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Artificial Intelligence meets Healthcare Industry

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Abstract:

Artificial Intellegence is an assemblage of many algorithms for analysing and interpreting knowledge from vast collection of heterogenous data, which influenced a wide range of indusries. The concepts of AI are related to fields like statistics, probability, pattern recognition, machie learning etc. collectively called as "computational intelligence". This paper analyses the impact of these techinques in the healthcare life cycle starting from diagnosis to treatment and also its contribution in prevention. As a small error in the applicability will lead to dangeous and ireversible effect, this paper analyses the means by which governments taking care of and ensuring their performance while giving permission for the products based on AI in healthcare.
Keywords: Artificial Intelligence, Types of AI, Healthcare lifecycle, Image reconstruction, regulatory process

1. Introduction

"Health is a state of complete harmony of the body, mind and spirit. When one is free from physical disabilities and mental distractions, the gates of the soul open." – B.K.S. Iyengar

To have a healthy community, along with health care industry, field of computer science – Artificial Intelligence (AI) – is palying a major role. AI The traditional health care industrial activites are transformed and taken a new face by the usage of Artificial intelligence. Healthcare landscape is proliferating by the use of AI and the showed improving health outcomes. Patient data are collected and stored as electronic health record (EHR). The high-risk conditions and co-morbidties can be predicted by applying machine learning algorithms [23], also it can be used to assist drug discovery [24], predicting the prepardedness of the healthcare unit in the pademic situations.

The area where are AI impacted are categoriedinto five namely (i) Keeping well (ii) Early Detection (iii) Diagnosis (iv) Decision making (v) Treatment

Intelligent devices which uses AI algorithms has to be approved by regulator authority, as it involves human life risk on their usage. Regulatory body should define the boundary conditions in the view of patient's safety, and also allow innovations for better solutions. There are many companies occupied in producing intelligent devices using various algorihtms. Section 2 discusses heath care life cycle ,Section 3 discusses the work flow of designing and implementing artifical intelligence models, section 4 devices and the algorihtms used.

2. Health care life cycle

Health care life cycle starts when patients experiences health issues and approaches heathcare system. Figure 1: shows the life cycle of health care which ends with treatment and getting well.

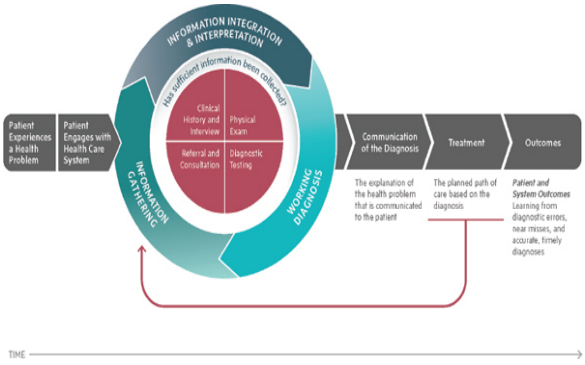

Figure 1: healthcare life cycle

Patients come to the health care system when they face health issues. The major stages in Health care system are:

(i) Information Gathering from the patients.
(ii)Working Diagnosis
(iii) Information integration and interpretation
(iv) Treatment

2.1 Information Gathering / Data Collection

Data of the patients may be collected in various ways, like

- Clinical history and interview
- Physical examination
- Referal and consultaion
- Diagnostic testing

Details/data from Clinical history, interview with the patients and physical examniation, and the refereal and consulatation details should be entered as and when collected in the data base. These details are maintaed as Electronic Medical Record (EMR). Applications software used should give all types of possibilities to be entered.

Diagnosis is done using may devices, which are may or may not be using AI. Devices which are using AI help in faster and accurate diagnosing. Many applications are used for keeping the population healtier. Those applications collect vital details which many be used for policy making, deciding diet suggessions, planning for exercises etc.

"The human body has been designed to resist an infinite number of changes and attacks brought about by its environment. The secret of good health lies in successful adjustment to changing stresses on the body." – Harry J. Johnson

The changes in the environment affect our body conditions and also the life style of human being has a striking impact on the body conditions. Making oneslef to practice healthier behaviour and help proactive management of lifestyle is facilitated by many technologies and applications. Using these applications health care professionals can collect the vital factors that affects and they can give guidance for the needed life style changes. Some the Few Applications that helps to keep people well are listed in table 1:

Category of application	Application name	Software	Purpose
Weight losing - excercise	Couch to 5K	Free, available for iOS, and Android	Eight-week program for running to reduce weight
Diet advice	Fooducate	Free, available for iOS, and Android	The product contents like sugar, whether genetically modified food etc. Will be shown to the customer they select products from the store
Diet advice	MySugr	Free, available for iOS, and Android	Helps the diabets to select meals, report to the doctors to get suggessions
Health monitoring	Stress and Anxiety Companion	Available on iOS, paid app	Provides brain exercises to reframe. Uses cognitive behavioural therapy techniques
Cost on medicine purchase	OneRx	Available on iOS, paid app	Checks for insurance and discounts while purchasing drugs

These data from various applications and clinical databaes are used as Training data and validation data for the model decided.

2.2 Working Diagnosis

Medical diagnosis is considered as a process of " mapping from patient's data (normal and abnormal history, physical examination, and laboratory data) to a nosology of disease states"[54].

Detecting life threatening disease in early stages will save many a life. Artificial Intelligence techniques are used in many technologies like mammograms to detect earlier. Mammograms and translated 30% faster which reduces the need to have unwanted biopsies[1], as they give the results with 99% accuracy.

Many other medical devices and wearables which are enabled with AI techniques helps to detect the conditions of life-threatening diseases at more early and treatable stage itself. Diagnosis is a process and classification scheme.

Diagnosis is a "pre-existing set of categories agreed upon by the medical profession to designate a specific condition"[2].

Health Committee [4] states that, diagnosis is a collaborative activity which involves information gathering, information integration and interpretation and clinical reasoning. Throughout the diagnosis the sufficient information collection should be assured. In [5], authors emphasised "recent explosion of imaging and laboratory testing has invered the dignosis paradigm". Dignosis tools such as sleep apnea testing, neurocognitive assessment and visionand hearing testing are improved a lot [6].

Machine learning is one of the AI technologies which influence the diagnosing medical images a lot. Images produced by devices such as CT, MRI, ultra sonic are analyesd by applying algorithms of machine leaning. These algorithms are used for specificity and accuracy in identification of affected parts. AI techniques identify the pattern changes in the images easily which is very difficult if not impossible for human [35,36]. For discussion on machine learning refer to section 3.2.1.

2.3 Information Integration and interpretation

As per statistics almost 25% of nurse's work is related to regulatory and adminstrative activities [31]. Robotic Process Automation,[refer section 3.2.4] - a type of AI technology will be used in this task. RPA is used in the task clinical documentation or medical record management [32] . Manual maintenance of such doculments will be error prone. RPA can also be used in revenue cycle management, claims processing.

Machine learning is also used in payment admistration, where it can compare the insurance status, by doingprobabilist matching of various databases.

Benfits of AI algorithms in medical imaging interpretation will be successful only when the false-positive rate should be less. The interpretation of the images should be assessed in terms of its meaningful classifications and the applicability.

2.4 Treatment

For healthy and long life, normal functioning of heart is important. Changes in left venticular function of heart should be given major considerations. By applying AI techinques on the images produced by MRI, CT health care persons can get the condition of leftlet mobility and outflow tract functioning of heart. These results can be used to decide whether medical therapy or valve replacement is a better choice.

After identification of the problems, patients will be on medication. In therapeutic process drug delivery is important activity. Therapeutic activity is controlled by the protein interactions with the prescribed drug. Method called protenomic scale has been used to predict side effects of the proposed drug which can be analysed by FINDSITE [66].

Drug delivery is the stage where the problem diagnosed is addressed. Human genomic data has been analysed to identify the durgs to be prescribed for neurological diseases by Verge Genomics Company.

Google's Stream project develped a technology using AI to predict patients in AKI 48 hours earlier thatn earlier[59].

Chatbbots are used by some healthcare organizaions to experiment patient interaction and mental health. Chatbots used the NLP, a type of AI technology will be used in this task. Woebot is an automated agent for conversation for healthy conversation with patients. It monitors the mod of the patients by asking questions and identifies by analysisng the text they typed.

3 . Work flow of Artificial Intelligence

Artificial Intelligence is a branch of computer science which is used in buliding machines that are smart enough to perform the tasks that require human expertice. When Aritifical Intelligence is used for a problem, there is a set of activites to be done in sequence. The flow of work to attain a solution by applying AI is given in figure 1.

3.1 Problem selection

Not all the problems can be solved by machines, so problem identification is the first step. Data related to the problem. Applicability of AI to the problem can be validated only when large amount of data about the problem can be collected. Validity of the solution is directly propotional to the amount of data. Model for the solution will be designed by applying different algorithms and techinques. These models are applied on the collected data to get useful information. Based on the usefulness of the information the model will be deployed.

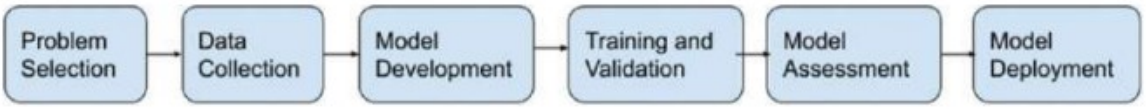

Figure 1: Work flow of AI solution (Source [14])

In first phase the applicatbilty of AI in the health care industry and also the type of issue to be addressed will be considered. For example if the application is for collecting menstrual details it should give the details of application, how the data will be used it privacy statements etc.

3.2 Data collection

As AI is used in many applications for healthy life, data can be collected from those applcations. Also data can be collected from clinical study whcih are uploaded in may wesites like kaggle [62], other agencies like [60,61]. Many researchers collect the data from interventions sole for their research.

3.3 Model development

Major tasks of Health care system is using Artifical Intelligence in many areas such as dignosing, drug delivery [17], providing personalized treatment [18]. Model of AI applied may vary from problem to problem. Following are the types of AI models in healthcare system.

- Machine Learning
- Natural language processing
- Rule-based expert systems
- Physical robots
- Robotic Process Automation

Based on the application and the availability of data any one model of AI will be selected.

3.4 Training and validation

Once the data are collected they will be preprocessed in make it suitable for the model. Generally the data is randomly divided into training set and validation set [63]. Model is fit on the training set, and this model is used for prediction [64].

Cross validation is a technique to evaluate the performance of the machine learning model. The issue that may arise in the model is overfiting i.e. model fails to generalize the patten of its usage.Models like k-fold-cross-validation [65] are used to test wheter the model is valid.

3.5 Model assessment

Model selected should be justified by showcasing the model performance indicators. Some of the performance indicators are positive rate, percentage of identfying the postive case correctly, percentage of identfying the negative case correctly etc. Some time the model selected will be compared with other models alos they will be checked for more number of iterations.

4. Types of AI in healthcare

System which uses Artificial intelligence mimics the fucntionality of the brain related to learning and problem solving skills [56,57]. Machine learning - the subset of AI, influence a lot in radiological applications. It analyses the radiology images to find patterens. forcharacteristizing and monitoring diseases.

There are many types of models or technologies in AI relevant to health care. Depending upon the processes and work they carry out, they will be appliend in specific filed of health care. Some of the importatnt technologies/models are

1. Machine learning
2. Natrual Language Procesing
3. Rule-based expert systems
4. Physical robots
5. Robotic Process Automation

4.1 Machine learning

Machine learning is a commonly used AI technology not only in health care but also in many other fields. Survey [30] states that ML has been used in approximately 63% of the companies they surveyed.

Medical imaging is an important branch of computer science which improved and helped the clinicians in detecting and treating the patients without involving the patients in any invasive procedures [7]. Medical imaging is mainly used in varity of injuries and their applicabilty to the problems are on the rise [8]. For example, researchers Estevaet. Al [15] and Hekler [16] , created model and applied the images related to visual problem inorder to diagonos whether it is skin cancer, psoriasis or skin cancer. They used 1,29,450 images and applied Deep Convolutional neural network.

Normally Artificial Intelligence techinques are used for the follwoing purpose in Medical imaging:

- Image quality enhancement
- Identification of Pattern changes
- Early detection
- Image reconstruction

Image quality enhancement

Imaging techniques are particularly useful because of its ability to diagnose accurtely. Their performance are assessed based on the parameters called sensitivity and specificity, clinical importance of the output [33,34].

Imaging techniques are used for interpretation of images. These methods are used to enhance visual interpretation. Multiple transformations are needed to extract the data needed.

Applications	Purpose	Algorithms used
Mamography	Noise reduction in image	Median filter
	To improve Accuracy and reliability of mass region segmentation	Mutli-layer topographic region growth algorithm, active contour modeling, adaptive region growth , a radial gradient index based modeling
	Characterisation of lesions	Sobel mask, cumulative edge gradient, Gabor filter
	Microclassification	k-nearest-neighbour, Bayseian, discriminant analysis, rule-based methods, genetic algorithm
Bone strength and osteoporosis	To classify bone strenght	Linear discriminant analysis,
	Diffusion MRI	De-phasing and re-phasing gradient

Identification of Pattern changes

Minute Pattern changes in the images helps in to learn its reflection in other diseases, it also helps in understanding disease process.Complicates issues that are showing symptoms in some other parts can be identified by analysis the image patterns. For example autoimmune myocarditis is a concequence of fatal immunotheraphy [39].
Cardiac imaging at the earlier stage can be adviced to identify and adminstercadiac disease caused by this autoimmune myocarditis.

In the application of cancer characterisation and detection AI played a vital role. Minute structural alterations are used to predict malignancy and tumor kinetics. In the case of prostate cancer, deep learning algorithms can be used to assess various features such as texture, shape and volume will help the physicians to identify the nature and status of prostrate cancer [41].
Quantitative texture analysis is used in the case of adrenal nodules to extract radiogrphic lesions and helps in avoiding invasive testing[42].

Deep Learning Methods in Image reconstruction in CT
Deep learning image reconstruction (DLIR) is used by GE healthcare for imgae reconstruction. They got clearence from U.S FDA in April 2019. They utilizes **deep neural network** to produce high quality CT images. They use the images produced by their Revolution Apex CT scanner. They compared ground-truth image on various parameters such as image texture, noise, contrast. **Back Propagation** technique is used to adjust the differences. To manage the amount of noise they allowed selecting three reconstruction strength levels – low, medium, high-.
Filtered back-probagation (FBP) is another method used in image reconstruction. This technique is used to reduce the doseageinorder to lessen the impact in patients. Because of the mathematicl assumptions used for tht analytical purpose, the image may be degraded significantly [48,49]. To reduce the image degradation by the application of FBP, another method called iterative reconstruction (IR) is uesd

Echocardiography is a common imaging technique for cardiovasular issues. By applying Convolutional neural network, an AI technique structural abnormalites and also functional abnormalities can be identfied [40].

Early detection

Genomic features of any disease can be used for early detection [57].Purpose of genenomic studies is to find the driver genes for the diseases[58]. After the advancement in the sequencing these techniques are used to find the cellular pathways [59]. Gene modifications/mutation can be detected which are the reason for cncer. This genomic studies uses are realised well during the pandamic days because day by day we are witnesing new mutated varient of covid virus.

Image reconstruction

Get back the original images or approximate image which will show all the relevant/curusial information for processing. Medical images from Computer tomography has to be reconstructed for better diagnosis. Following are the algorithms used by CT vendors.

CT Vendor	Algorithm name
GE Healthcare	ASIR: Adaptive statistical image reconstruction
Philips Healthcare	IMR: Iterative model reconstruction; ASIR: Adaptive statistical image reconstruction
Siemens Healthineers	IRIS: Iterative reconstruction in image space; ADMIRE: Advanced modelled iterative reconstruction

Canon Healthcare	FIRST: Forward projection model-based iterative reconstruction solution AIDR3D: Adaptive iterative dose reduction 3D

Table 1: CT Vendors and the algorithms used for image reconstruction

As the applicability of AI in reconstruction is a mandatory one, many proposals for new algorithms were proposed by many companies. AI based image reconstruction proposals [13]. In an image the reconstuction may bring back the structure of the image, reduced the noise etc. Table 2 shows the Proposed algorithms for image reconstruction and their purpose.

Purpose	Posposed algorithms
Arrefact reduction, Structure Preservation, Faster computational speed[9]	Deep residual learning architecture for sparse-view CT reconstruction based on a persistent homology analysis to remove streaking artefacts and achieve faster computational speeds
Noise suppression Artefact reduction Structure preservation[10]	Combining the autoencoder, deconvolution network, and shortcut connections into the residual encoder-decoder convolutional neural network (RED-CNN) for low-dose CT imaging
Optimise IR methods Noise suppression Structure preservation[11]	Iterative low-dose CT reconstruction with k-sparse autoencoders (KSAE) trained by artificial neural network
Optimise IR methods Noise suppression[12]	Deep learning IR approach involving a synthetic sinogram-based noise simulation approach for training of convolutional neural network (CNN) to denoise and improve image quality
Optimise IR methods	Fast reconstruction algorithm using deep learning to approximate model-based IR (DL-MBIR)

4.2 Natrual language Processing

IBM produced Watson, which employes a set of ‘cognitive services’ such as speech, vision, and analytics[51], for precision medicine. Preision medicine is the technique which predicts the kind of treatment is essential based on the patients’ parameters and the context [52].

4.3 Rule Based system

These systems are based on a collection of ‘if-then-else’ rules called knowledge for a particular domain to solve the problems [54]. The base of this thechnique is to convert the human knowledge into set of hardcoded rules. Systems which are applied in medical purpose are termed as “Medical expert systems”.

Usually they will be used in the applications of decision making such as ‘clinical decision support system’ [53]. For example in the case of aneurysms- an excessive localized swelling of the wall of an artery- in the abdomine whether imediateitervention for the condition is needed can be decided based on the diameter of the swelling.

Medical rule based systems consists of two components

(i) a knowledge base – set of if then else rules. These rules will be designed based on medical experts knowledge derived from the evidance. Medical diagnostic knowledge base will have diseases, symptoms, history, lab test results their relationship among them.
(ii)Inference engine – program that operates and produces dignostic results.

Rule based system MYCIN was developed to diagnos blood-bone micro-organisim infection especially bacterial infections [50]. Even though this is moved to the clinical trail stage, these rule based systems are used in clinical relevant alerts, and in the cases of telemonitoring.

4.4. Physical robots

Ways in which robots can be used in healthcare are:

Medical device packing – Condamination risk of devices which needs complete sterlization can be solved by robots in packing medical devices.

Lab Test Automation – Blood Tests which requires repeted actions for tesing the blood samples. Adding robots for these repeated activities will help acheive faster perfomance.

NeuroSurgery – Cobot is used to position the microscope inorder to get best view of the surgery part. This can also be used for better precision in the case of neurosurgery. Synaptive Medical is a company which uses the cobot for neurosurgery.

Cutting Bone – To do bone ablation with the application of laser to cut bones lightweight robots are used. The CARLO – Cold Ablation Robot guided Laser Osteotome- systems uses this.

Thearapeutic massage – the role of physiotherapist is taken care by robots. For example Alex is a robot which does full body massage using round end effectors.

Based on their type of task they provide physicla robot are named as

- Surgical robots - these robots are helping in surgical procedures. They help doctors to do many procedures with more precision. Usually these robots are used in surgeries with minimal invasive surgeries. Usually in these robots's arm small tools will be attached. These arms wll be controlled with a computer by the surgeon.
  - o Surgeon will make a cut to insert the instrument into the patients body
  - o Endoscope attached at the end will give enlarges 3D images of the body part.
  - o Doctors's hand movements are used to move the robot's arm to perform the tasks
- Service robots (stock control, cleaning, delivery, sterilization)–usually this kind of robots are used in the situation when the task to be performed are dangerous, repetitive, dirty, in general, uncomforatble tasks for human to do.
- Cognitive theraphy robots – Robots used in cognitive training to improve attention skills, imitation skills, turn-talking skills and social interaction skills. For detailed list of usage refer [54]. This type of robots will be using sensors
- Companion robots – Robots created for the purpose of giving comapnionship for human being [55]. Methods of speech synthesis with emotional, speech recognition methods are used in these robots.
- Robotic limbs and exoskeletons
- Humanoids–is a non-human entity but having the human form and show characteristics. They are also called as Gynoids. The sensors and cameras capture the details in these parameters are processed by the controlling system to direct the motors or otherewised called as actuators placed in the strategic points will move or make gestures.
  - o Normally they will be used to create charaters in games application.
  - o Sophia – world's first robot which was introduced by United Nations on 11th October 2017. Sophia is capable of doing fifty facial expressions and she can be able to show expressions.
  - o Kodomoroid TV Presenter – this humanoid is invented in Japan. She is named after the japanese word Kodomo- which means child.
- Telepresence robots

4.5. Robotic Process Automation

Cognetive Behaviour Therapy (CBT) is one of the techology which uses AI. It helps patients to change the way the think .It helps them to reframe their negative thoughts into positive thoughts. Woebot is an application that uses

CBT. Many other Applications that are using CBT are available such as Moodkit, Moodnotes from Thriveport, Pacifica, Wysa, Joy App.

5. Approval for Intelligent devices.

Intelligent devices which uses AI algorithms has to be approved by regulator authority, as it involves human life risk on their usage. Regulatory body should define the boundary conditions in the view of patient's safety, and also allow innovations for better solutions

McCarthy J[20] defined AI as " the science and engineering of making intelligent machines, especially intelligent computer programmes". Machines based on Artificial Intelligence are called as intelligent machines as they use algorithms to explore the data to make decisions or any kind of health related activities.

All these intelligent devices that are used for the purpose of health care should be approved by Authorising agnecies of the respective governments.

In general, the regulatory process should (i) identify the risk involevd in using the designed devices and should showcase the ways to mitigate it (ii) create standards and cerification procedure and (iii) define penalities if the standards are no followed and incentives if the standards are adhered to.This traditional method is shown in figure 3.

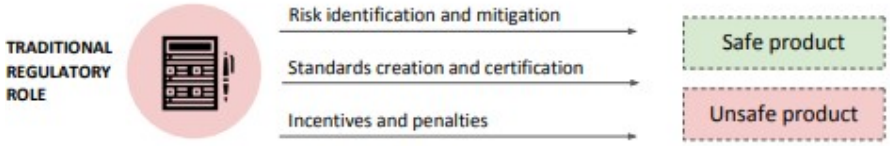

Figure 3: Traditional regulatory process (Source[24])

Every stakeholders of health care must assess the implemenation of AI both in technical aspect as well as ethical aspects [25]. As the intelligent devices collects many patient related data security of the data should be ensured by the companies. Policies related to data sharing [26] has been deviced by many countries. The regulatory authorities for intelligent devices should take into consideration of the following:

- Security of patient personal data
- Defining the Experimental regions of the devices
- Administer the organizations that are using the Intelligent devices
- Certification of Working professionals such as software engineers with the data
- Confirming the effectiveness and worth of the devices

In US the US Food and Drug Adminstration (FDA) is the authorized governemmnt agency to approve the AI and Mechine Learning based medical devices. Policy defined by FDA defines Machine learning as "a system that has the capacity to learn from training on a specific task by tracking performance measures" [21]. For the sake of clarity FDA provides examples for these Intelligence devices such as skin care diagnosis system that uses ML algorithms for imaging, electrocardiogram device which estimates the possibility of heart attack are categorised as intelligent devices. Devices are cregoriesd based on the risk and higher the risk higher the control will be.

In European Union (EU) the "In vitro Diagnostic Medical Device Regulation" (IVDR) is in effect from 26 may 2022[27]. Also for data sharing the General Data Protection Regulation (GDPR) of EU is in effect from 2018 May. This regulation provides more rights and responsibilities to the patients and people who are using personal data [28].

Based on the Federal Law No 323-FZ of Russian Federation, "medical device is any tool, equipment, devices, materials and other products used for medical purpose, necessary accessories and software" [29]. This definition imposes control on any device with AI whether it is used independently or in combination with other medical devices must be registered and gets approval based on the Federal Law. The updation released on 2020 imposes regulations on various categories such as "clinical test" ,"Technical test program and methodology", "Application of quality

In china, the National Medical Product Adminstration (NMPA) is the certifying authority for Intelligent devices for health care. "Technical Guideline on AI-Aided Software" of NMPA issues regulations for the software versioing and naming convention of the data-driven and algorithm-driven sofware and its updates.

Apart from these a voluntary group called International Medical Device Regulatory Forum(IMDRF) which is constituted of members from EU, US, Canada, Australia, Brazil, China, Japan, Russia, Singapore and south korea working on regulations to be imposed globally on Intelligent medical devices

6. Barriers in adopting AI solutions

Managing the large volume of data in terms of collection, verification of data sets, integrate them into the healthcare workflow. Voluminous data will have the implicit issue of inconsistency.

Data collection may involve many a format and type, each may produce data differnt format. The non-standardisation of data formats and the issue of interoperability is a barrier of adopting AI. Every image used for training and validations should be labeled. This data labeling [43] is an important task for the entire application of AI, as the mis-labeling will give a serious issue and many false positives or false negatives.

AI system lacks in using contextual knowledge and social clues[44].

Even though there are many advantages, reliability of AI is still a question. If there is any error which colud not be detected then it will lead to a serious implications [45]

Use of technology like CT will raise the issue of ionization, which impacted the public health a much [46,47].

The applicability of AI in healthcare should reassure that no AI technique can replace the human expert. For example radiologist using AI can be more productive, but radiologist can not be replaced [37,38].

7. Conclusion

Artificial Intelligence has many types of algorithms and techniques. These techniques can be used in medical field in various life cycle stages of it. Starting from data collection ending with drug delivery and treatment their application improves performance and precision. In this paper some of the techiques used and the procedure to be followed to get approval form government agencies. In future the imaging technique will be analysed in detail.

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