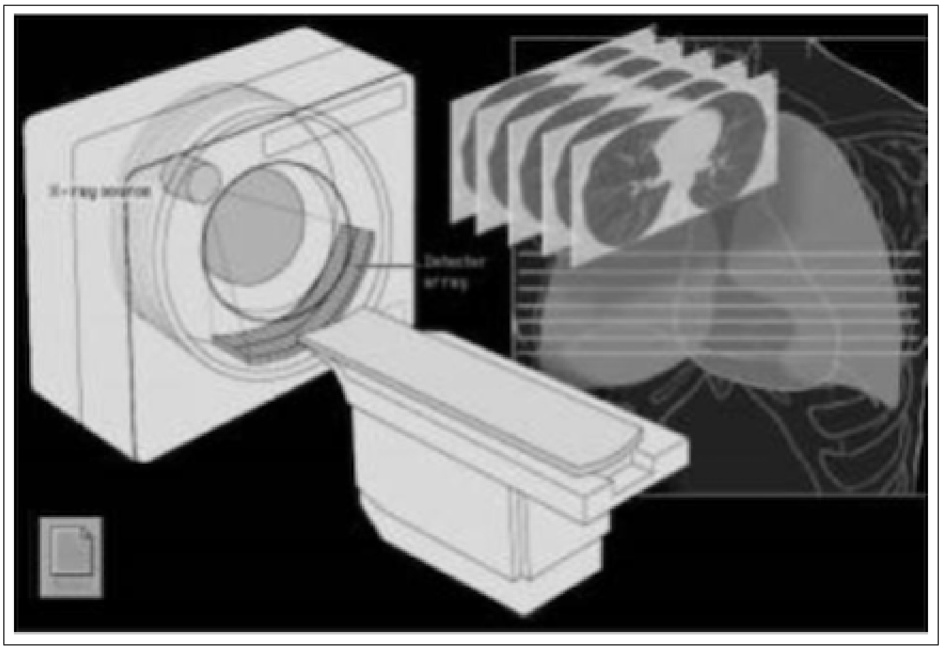

Figure 2.8 CT system and lungs image slices [15].

probability of malignancy in nodules smaller than 4 mm is less than 1% and greater than 50% in patients greater than 20 mm [26]. Computed tomography follow-up is often preferred in patients with low risk of malignancy (especially in nodules smaller than 8 mm). In addition, CT follow-up may be preferred in patients who are at high risk for surgical complications, who have a poor prognosis due to concomitant diseases, or who are well informed and do not accept any procedure. Nodules are classified as solid, subsolid (nonsolid) according to their density in BT [26]. Single lung nodule is a common finding.

With the increase in the use of computerized tomography, the visibility of the nodules increased [26]. In addition to the generally accepted algorithms in nodules, there are also controversial points. The main purpose is to make a distinction between benign malignant and benign malignant. Comparative evaluation with previous reviews, morphological features such as nodule size, margin structure and internal features should be evaluated first. When necessary, functional methods such as PET/CT or thorax MR should be preferred. Finally, an invasive biopsy, follow-up or discontinuation decision should be made [26].

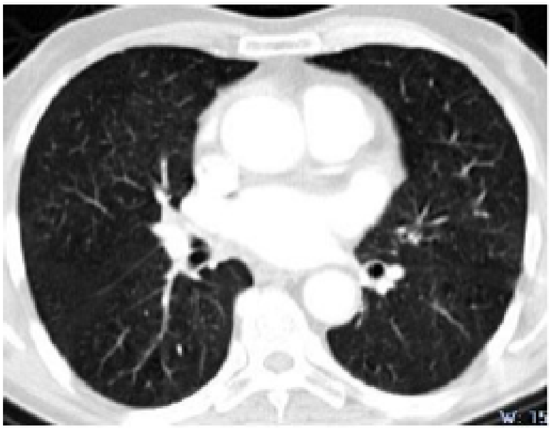

Figure 2.9 CT lung image example [15].

3. METHODOLOGY

The measurement had been applied in the Ceyhan Hospital with two radiologists. Radiologists are Omer Kaya and Ibrahim Inan.For measurement in the mobile phone application, it was measured in illuminated environment.As a DICOM viewer in mobile phone, Medfilm application was executed to examine the images.As a mobile phone, radiologists have used Iphone 6S. As a DICOM viewer in PACS, Radiant Dicom Viewer Version 4.1.16 was executed to examine the images. On the other hand, for measurement in the PACS, it was measured in dark environment. So, the results can be compared with each other.Lux Meter mobile application is a simple light meter for measuring illuminances (lux, fc) by using the light sensor of android device. It was used in order to measure light.

It was used Bland-Altman analysis, which is the most accurate method used to describe the harmony between the two measurements. Correlation determines the degree to which two methods are related. But high correlation does not mean that there is a good fit between the two methods. Therefore, this measurement has an approach that includes compliance limits, graphic techniques and simple calculations to analyze comparative data. Chart, the differences between the two methods compared (PC observation- Mobile phone observation) was constructed by plotting the mean of the two methods.

The method comparison study is started by drawing the scatter plot of the differences of the measurements obtained from the two methods against the averages. The graph of the averages against the differences allows for the examination of any relationship between measurement errors and actual values (averages which are the best estimator since the actual values cannot be obtained). It is also possible to review the error and examine the error. If there is no relationship between differences and averages, the agreement between the two methods can be examined using the mean and standard deviation (s) of the differences.

Data was taken from TCIA collection [4]. TCIA is a service which de-identifies and hosts a large archive of medical images of cancer accessible for public download.

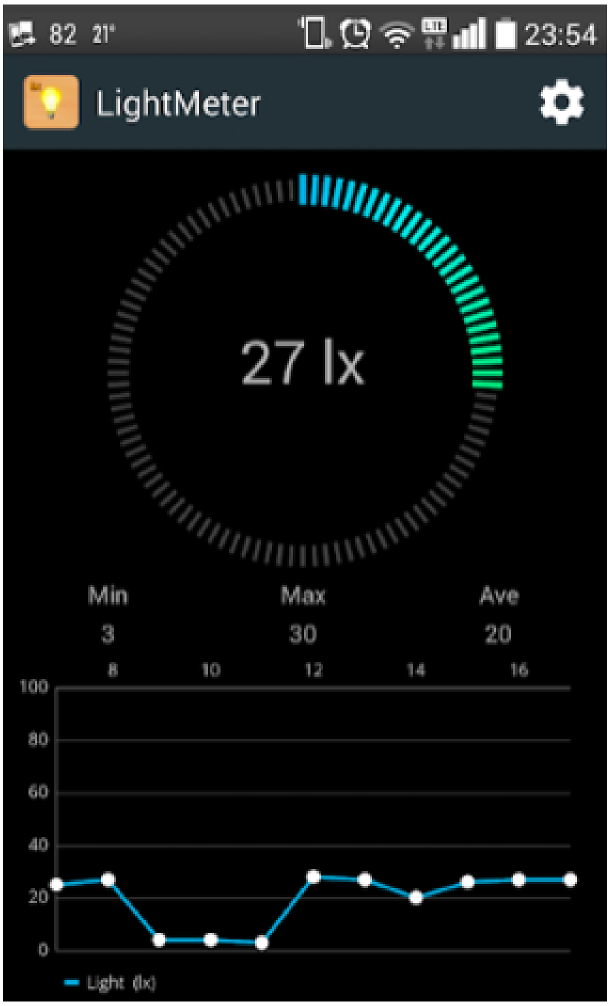

Figure 3.1 Lux Meter (Light Meter) Mobile Application [17].

The data are organized as , typically patients related by a common disease (e.g. lung cancer), image modality (MRI, CT, etc) or research focus. DICOM is the primary file format used by TCIA for image storage. Supporting data related to the images such as patient outcomes, treatment details, genomics, pathology, and expert analyses are also provided when available. The TCIA distribution was made available early in July 2011 and is hosted at Washington University in St. Louis.

Figure 3.2 Iphone 6S Mobile Phone [15].

4. RESULTS

271 cases were included in the study.

In both the observer 1 and the observer 2, the nodule was detected in 266 cases (98.2%) and no nodules were found in 5 cases (1.8%). In the evaluation made by the telephone, the first observer detected nodule in 251 cases (92.6%), while the second observer detected nodules in 252 (93%) patients.

Nodular localization was similarly classified for both observers in 67 patients (24.7%) in the right lung upper lobe, in 21 patients (7.7%) in the right lung middle lobe, in 58 patients (21.4%) in the right lung lower lobe, 71 (26.2%) patients had left lung upper lobe and 49 patients (18.1%) had nodules in the left lower lobe.

When the cases were classified according to the status of nodules, nodules were detected in 250 cases (92.3%), possible nodules were detected in 16 cases (5.9%) and no nodules were found in 5 cases (1.8%).

In the nodul size measurement for observer 1, the minimum nodular size was

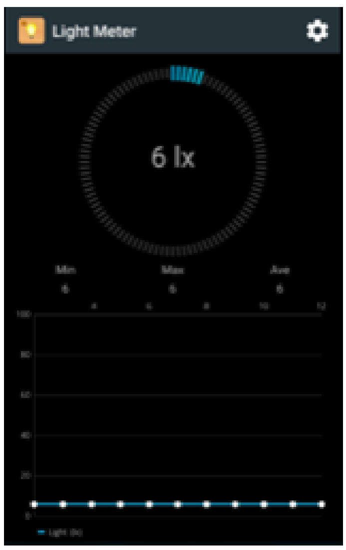

Figure 4.1 Light measurement for Mobile dicom viewer environment.

calculated as 3.5 mm, the maximum nodule size was 51 mm, and the median nodule size was 7.75 mm. In the evaluation made by telephone, the minimum nodule size was calculated as 3 mm, the maximum nodule size was 50 mm and the median nodule size was 7 mm. Of the 251 patients, 214 were less than 1 patient, while in 36 cases, measurements from the phone and computer were equal (p <0.0001).

In the nodule size measurement for observer 2, the minimum nodular size was

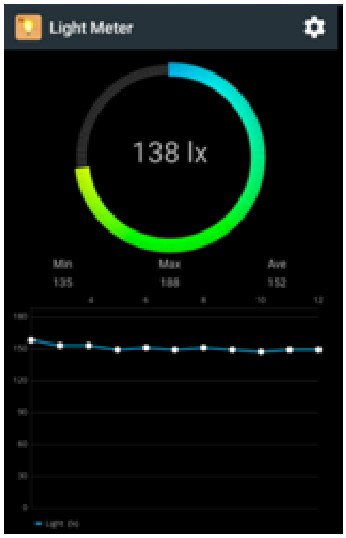

Figure 4.2 Light measurement for PACS monitor environment.

calculated as 4 mm, the maximum nodule size was 52 mm, and the median nodule size was 7.9 mm. In the evaluation made by telephone, the minimum nodule size was calculated as 3 mm, the maximum nodule size was 50 mm and the median nodule size was 7 mm. Of the 252 cases, 216 were smaller than the measurement of the phone, while in 1 case the measurements were greater than that of the 35 patients and the measurements from the phone and the computer were equal (p <0.0001).

Observation of the nodules in the evaluation of the computer by observers showed a perfect fit between observers ($\kappa = 1.0$). On the other hand, nodul detection was poorly observed among the observers ($\kappa = 0.586$). A perfect fit for both the phone and the computer was found in the evaluation of the compatibility of the nodule size between the observers (ICC = 0.999 for the computer, ICC = 0.998 for the phone).

For observer 1, the sensitivity of the nodules was 100%, specificity was 25%, accuracy was 94.4%, negative predictive value was 100% and positive predictive value was 94.4%. For the observer, the sensitivity was 100%, specificity was 26.3%, accuracy was 94.8%, negative predictive value was 100%, positive predictive value was 94.7%.

For observer 1, the measurement in the PACS was calculated as average 0,674 ± 0,39 mm, and statistically significant (p <0,0001). In the Bland-Altman graph, the difference in nodule size in 99.6% of the cases was between -0.095 and 1.443 mm.

The mean difference in the measurements made by the PACS station for the

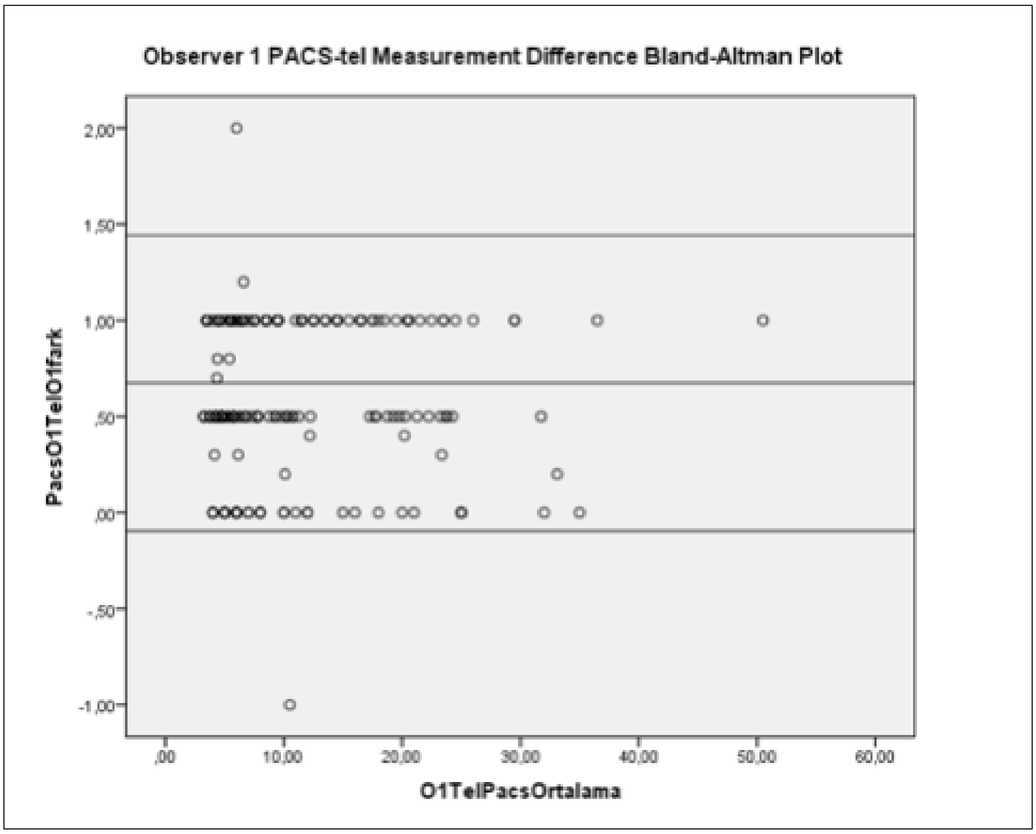

Figure 4.3 Bland-Altman analysis results for observer 1.

observer 2 was 0.66 ± 0.387 mm, which was statistically significant (p <0.0001). In the Bland-Altman graph, the difference of nodule size in the 96,11% of the cases was between -0,107 and 1,426 mm.

The measurement difference between observer 1 and observer 2 was calculated as -0,162 ± 0,55 mm in PACS station and it was statistically significant (p <0,0001). In the Bland-Altman graph, the difference in nodule size is between -1.25 and 0.926 mm in 92.83% of the cases.

The measurement difference between observer 1 and observer 2 was calculated as -0.19 ± 0.666 mm on the phone and it was statistically significant (p <0.0001). In the Bland-Altman graph, the difference in nodule size in 98.35% of the cases is in the

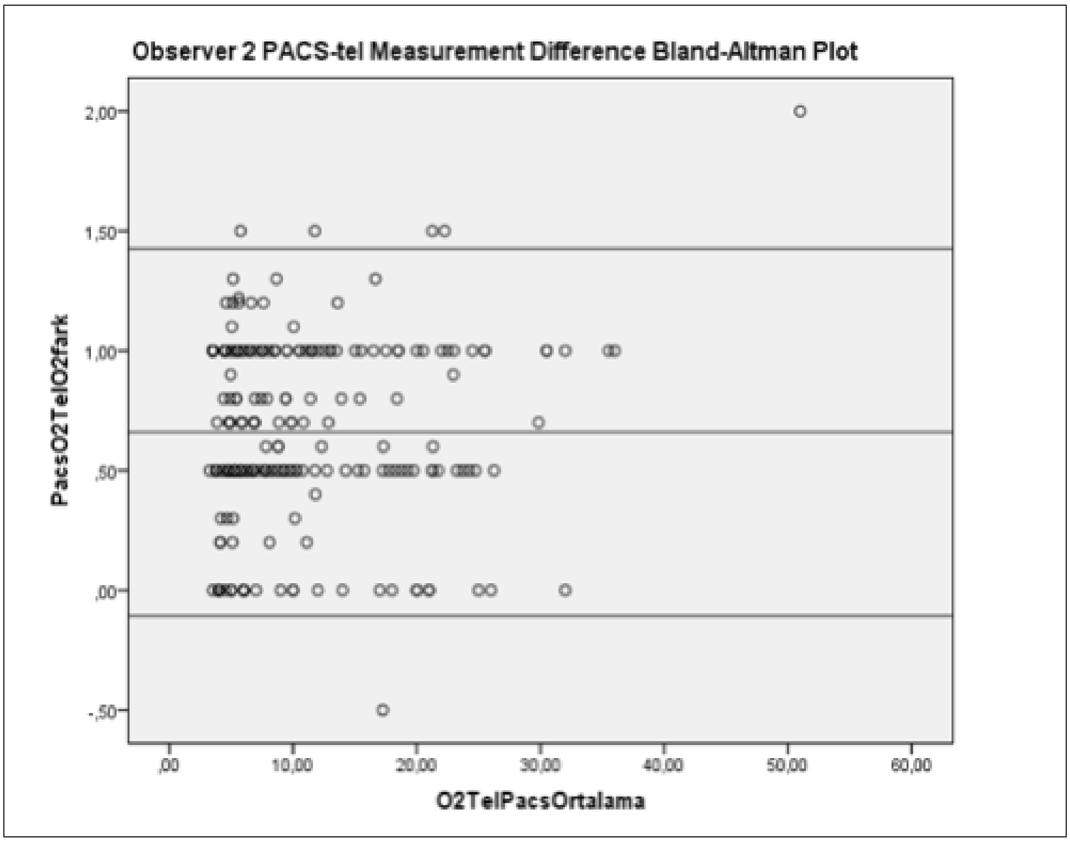

Figure 4.4 Bland-Altman analysis results for observer 2.

range of -1.5 to 1.12 mm.

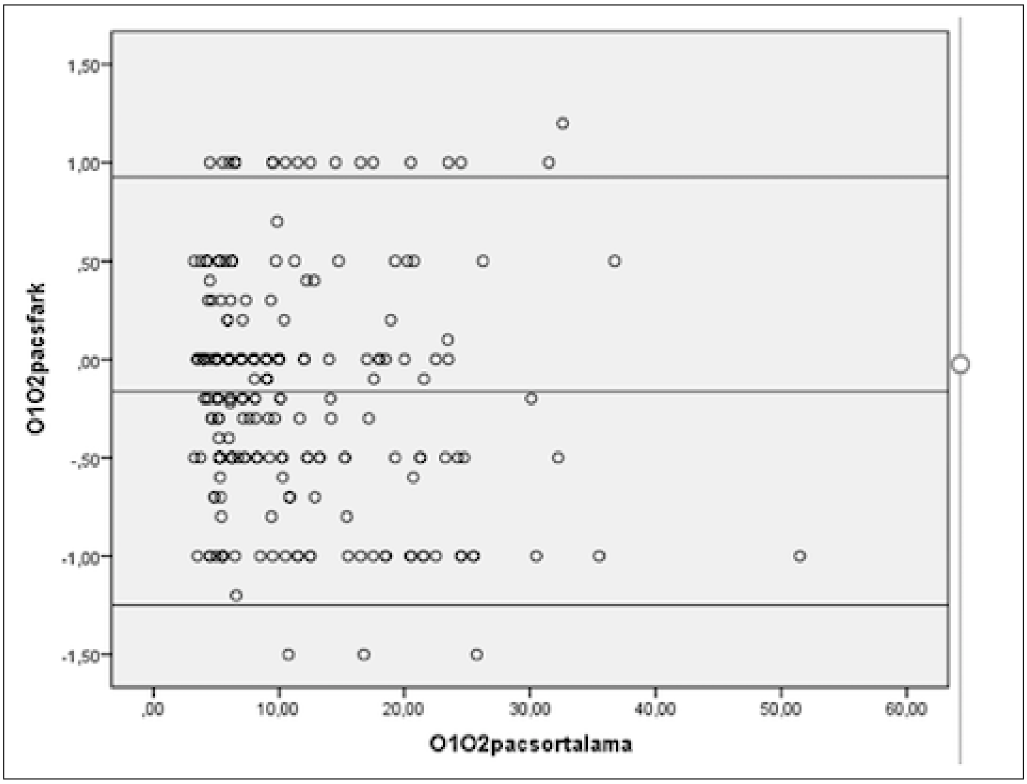

Figure 4.5 Bland-Altman analysis results between observers in PACS.

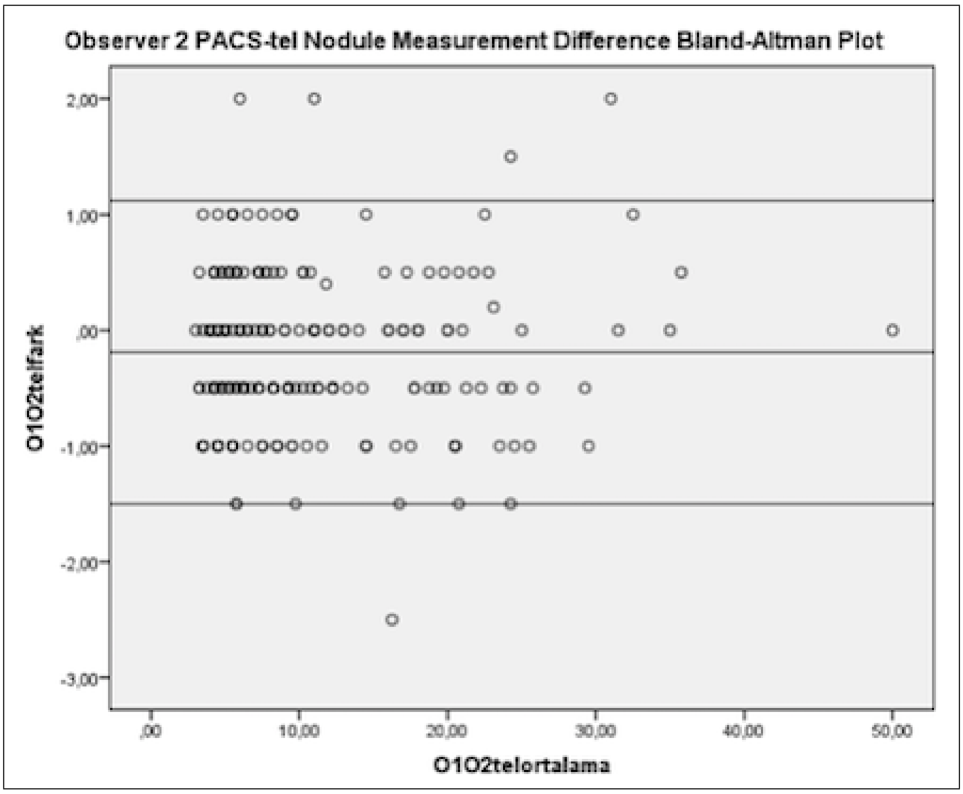

Figure 4.6 Bland-Altman analysis results between observers in mobile.

5. DISCUSSION AND CONCLUSION

A small mean offset between measurements from the two devices was observed.This offset can be corrected using a calibration curve. Also,there was not a significant difference between the observers on the two devices. Medfilm is considered as an image processing software suitable for simultaneous imaging of DICOM PACS workstation and medical research (radiology and nuclear imaging), functional imaging, 3D imaging, confocal microscopy and molecular imaging. There were the differences between mobile dicom viewer measurement and PACS dicom viewer measurement. There was 0.6 mm difference between two observer in the mobile application. On the other hand, the difference between measurement type by the same observer was 0.2mm. Therefore, all these parameters were checked with the phantom measurement. In order to control whether there was a calibration problem in MedFilm mobile dicom viewer, phantom dicom images were measured. The FDA anthropomorphic thorax phantom with 12 phantom lesions of different sizes (10 and 20 mm in effective diameter), shapes (spherical, elliptical, lobulated, and spiculated), and densities was scanned at Columbia University Medical Center on a 64-detector row scanner (LightSpeed VCT, GE Healthcare, Milwaukee, WI). The CT scanning parameters were 120 kVp, 100 mAs, 64x0.625 collimation, and pitch of 1.375. The images were reconstructed with the lung kernel using 1.25 mm slice thickness [28]. There was no issue identified regarding the calibration of Medfilm application.

The encouraging results show that smart phones can potentially be used in teleradiology for evaluating therapy response in lung cancer during clinical trials or actual therapy for the lung nodules.

Medfilm is considered as an image processing software suitable for simultaneous imaging of DICOM PACS workstation.

The new open source software, Medfilm, allows you to process images in many ways, to navigate, view and transmit multi-dimensional DICOM image data sets. Synchronization of old-new tests with Medfilm, all basic imaging, measurement and calculation processes can be performed. The software can perform detailed search on the

PACS, and can display and display the search results in DICOM format without loss loss in PICS. With this software, CD / DVD recording and DICOM Print can be made and images can be saved and exported in standard image formats (jpeg, tiff, etc.).

As a result, Medfilm can be used as a teleradiology tool to evaluate lung cancer therapy response.

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