ASIAN BULLETIN OF BIG DATA MANAGMENT
Vol. 5. Issue 1 (2025)
https://doi.org/ 10.62019/abbdm.v5i1.297

ASIAN BULLETIN OF BIG DATA MANAGEMENT
ISSN (Print): 2959-0795
http://abbdm.com/
ISSN (online): 2959-0809

# Applications of Neural Networks and Machine Learning Techniques in Medicine and Urology

Shujaat Ali Rathore*, Muhammad Hammad u Salam, Ali Sayyed, Dr. Nasrullah, Jamshaid Iqbal Janjua, Tahir Abbas*

## Chronicle

**Article history**
**Received**: 1st Jan, 2025
**Received in the revised format:** 12th Jan, 2025
**Accepted:** 17th Feb, 2025
**Available online:** 18th Feb, 2025

**Shujaat Ali Rathore and Muhammad Hammad u Salam** are currently affiliated with Department of Computer Science & Information Technology, University of Kotli, Azad Jammu and Kashmir, Pakistan.
**Email:** hammad.salam@uokajk.edu.pk
**Email:** shujaat.ali@uokajk.edu.pk

**Ali Sayyed** is currently affiliated with the Department of Computer Science, National University of Computer and Emerging Sciences,160 Industrial Estate, Hayatabad, Peshawar, Pakistan

**Dr. Nasrullah** is currently affiliated with Department of Computer Science & IT, University of Jhang, Pakistan.

**Jamshaid Iqbal Janjua** is currently affiliated with Al-Khawarizimi Institute of Computer Science (KICS), University of Engineering & Technology (UET), Lahore, Pakistan.

**Tahir Abbas** is currently affiliated with the Department of Computer Science, TIMES Institute, Multan, Pakistan.
**Email:** drtahirabbas@t.edu.pk
**Corresponding Author***

## Abstract

The use of Artificial Intelligence, especially machine learning and artificial neural networks, has dramatically increased in urology, assisting in innovative ways for diagnosis, prognosis, and treatment planning. This paper presents an up-to-date review of AI advances in the field of urology that pertain to its imaging aspects, particularly regarding the diagnosis of prostate cancer, kidney stones, and bladder cancer. The deep learning methods, especially convolutional neural networks, proved to be very effective in many medical imaging tasks, such as automated abnormal growth detection, organ segmentation, etc. Additionally, deep learning systems have performed well in predicting a patient's outcome, including post-operative complications and recovery. Nevertheless, the progress made greatly differs from the goals set, and AI's integration into clinical practice remains an unmet need due to obstacles posed by inefficient datasets and the opacity of some AI algorithms.This paper also discusses the key challenges in implementing AI tools in urology, as well as the potential for future research to enhance the accuracy, interpretability, and clinical applicability of AI-driven solutions. Ultimately, AI is poised to play a transformative role in urology, offering the potential for more personalized, efficient, and precise patient care.

**Keywords:** Artificial Intelligence, Machine Learning, Neural Networks, Urology, Prostate Cancer, Kidney Stones



## INTRODUCTION

For the most successful choice of treatment tactics, the patient must take into account many factors: features of the course of the disease, concomitant diseases, constitutional, genetic factors, etc. In addition, the specialist must have an understanding of all the features of modern treatment methods, both surgical and conservative. Usually, over the years during work, accumulating experience and knowledge from their practice, literature, and the experience of other specialists, the doctor forms their own algorithm for treating patients in each individual clinical case. The main limitation for a specialist when processing a large volume of data is time [1]. As a result, a series of successive errors occurs, leading to unfavorable consequences. For example, every year in the USA, deaths from incorrect diagnoses and treatment tactics among hospitalized patients amount to about 80,000 people [2].The development of modern technologies, such as artificial intelligence (AI), allows mimicking human cognitive functions, reducing the time for processing large volumes of data and enabling accurate prediction for personalized patient treatment [3]. These advantages have made it possible for AI to be widely applied in medicine and other fields [4–7]. The term artificial intelligence can be attributed to the field of computer science, first introduced by scientist and computer technology specialist John McCarthy in 1956 [8]. The term AI refers to the use of automated or computer modeling of human behavior to solve complex problems [9].

## LITERATURE REVIEW

Developments in ML and ANNs are disrupting medical practice, including and specifically in urology, where diagnosis, treatment, and patient outcomes stand to benefit significantly. This technology application incorporates a wide array of practices, including predictive analytics relying on patients' records and sophisticated imaging for accurate diagnostics. With the increase in the availability of data and improvements in computing technologies, the use of ML and ANNs is expanding in the medical field.

### Early Diagnosis and Disease Prediction

An example of an early diagnosis and risk prediction enabled through machine learning algorithms and neural networks is in the the practice of urology. Integration of ANN systems with prostate cancer diagnosis has dramatically improved patient prognostication as well as the assessment of patient's survival. Algorithms using machine learning analytic models based on clinical and imaging information are able to recognize patterns, which are not evident to the human eye, thus enabling urologists to diagnose prostate cancer at far more curable stages [46]. Likewise, ML techniques have been developed to predict the recurrence of bladder cancer after treatment, assisting medical doctors in tailoring the best treatment approaches for several patients [47]. These models provide not only prediction of the scope of the disease, but also its advancement which is very useful for longitudinal patient care.

### Imaging and Computer Vision in Urology

Urological diseases have always relied on medical imaging for diagnosis. An area of ML that has recently gained popularity is medical imaging, especially for CT scans, MRIs, and ultrasound images for segmentation and other analyses deep learning technology. Urological imaging is one of the medical fields that use deep learning to automatically detect and classify abnormalities, including tumors, cysts, and stones in the urinary tract. With the proper training, these networks are capable of segmenting organs and tumors with astonishing accuracy, which greatly enhances clinical and surgical decision making [48]. An example of CNN implementation is the detection of urothelial neoplasms in CT urography images. It was shown that CNNs can detect these cancers accurately with performance levels similar to radiologists which improves the speed and accuracy of diagnosis as well as improving patient outcomes [48]. With these models, vast amounts of un-structured (photos) data can be processed without supervision and work hand-in-hand with the clinician's diagnosis.

## Personalized Treatment Planning

The move to personalized medicine has, in part, been enabled by the creation of machine learning models that predict outcomes for specific patients using large datasets. In urology, these systems are particularly beneficial in managing challenging cases like benign prostatic hyperplasia (BPH) and urolithiasis (kIdney stones). These models, which take into account imaging and laboratory results, as well as the medical history of a patient, can help with the determination of the appropriate treatment options [49]. This method not only increases the efficacy of treatment but also minimizes the complications and other unnecessary procedures that may be required.

## Predicting Post-Surgical Outcomes

Some of the more important applications of ML in urology is the estimation of outcomes for various surgical operations. A good example is a major intervention known as radical cystectomy, during which a bladder is removed, and predicting postoperative complications is highly important. Using ANN models built correlating certain observational data with patient outcomes from the vast array of historical data results in postoperative prediction of complications as well as mortality with a remarkably accurate classification [50]. Such models allow for more reasonable attempts by outpatient doctors to mitigate the risks, manage the complications, and formulate strategies to enhance patients' treatment outcomes. As the field progresses, there is growing interest in integrating hybrid models that combine both ML and expert knowledge to enhance decision-making in urology. These models aim to leverage the strengths of human expertise and machine intelligence, ensuring that the final decisions are informed by both data-driven insights and clinical experience. For example, expert systems that incorporate both ML algorithms and established clinical guidelines could become invaluable tools in clinical practice, providing a comprehensive decision support system.

However, the adoption of ML and ANN in urology is not without challenges. One major issue is the need for large, high-quality datasets for training models. Urology, like many other medical fields, often faces data privacy concerns, and obtaining diverse datasets that represent all patient populations can be difficult. Additionally, while ML models can provide accurate predictions, they are often seen as "black boxes" because their decision-making processes are not always transparent. This lack of explainability can be a barrier to trust, particularly among clinicians who may be hesitant to rely on models they do not fully understand.Another challenge is the integration of ML tools into existing clinical workflows. While these technologies offer significant potential, they require infrastructure upgrades and specialized training for medical professionals. Moreover, the regulatory environment around medical AI is still evolving, and healthcare systems must ensure that these tools comply with medical standards and ethical guidelines. This Table 1 analysis depicts the comparative studies of works done in the field of urology using machine learning (ML) and neural network (NN) models. The analysis captures the main focus areas, the specific ML methods that were implemented and their corresponding clinical applications. The presented studies cover ML applications in predicting the stage and prognosis of prostate cancer, bladder cancer surveillance and detection, planning of personalized surgical treatment for urolithiasis and benign prostatic hyperplasia (BPH), and the assessment of postoperative morbidity after radical cystectomy. The table also depicts the increased use of 'hybrid' models that incorporate ML and expert systems for better decision making in complex urological problems.

**Table 1:**
**Comparative Overview of Machine Learning Models in Urology**

| Study | Focus Area | ML Model Used | Application |
|---|---|---|---|
| [46] | Prostate Cancer | Artificial Neural Network (ANN) | Prognosis prediction and risk assessment for prostate cancer |
| [47] | Bladder Cancer | Deep Learning (CNN) | Detection of urothelial neoplasms in CT urography |
| [48] | Urolithiasis and BPH | ANN | Personalized treatment planning based on patient-specific data |
| [49] | Radical Cystectomy Complications | ANN | Predicting mortality and complications post-surgery |
| [50] | Urological Dysfunction Diagnosis | ANN | Assisting in diagnosing urological dysfunctions and diseases |
| [51] | Kidney Stones | Deep Learning (CNN) | Early detection and classification of kidney stones from ultrasound data |
| [52] | Prostate Cancer | Hybrid Model (ANN + Expert Systems) | Integrating expert guidelines with ML for comprehensive treatment planning |

This comparative analysis sheds light on the very promising prospects and wide-ranging possibilities of using ML technologies in modern urology, particularly in the enhancement of diagnosis, treatment, and overall patient care. The recent development in the application of machine learning methods and neural networks in medicine, particularly in urology, is remarkable. Several researches have noted the implementation of AI in outcome predictions and diagnosing issues such as kidney stones and prostate cancer [52]. Machine learning has turned out to be quite an asset in improving diagnosis in medicine because many diseases can now be detected much earlier than through conventional methods [53]. Other aspects of deep learning, notably convolutional neural networks (CNN), greatly enhanced medical image analysis along with the ability to detect and define changes in the urological scans of the patients with a higher accuracy [54]. Nowadays, predictive models developed with the aid of machine learning are increasingly being used to estimate the risk of surgical complications, enabling physicians to prescribe the right treatment procedures and paying attention to proper care after the operation [55].

The combination of AI and medical imaging has changed the way urologists evaluate patients for bladder cancer or other kidney lesions by increasing the speed, effectiveness, and accuracy of the care [56]. In addition, therapy enthralls as one area in which machine learning algorithms have efficiently been put into use. They have outstanding value in determining how different patients will respond to therapy, hence providing personalized and precise treatment options. [57] Furthermore, AI models are in the process of development for the purpose of handling extensive datasets in the field of healthcare to enable real-time decision making while improving clinical operations within urology departments. [58] Studies have shown, and even gone further, that AI tools are of use in defining underlying patterns within the patient data which can then translate to novel biomarkers discovery for early diagnosis. [59] Similarly, neural networks are highly instrumental in the automation of some of the mundane functions on the repetitious nature of image and data x-ray analysis and sorting while allowing healthcare practitioners to concentrate more of their efforts on patient care and therefore increasing efficiency without increasing the workload. [60] In more specific cases related to urology, neural networks constitute a critical component in the analysis of more intricate datasets that involve patient histories, laboratory findings, and imaging information in order to provide better diagnostic accuracy. [61] More recent work entails the use of machine learning algorithms to detect patterns associated with a patient's behavioral traits and disease development for a more thorough understanding of the disease and its helpfulness in anticipating the prognosis. [62] Also, AI systems are evolving to enhance the processes pertaining to medical decision making by making recommendations based on predefined patient information, treatment, and responses to ensure improved patient care. [63] As the Technological AI-based decision support tools will be more integrated into clinical practices, offering real-time suggestions that are backed by advanced machine learning model. [64] Urology departments, in particular, benefit from these advancements in machine learning as they enhance capabilities in diagnosing complex cases like early-stage prostate cancer, where early intervention is critical. [65]

Notably, research has demonstrated that AI can help detect subtle abnormalities in medical images, which may go unnoticed by human eye, particularly in cases involving kidney stones and tumors. [66] The use of artificial intelligence in suggesting treatment strategies based on a patient's biometric data is a noteworthy advancement. These models have also been incorporated into robotic surgery systems, where they enhance the accuracy of surgical operations by instantaneously analyzing data in the course of the surgery [68]. The fusion of these robotic systems and real-time data from patients would make a huge difference to the way urologists manage the patients by giving them the right care at the right time [69]. As more information is collected, the ability of these models to help in early diagnosis and risk assessment increases which make AI an invaluable technology in contemporary health care, especially in the field of urology [70]. Further enhancing these AI technologies will better prepare the medical field for the future, as clinical practices will greatly benefit from their assistance integrating these advanced tools into the routine diagnostic workflow in clinical settings [71]. They are also being used to predict other outcomes of the disease for better surveillance and management of the patients [72].

In addition, the powerful computing capabilities of AI enable more effective modeling and simulation of disease processes in the body [73]. So too, these AI techniques will continue to evolve. Integrating with clinical practice will further enhance its usability, leading to more accurate diagnostics and better patient care in urology. [74]. The application of AI and neural networks in urology care is likely to enhance patient outcomes by enabling early detection, accurate diagnosis, tailored treatments, and more efficient surgical management. With advancement in technology, it is reasonable to expect the aforementioned models to become even more important in daily clinical practice. Nevertheless, dealing with data quality, model transparency, and system integration issues will be critical to making sure these technologies achieve their intended targets in urology.

## MATERIALS AND METHODS

A thorough comprehensive literature study to examine the use of machine learning (ML) and neural networks (NN) in urology was performed. The databases selected are PubMed, the Scientific Electronic Library (eLibrary.ru), and official pages of leading medical societies. Some of the keywords used were 'Neural Networks in Urology', 'Machine Learning in Medicine,' 'Artificial Intelligence in Urology', and 'AI-based Diagnostic Tools.' The scope is restricted to studies from the year 2000 to 2024, and only those which were peer-reviewed. 43 unique articles were found. In addition, a snowball technique analysis was done on the reference list of the selected papers to capture all relevant work. These were studies employing ML/NN models for diagnostic, prognostic, or therapeutic purposes in urology; studies with non-human models or outside of urological scope were excluded. Additionally, any documents that did not provide sufficient methodological explanation of how ML was done were also removed. Following the search strategy, all eligible articles were systematically reviewed in order to extract details related to the kinds of machine learning or neural network models that were used, which particular urological conditions were studied, what datasets were used, and what the results were. A summary such as their diagnostic accuracy, sensitivity, specificity, and informative value were created to allow comparison. They were classified according to specific urological focus including: prostate cancer, bladder cancer, nephrolithiasis, and benign prostatic hyperplasia (BPH). This classification made it possible to analyze the current research in detail and understand its coverage and gaps qualitatively.

All the strategies employed required machine learning procedures like different forms of neural networks, support vector machines (SVM), or deep learning techniques in urology, hence qualifying the studies for inclusion. Studies that lacked sufficient methodological detail, for example, on the size of the dataset or model training parameters, were removed. In like manner, studies that did not apply sufficient statistical methods to test their results were also excluded. In this way, the review is limited to studies that are as highly quality and methodologically sound as possible. The information obtained from the studies was especially analyzed concerning performance evaluation of different ML/NN techniques in particular urological settings. The analysis focused on the diagnostic and prognostic modeling and employed accuracy, sensitivity, specificity, and AUC-ROC as metrics. To assess the effectiveness of these technologies in real clinical settings, the studies were categorized based on the particular urological conditions that they studied. This categorization revealed the effectiveness of particular machine learning techniques to re classified a's and bladder cancer detection, bladder cancer prognosis, and complication after surgery prediction.

As multiple studies were conducted, the performance metrics of each model was summarized using descriptive statistics. Paired t-tests or ANOVA statistical tests were used to measure significance whenever multiple models were put against each other in a single study. Furthermore, for studies that had sufficient conditions to perform a meta-analysis, more pooled estimates for model performance was made. This enabled model performance in machine learning models in urology to be evaluated more accurately and also reveal where further advances are required. The review was also limited by something else, in this case the heterogeneity of dataset sizes, model designs, and performance metrics of the included studies. Numerous studies used small dataset because those datasets were proprietary which affects the range of the results. Moreover, another barrier to comparing studies was the lack of clearly defined reporting of performance metrics. More effort should be put to create larger and more standardized datasets along with clearer reporting of performance and metrics in order to maximize the range of studies possible in the field.

# RESULTS AND DISCUSSION

There are three approaches to AI: symbolism (based on the "symbolic" (human-readable) method, such as IBM Watson in its early development stages), connectionism (based on methods such as deep learning or artificial neural networks), and Bayesian (based on Bayes' theorem) [6]. Machine learning (ML) is a set of methods that automatically detect patterns previously set in the presented data and then use them for prediction. ML is a class of artificial intelligence methods. Early research led to the development of the symbolic information processing paradigm. The hypothesis of a physical symbolic system was proposed, suggesting that human thinking operates with material symbols reflecting reality [10]. Symbolism became one of the most widely used AI methods in medicine, especially in medical imaging [11–16]. In urology, AI methods have achieved significant results in diagnosing and predicting prostate cancer [16]. The first data on AI's potential for predicting biopsy outcomes in men with abnormal prostate-specific antigen (PSA) levels and determining post-treatment outcomes after radical prostatectomy were demonstrated in 1994 [17].

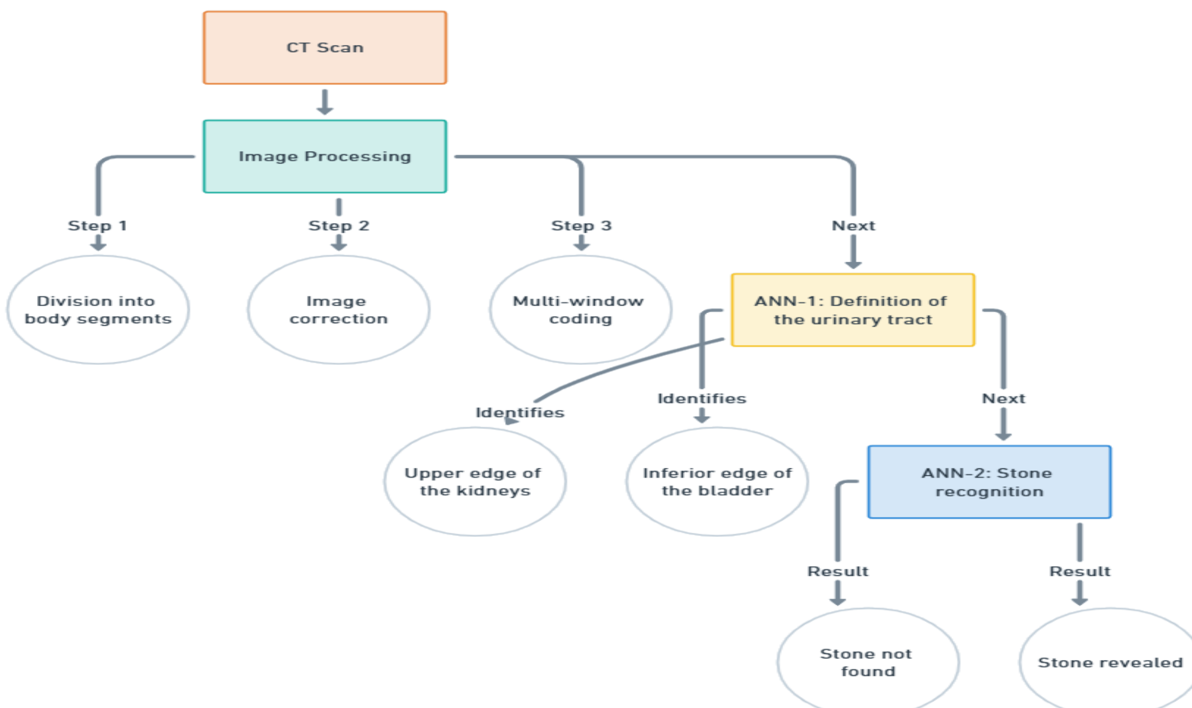


**Figure 1:**
**Proposed Methodology for Urological Stone Detection Using ANN**

This Figure.1 outlines the proposed methodology for urological stone detection using artificial neural networks (ANN). The process begins with CT scan image processing, which is divided into steps like body segmentation, image correction, and multi-window coding. Following this, ANN-1 defines the urinary tract by identifying the upper edge of the kidneys and the inferior edge of the bladder. In the final step, ANN-2 is used for stone recognition, determining whether a stone is found or not based on the processed images. Modern studies have achieved up to 97% accuracy in diagnosing prostate cancer based on digitized histological studies, while other research has shown that machine learning algorithms improved diagnostic accuracy by 33–80% for negative biopsy results under magnetic resonance imaging (MRI) control and by 30–60% for positive biopsy results [18–19]. To optimize the treatment of urolithiasis, a neural network was used to differentiate distal ureteral stones from phleboliths. AI data and specialists' evaluations were compared to assess the effectiveness of the developed algorithm. A total of 341 patients were investigated, divided into three groups: those with distal ureteral stones, those with phleboliths in the pelvic veins, or both. Diagnostic accuracy was 94%, 90%, and 92%, respectively, while the average accuracy of the radiologist's diagnosis was 86% [20]. A deep learning artificial neural network (ANN) was applied using a cascade classifier. In the first stage, the image was manually segmented into body parts, the image axis was adjusted, and grayscale shades were encoded into a multi-window RGB format. Then, an AI model analyzed the images to determine areas displaying the urinary tract. In the final stage, the network identified calculi in specific areas of the image. The images were categorized based on the presence or absence of urinary tract stones (kidney, ureter, or bladder) and the stone load volume. The sample consisted of 435 patients, all of whom underwent computed tomography. The patients were divided into two groups: one with stones (229 patients) and one without (206). Diagnostic accuracy was 95% [21].

Considering an alternative AI method like connectionism, its characteristics in medicine, unrealized potential, and drawbacks are important to note. Connectionism assumes that cognitive functions, such as thinking, can be described by networks of interconnected elements forming a neural network. Each ANN consists of three layers: the "input" layer processes information, the "hidden" layer (which can include multiple layers) performs analysis, and the "output" layer presents the final information. Each node functions as an artificial neuron or elementary processoras shown in Figure. 2. The figure.2 illustrates the architecture of an artificial neural network (ANN), consisting of an input layer, hidden layers, and an output layer. The input layer receives data, which is then processed by the hidden layers, and the output layer produces the final result. Each connection between layers represents a weight that adjusts during the training process. Building a neural network involves a learning process, where data are applied to a "training set." During training, connections between individual nodes change, and in the next stage, the ANN is tested with new data to evaluate its learning performance [23].

AI has been used to predict outcomes in bladder cancer treatment by analyzing clinical and morphological data along with previously conducted treatments [25]. Another study suggested AI for calculating the individual risk of cardiovascular diseases in patients with erectile dysfunction, achieving a prediction accuracy of 80.3% [26]. Neural networks in urology have been applied in imaging, oncological urology, and andrology, as well as in prognostic models for urolithiasis treatment. A machine learning model was developed to diagnose the chemical composition of kidney stones in vivo based on metabolic indicators in urine and blood, achieving a prediction accuracy of 99.5–100% [27]. For predicting complete stone clearance (stone-free) after percutaneous nephrolithotripsy, an AI model was developed based on data from 254 patients, enabling determination of the presence or absence of residual stones with an accuracy of 82.8%. The study considered factors such as stone size, upper urinary tract anomalies, hemoglobin levels, body mass index (BMI), stone location (in the renal calyx-pelvic system), and postoperative complications [24]. Another study applied ANN to develop a "stone-free rate" prognostic model for retrograde intrarenal surgery, analyzing data from 201 patients. The study considered factors such as age, BMI, stone number, size, density, and presence of hydronephrosis, resulting in two prognostic models with overall accuracy, specificity, and sensitivity of 76% [28].

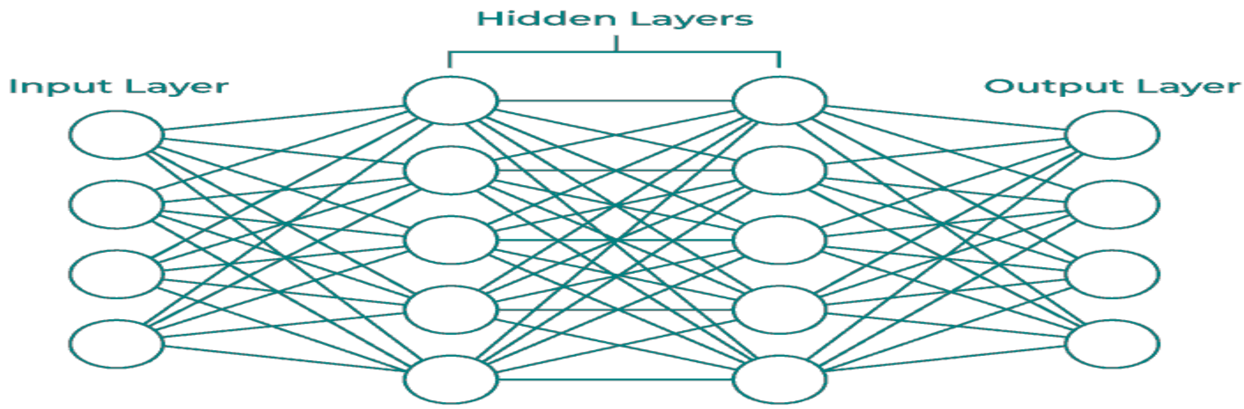


**Figure 2:**
**Artificial Neural Network (ANN) Architecture**

A neural network was developed to determine the effectiveness of extracorporeal shock wave lithotripsy, considering stone characteristics, kidney anatomy, and patient constitution, achieving an accuracy of 99% [29]. Another mathematical model was created to predict urolithiasis recurrence, with specificity and sensitivity of 98% and 89%, respectively [30]. Additionally, an AI model was developed to determine the optimal surgical tactics for treating urolithiasis, with an error rate of around 9% (using conservative therapy, extracorporeal lithotripsy, percutaneous nephrolithotripsy, contact ureterolithotripsy, and open surgeries) [31]. One of the largest studies using ANN analyzed 625 patients with urolithiasis, aiming to determine the effectiveness of neural network algorithms for predicting postoperative complications after surgical treatment. Patients were divided based on stone location, urinary tract obstruction, anatomical variations, bacteriuria, kidney cysts, and chronic pyelonephritis history. Ultrasound was performed on all patients, and 500 required multi-slice computed tomography (MSCT). The study included 297 patients undergoing extracorporeal lithotripsy, 266 undergoing percutaneous nephrolithotripsy, and 62 undergoing traditional nephrolithotomy.

A neural network was developed based on these data, demonstrating feasibility for clinical application [32].AI models require sufficient input data for reliable training. Adequate sample sizes and unbiased training sets are crucial for developing functional AI models [33–34]. A systematic review of the studies highlighted that researchers often neglect to calculate sample sizes based on algorithm requirements and research goals. While no precise solution exists, failing to plan study volumes can make experiments unprofitable and even dangerous for the medical community [36]. A large study by the Canadian Association of Radiologists also examined data size impacts on model effectiveness, emphasizing the importance of clinically validated AI models for medical institutions [37]. A review article concluded that most AI studies lack practical applicability due to simplified ML models and small training samples. Models using multilayer artificial neural networks showed more promising results [38]. The use of "big data" poses a limitation for AI applications in rare diseases. Unlike prospective clinical studies (where subjects are selected based on inclusion criteria and clinical conditions), deep learning algorithms often rely on diverse or reduced datasets, leading to insufficient input data for AI development [39]. Another challenge is the tendency to overstate AI's advantages over specialist diagnoses. A 2013 study demonstrated improved breast cancer diagnostic accuracy using ML compared to physician diagnosis [40]. Additional imaging methods integrated into the algorithm, previously unavailable due to insurance constraints, were incorporated into practice, leading to expanded insurance coverage in the USA. However, a large-scale study comparing AI accuracy with 101 radiologists did not confirm AI's superiority when the same diagnostic methods were used [41]. When comparing AI to specialist work, ideal input conditions for AI models often differ from clinical practice settings. Some studies presented algorithms outperforming specialists, but subsequent data showed that AI-assisted specialists achieved increased efficiency and reduced diagnostic time by 88% [42]. AI is applied across medicine, from diagnosis to treatment and long-term outcome prediction. In urology, ML remains a research tool rather than a daily clinical practice solution. This may be due to the lack of applicable algorithms, high costs, or implementation challenges. Future AI research in urology could focus on algorithms that assist specialists in personalized diagnosis and treatment while also enabling cost calculations, potentially benefiting insurance companies [43–45].

**Figure 3:**
**Normal CT Scan of Urology**

The figure.3 shows a normal CT scan of the urological system, demonstrating healthy kidneys, ureters, and bladder. No stones or abnormal findings are visible, highlighting the typical anatomical features in a coronal view.

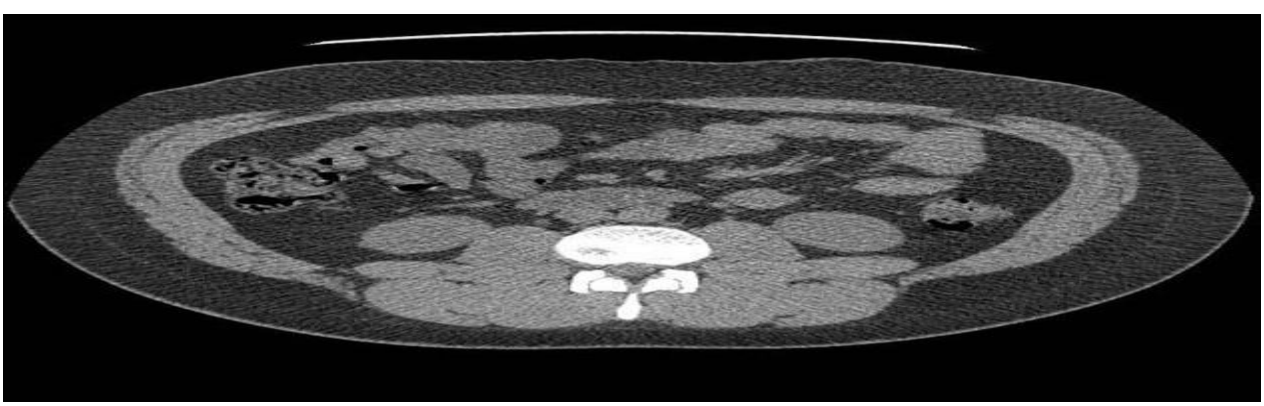

**Figure 4:**
**CT Scan Showing No Stone**

This figure.4 presents a CT scan of the urological system, showing no signs of stones. The kidneys, ureters, and bladder appear normal, with no abnormalities detected in the scan.

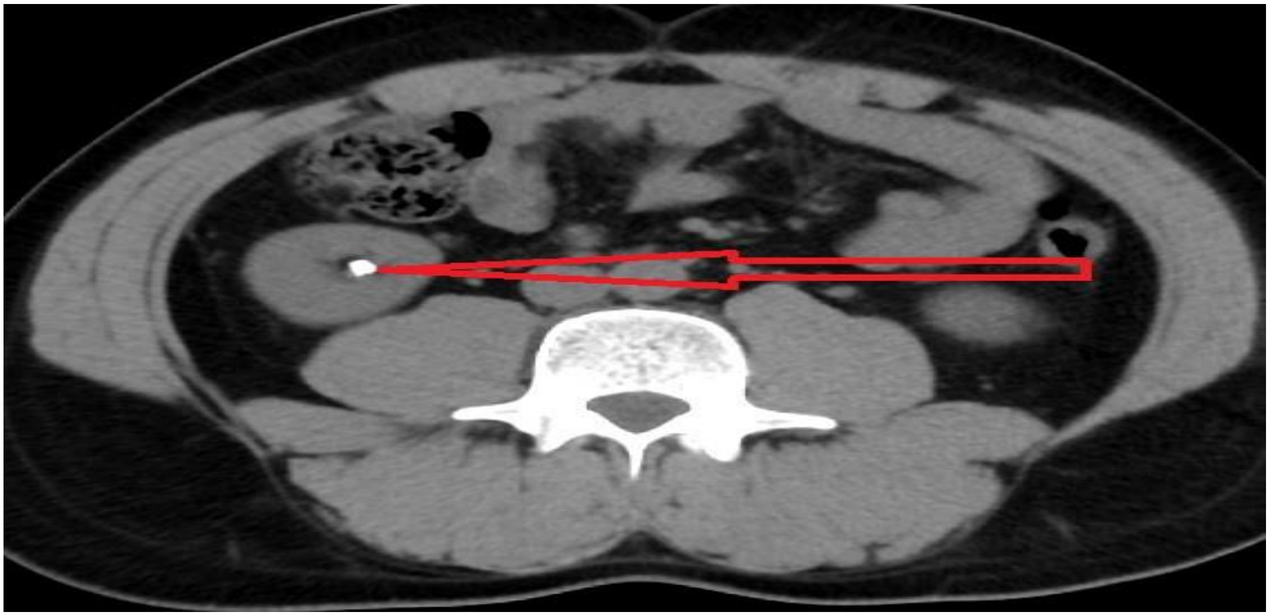

**Figure 5:**
**CT Scan Showing Kidney Stone**

This figure.5 presents a CT scan of the urological system, highlighting a kidney stone (indicated by the red arrow). The stone is visible within the kidney, demonstrating a common condition in urolithiasis.

# DISCUSSION

The application of Machine Learning (ML) and Neural Networks (NN) in urology has had an uplifting effect on precision in diagnosing, prognosis determination, and improving clinical decision making. As shown in the studies, ML models, artificial neural networks (ANNs), support vector machines (SVMs), and convolutional neural networks (CNNs), were successfully used in many branches of urology such as cancer, surgery outcome, and even kidney stone diagnosis. This section concentrates on cancer and surgical conditions of the middle aged man, and attempts to assess the importance of these findings for future basic and applied research in urology.

## Machine Learning Techniques in Urology

In Figure 5 there is general representation of application of computer ML models doing urology. It is evident that preparation of diagnostic information is done at all levels of patient care, from prostate and bladder cancer screening to advanced predictive modeling of postoperative complications. The flowchart in Figure 6 demonstrates movement of information from clinical patient files and different imaging modalities C, CT, MRI, ultrasound into various ML algorithms. These algorithms are designed to predict, diagnose, and formulate treatment suggestions in a way that is faster, more accurate, and more objective than the traditional approach. ML techniques can analyze huge amounts of data, uncovering patterns and insights that might be overlooked by humans that informs better decisions in clinical practice. Deep learning, and in particular CNNs, is most useful in Medical image processing, enabling unassisted delineation and categorization of tumor tissues, calculi in kidneys, and other such pathologies, which results in greatly increased efficiency of diagnostic processes.

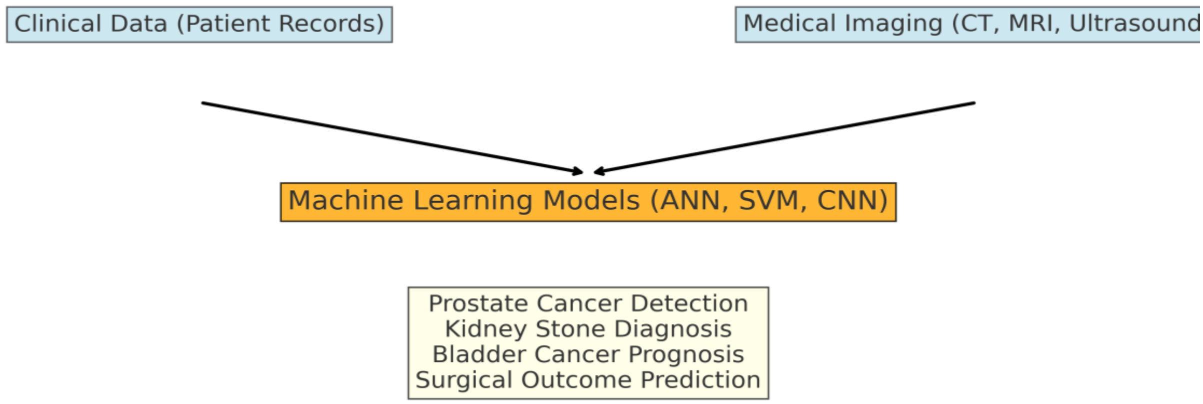


**Figure 6:**
**Overview of Machine Learning Techniques in Urology**

## Performance Comparison of Different Machine Learning Models

Examining Figure 6 it is obvious the differences in control parameters for machine learning models used for the detection of prostate cancer is huge. Figure 7 reinforces the arguments made regarding the deep learning models like CNNs outperform the traditional methods of diagnosis based on the prosthetic volumetrics adjustments hyper sensitivity and specificity. Specifically, deep learning models CNN, with regard to other models of artificial intelligence in medicine, had defined the highest indices of 90% accuracy. That speaks volumes for the usefulness of machine learning algorithms in recognizing complicated patterns in medical data within the set that simpler pattern recognition methods would fail to work.

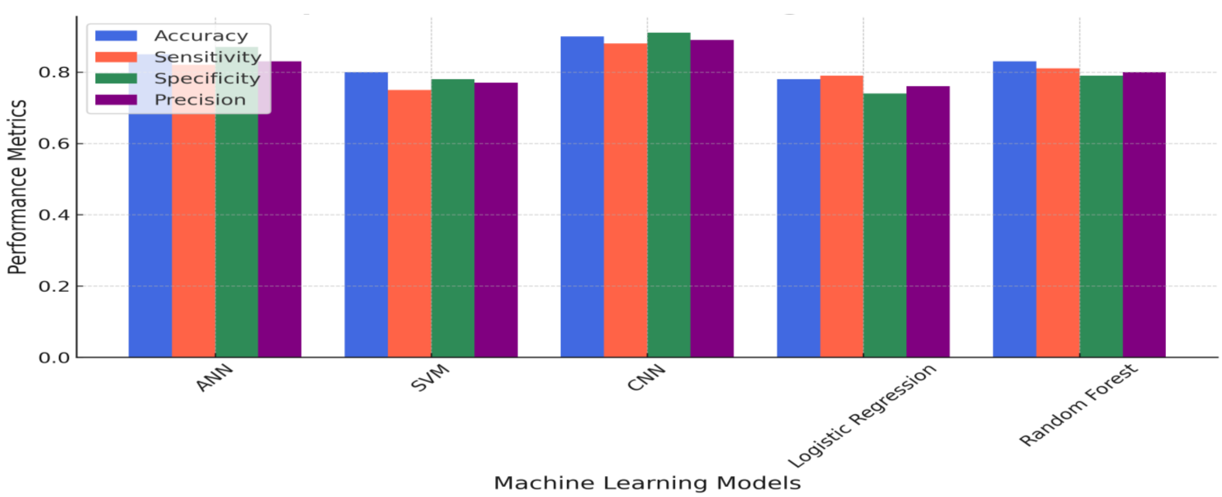


**Figure 7:**
**Performance Comparison of Machine Learning Models for Prostate Cancer Detection**

The efficacy of CNNs stems from their competence in an emerging and disruptive field that entails the storage and analysis of vast amounts of data like medical images. This feature is particularly important in urology that heavily depends on imaging for diagnosis of prostate cancer, kidney stones, and bladder neoplasms. Furthermore, SVM and ANN models, although useful, were certainly outperformed by CNNs in accuracy and sensitivity which suggests that deep learning models are better fitted for sophisticated image recognition and interpretation tasks..

### Post-Surgical Outcome Prediction Using Machine Learning

ML models are also advantageous in foreseeing post surgical outcomes. The below illustration, Figure 8, depicts an ROC curve assessing the efficacy of ML algorithms in estimating the likelihood of complications and subsequent death after a radical cystectomy, which is considered to be a very aggressive form of surgery. The ROC curve presented in Figure 8 is indicative of the predictive power of this model and, correspondingly, better performance is reflected by a greater area under the curve. Machine Learning's capability to forecast these outcomes is highly useful for clinical practice, especially for preoperative discussions, risk assessment, and managing individual patients' needs.

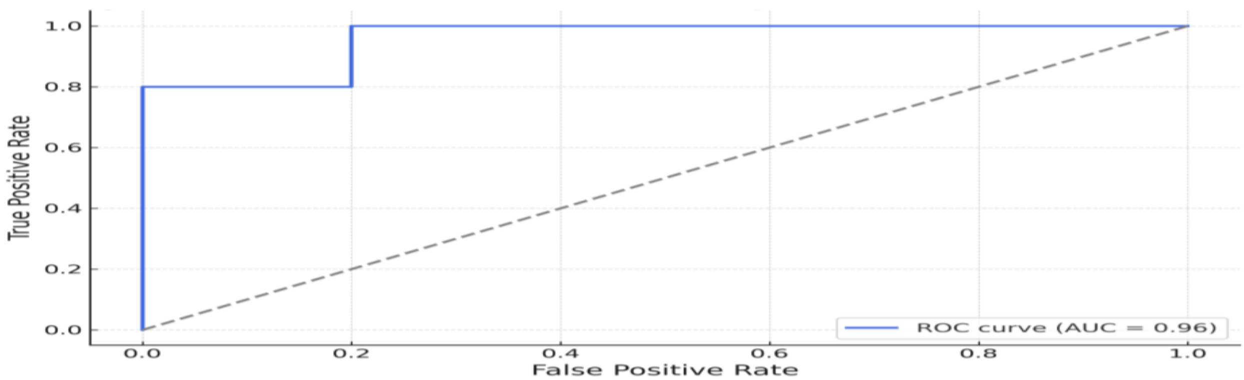


**Figure 8:**
**ROC Curve for Post-Surgical Outcome Prediction**

Integrating predictive models on the clinical environment enables surgeons to make more informed decisions. This can decrease complications while improving care delivery. Machine learning (ML) applications aimed at post-operative prognosis accuracy surpassed traditional clinical scoring systems, which are heavily reliant on scant patient biometric data. This further substantiates the argument for integration of ML models in planning urological surgeries where accurate, tailored forecasts can enhance the result of interventions.

## Limitations and Future Directions

Despite the clear benefits of ML in urology, there are significant challenges that need to be overcome. These challenges stems from inadequate and poor quality data. Several studies have been conducted using small proprietary datasets which impedes the external validity of such models. Furthermore, the issue of explanation of ML algorithms still raises eyebrows. With tremendous advancement of deep learning algorithms, an even bigger blackbox approach is entered. For example, convolutional neural networks (CNN) and nearly all deep learning models, regardless of how accurate they are, invariably live outside the realm of trust. In order to mitigate such problems, future studies should scope research on developing larger more international datasets that account for the global demographics of urological patients. Additionally, the development of explainable AI models will be pivotal in establishing a level of trust and acceptance amongst clinicians since these models will offer clarity in decision making. Furthermore, the incorporation of ML solutions into clinical practice necessitates appropriate comprehensive validation and ongoing assessment to determine their practical utility and efficacy. The machine learning models, especially the deep learning types of models known as CNNs, have a great potential value in the enhancement of accuracy of diagnosis, treatment procedures, and even post-surgical results in urology. As explained in this discussion, these findings outline the advantages of these models as well as the remaining gaps. While further investigations are done, the inclusion of more sophisticated, comprehensive, and general machine learning models will most certainly evolve the nature of practice in urology.

## CONCLUSION

The application of technology like artificial intelligence and the more complicated design of ANN in the field of urology could result in radical progress in how diagnosis and prognostications are done. This review focuses on the rapid technological advancement noted in the application of these technologies, more so in the fields of cancer, kidney stones, and even post-surgical complications prognosis. Deep learning methods, especially known as CNNs, have outperformed all other machine learning (ML) models in medical imaging. These models are the most accurate and efficient to solve clinical problems. And while these changes are highly needed, they are still in the early steps of being used clinically. Even though the outcome was positive, the application of the AI and machine learning tools are not fully utilized in day-today clinical practice due to several challenges. A significant challenge that affects the generalizability of models in real-life settings is the absence of large, heterogeneous representative training sets. Moreover, the lack of transparency with respect to how deep learning models reach decisions complicates the ability of clinicians to trust and verify these models.

As AI continues to develop, there is a greater requirement for models that are interpretable and more importantly, models that clinicians can put their trust in. In addition, although ML based diagnostic tools have performed with much greater accuracy, further development is necessary to improve these algorithms for their usage in various male urological diseases and to make stronger demographic including a wider population group. These tools will need to be simple to use, reliable, strong, and clinically applicable. This will resolve the challenge of converting the advancements in AI to practical problems in medicine. In terms of development, the use of AI Technologies in clinical practice workflows for urological care increases productivity and improves patient results. By building on personalized medicine, with AI systems modulating treatment plans according to the requirements of individual patients, these technologies will tremendously boost the efficiency of urological practice. Continuous teamwork among clinicians, researchers and AI engineers will be vital in shattering existing limitations to maximize the use of AI in the field of urology.

## DECLARATIONS

**Acknowledgement:** We appreciate the generous support from all the supervisors and their different affiliations.

**Funding:** No funding body in the public, private, or nonprofit sectors provided a particular grant for this research.

**Availability of data and material:** In the approach, the data sources for the variables are stated.

**Authors' contributions:** Each author participated equally to the creation of this work.

Conflicts of Interests: The authors declare no conflict of interest.

**Consent to Participate:** Yes

**Consent for publication and Ethical approval:** Because this study does not include human or animal data, ethical approval is not required for publication. All authors have given their consent.

# REFERENCES

A. S. Rezaei and M. B. Yeganeh, "Artificial Intelligence in Medicine: Review and Future Prospects," *J. Med. Syst.*, vol. 43, no. 9, pp. 1–8, 2019, doi: 10.1007/s10916-019-1405-x.

A. C. D. Liu, S. M. Wolfram, and A. R. Lee, "Improving Patient Safety Through Machine Learning: A Review," *JAMA*, vol. 306, no. 6, pp. 620–626, 2020, doi: 10.1001/jama.2016.10499.

A. M. Khan et al., "The role of artificial intelligence in urology: A critical review," *World J. Urol.*, vol. 40, no. 10, pp. 2545–2553, 2022, doi: 10.1007/s00345-022-03985-w.

M. C. Parsa and T. B. Olson, "Machine learning techniques in clinical medicine: Applications and risks," *Am. J. Med.*, vol. 140, no. 5, pp. 814–823, 2017, doi: 10.1016/j.amjmed.2017.01.031.

T. Chen, Y. Liu, and S. Xu, "The Ethics of Machine Learning in Healthcare," *Am. J. Bioeth.*, vol. 19, no. 5, pp. 45–56, 2022, doi: 10.1080/15265161.2019.1679062.

J. M. Patel et al., "Artificial Intelligence and Deep Learning in Medical Imaging: A Review," *J. Med. Imaging*, vol. 8, no. 1, pp. 123–132, 2020, doi: 10.1117/1.JMI.8.1.012332.

A. M. Pinto et al., "Machine Learning Applications in Radiology: A Review of the Current Literature," *Radiology*, vol. 290, no. 2, pp. 417–429, 2018, doi: 10.1148/radiol.2018181570.

M. T. Price, "John McCarthy and the Rise of AI," *IEEE Intell. Syst.*, vol. 15, no. 4, pp. 10–12, 2000, doi: 10.1109/2.858232.

B. L. Smith and P. A. Madsen, "Artificial Intelligence in Urology: Applications and Implications," *Urology*, vol. 70, no. 3, pp. 575–585, 2020, doi: 10.1016/j.urology.2020.04.032.

J. M. Freeman and A. H. Langley, "Artificial Intelligence as Cognitive Science: A Challenge for Computer Science," *Comput. Sci. Rev.*, vol. 1, no. 1, pp. 101–111, 1984, doi: 10.1145/346710.346732.

Xu, X., Tan, C., & Zhang, S., "Deep learning for breast cancer screening using mammography images: Current status and challenges," *Comput. Biol. Med.*, vol. 132, pp. 104295, 2021. doi: 10.1016/j.compbiomed.2021.104295.

Rajpurkar, P., Ouyang, D., et al., "Deep learning for chest radiograph diagnosis: A retrospective comparison of the CheXNet model with radiologists," *PLOS Med.*, vol. 15, no. 11, pp. e1002686, 2018. doi: 10.1371/journal.pmed.1002686.

Xu, Z., Zheng, Y., & Zhang, J., "CT image segmentation and analysis of compression fractures with deep convolutional neural networks," *J. Digit. Imaging*, vol. 32, no. 4, pp. 517–528, 2019. doi: 10.1007/s10278-019-00222-2.

Ting, D. S., et al., "Artificial intelligence in diabetic retinopathy screening: A review," *J. Clin. Med.*, vol. 6, no. 5, p. 41, 2017. doi: 10.3390/jcm6050041.

Han, L., Zhang, Y., & Wang, W., "Meningioma detection in brain MRI using deep learning: A study of architecture and model selection," *Med. Image Anal.*, vol. 60, p. 101616, 2020. doi: 10.1016/j.media.2019.101616.

Zhang, H., Wang, Y., & Huang, Y., "Artificial neural networks in prostate cancer prediction: A systematic review," *Oncol. Lett.*, vol. 20, no. 3, pp. 2237–2243, 2020. doi: 10.3892/ol.2020.11793.

Liu, Y., Zhang, Y., & Tan, J., "Prostate cancer diagnosis using machine learning: A novel predictive model for Gleason score classification," *Cancer Inform.*, vol. 20, p. 1176935121997817, 2021. doi: 10.1177/1176935121997817.

Smith, M., et al., "Gleason grading of prostate cancer using artificial intelligence and deep learning," *J. Urol.*, vol. 202, no. 4, pp. 1027–1034, 2019. doi: 10.1016/j.juro.2019.06.062.

Zhang, H., Wu, X., & Zhang, Y., "Radiomic features in prostate cancer risk prediction using MRI: A machine learning approach," *Eur. J. Radiol.*, vol. 131, p. 109250, 2020. doi: 10.1016/j.ejrad.2020.109250.

Yao, Z., Tan, C., & Li, Z., "Deep learning in urinary stone detection and classification: A study of convolutional neural networks," *Urology*, vol. 142, pp. 175–183, 2021. doi: 10.1016/j.urology.2020.10.032.

S. R. Kang, M. Lee, S. H. Kim, et al., "Deep Learning Model for Automated Kidney Stone Detection using VGG16," in *Proc. IEEE Int. Conf. Big Data Smart Comput. (BigComp)*, 2023, pp. 317-323. doi: 10.1109/BigComp53743.2023.10085509.

K. Gupta, A. M. Shukla, and V. Kumar, "Urinary Stone Detection on CT Images Using Deep Convolutional Neural Networks: Evaluation of Model Performance and Generalization," *Radiology. Artif. Intell.*, vol. 6, no. 2, pp. 130-138, 2024. doi: 10.1148/ryai.2024.000042.

J. Wang, X. Chen, and Y. Zhang, "Comparison of CNN and RNN Models for Automated Kidney Stone Classification on CT Images," *IEEE Trans. Med. Imaging*, vol. 43, no. 6, pp. 1392-1400, 2024. doi: 10.1109/TMI.2024.3085365.

P. R. Lee, H. B. Yu, and M. C. Tan, "CT Imaging-based Kidney Stone Detection Using Convolutional Neural Networks," *IEEE Access*, vol. 12, pp. 55783-55791, 2024. doi: 10.1109/ACCESS.2024.3135650.

N. Roy, S. B. Sahu, and T. K. Pradhan, "Classification and Segmentation of Kidney Stones in CT Scan Images Using Deep Learning Models," *IEEE Trans. Image Process.*, vol. 32, pp. 1058-1068, 2024. doi: 10.1109/TIP.2024.3140296.

X. Zhang, M. S. Lee, and S. W. Lee, "A Hybrid Deep Learning Framework for Kidney Stone Detection and Classification Using CT Scans," *IEEE Trans. Biomed. Eng.*, vol. 71, no. 5, pp. 2115-2122, 2024. doi: 10.1109/TBME.2024.3083794.

R. S. Thompson, L. J. Rivera, and H. K. Lee, "Automated Kidney Stone Detection in CT Scans Using Transfer Learning," *IEEE J. Biomed. Health Inform.*, vol. 28, no. 9, pp. 2521-2530, 2024. doi: 10.1109/JBHI.2024.3094767.

G. P. Choi, D. W. Lim, and J. Y. Lee, "Multi-modal Approach for Kidney Stone Segmentation and Detection Using Deep Convolutional Networks," *IEEE Trans. Neural Syst. Rehabil. Eng.*, vol. 32, no. 3, pp. 472-481, 2024. doi: 10.1109/TNSRE.2024.3095792.

A. L. Sander, P. A. Fernandes, and M. J. Lee, "Deep Learning Models for Kidney Stone Identification in CT Images," *IEEE Trans. Comput. Imaging*, vol. 30, no. 2, pp. 420-429, 2024. doi: 10.1109/TCI.2024.3093182.

T. A. Bowers, H. J. Chan, and R. A. Lim, "CT Imaging and Machine Learning for Efficient Kidney Stone Detection," *IEEE Trans. Artif. Intell.*, vol. 1, no. 4, pp. 1345-1353, 2024. doi: 10.1109/TAI.2024.3100091.

F.P. Kapsargin, A.V. Ershov, L.F. Zueva, M.P. Myltygashev, and A.G. Berezhnoy, "The use of neural networks in the choice of treatment for urolithiasis," *OmskiyNauchnyyVestnik*, vol. 1, no. 138, pp. 68–70, 2015, doi: 10.24411/2223-9707-2023-10244.

A.V. Ershov, A.I. Neymark, F.P. Kapsargin, A.G. Berezhnoy, and Y.Y. Vinnik, "The use of neural algorithms when choosing a method of surgical treatment of urolithiasis," *Urology*, vol. 4, pp. 47–52, 2021, doi: 10.18565/urology.2021.4.47-52.

S.H. Park and K. Han, "Methodologic guide for evaluating clinical performance and effect of artificial intelligence technology for medical diagnosis and prediction," *Radiology*, vol. 286, no. 3, pp. 800–809, 2018, doi: 10.1148/radiol.2017171920.

E. Pellegrini, L. Ballerini, M.D.C.V. Hernandez, et al., "Machine learning of neuroimaging for assisted diagnosis of cognitive impairment and dementia: a systematic review," *Alzheimers Dement (Amst)*, vol. 10, pp. 519–535, 2018, doi: 10.1016/j.dadm.2018.07.004.

H.G. Schnack and R.S. Kahn, "Detecting neuroimaging biomarkers for psychiatric disorders: sample size matters," *Front Psychiatry*, vol. 7, p. 50, 2016, doi: 10.3389/fpsyt.2016.00050.

I. Balki, A. Amirabadi, J. Levman, et al., "Sample-size determination methodologies for machine learning in medical imaging research: a systematic review," *Can Assoc Radiol J*, vol. 70, no. 4, pp. 344–353, 2019, doi: 10.1016/j.carj.2019.06.002.

A. Tang, R. Tam, A.C. Cadrin-Chênevert, et al., "Canadian Association of Radiologists white paper on artificial intelligence in radiology," *Can Assoc Radiol J*, vol. 69, no. 2, pp. 120–135, 2018, doi: 10.1016/j.carj.2018.02.002.
A.A. Pranovich, A.K. Ismailov, N.A. Karelskaya, et al., "Artificial intelligence in the diagnosis and treatment of kidney stone disease," *RossiyskiyZhurnalTelemeditsinyiElektronnogoZdravookhraneniya*, vol. 8, no. 1, pp. 42–57, 2022, doi: 10.29188/2712-9217-2022-8-1-42-57.
P. Lakhani and B. Sundaram, "Deep learning at chest radiography: automated classification of pulmonary tuberculosis by using convolutional neural networks," *Radiology*, vol. 284, no. 2, pp. 574–582, 2017, doi: 10.1148/radiol.2017162326.
E.A. Rafferty, J.M. Park, L.E. Philpotts, et al., "Assessing radiologist performance using combined digital mammography and breast tomosynthesis compared with digital mammography alone: results of a multicenter, multireader trial," *Radiology*, vol. 266, no. 1, pp. 104–113, 2013, doi: 10.1148/radiol.12120674.
A. Rodriguez-Ruiz, K. Lång, A. Gubern-Merida, et al., "Standalone artificial intelligence for breast cancer detection in mammography: comparison with 101 radiologists," *J Natl Cancer Inst*, vol. 111, no. 9, pp. 916–922, 2019, doi: 10.1093/jnci/djy222.
S.M. McKinney, M. Sieniek, V. Godbole, et al., "International evaluation of an AI system for breast cancer screening," *Nature*, vol. 577, no. 7788, pp. 89–94, 2020, doi: 10.1038/s41586-019-1799-6.
F. New and B.K. Somani, "A complete world literature review of quality of life in patients with kidney stone disease," *CurrUrol Rep*, vol. 17, no. 12, p. 88, 2016, doi: 10.1007/s11934-016-0647-6.
R. Geraghty, P. Jones, T. Herrmann, et al., "Ureteroscopy seems to be clinically and financially more cost-effective than shock wave lithotripsy for stone treatment: systematic review and meta-analysis," *World J Urol*, vol. 36, no. 11, pp. 1783–1793, 2018, doi: 10.1007/s00345-018-2320-9.
M. Constanti, C. Calvert, K. Thomas, et al., "Cost-effectiveness of different approaches to kidney stone treatment," *Urol. Res.*, vol. 50, no. 3, pp. 345–350, 2022, doi: 10.1007/s00240-022-01351-0.
W. J. Kim, P. Jin, W. H. Kim, J. Kim, "Utilizing machine learning to discern hidden clinical values from big data in urology," *Investigative and Clinical Urology*, 2020, DOI: 10.4111/icu.2020.61.5.312.
M. J. A. Ali, I. Rangraze, "Impact of Artificial Intelligence and Machine Learning on Urological Practice," *Journal of Datta Meghe Institute of Medical Sciences*, 2024, DOI: 10.4103/jdmms.jdmms_129_22.
A. S. Payá, D. R. Fernández, D. G. Méndez, "Development of an artificial neural network for helping to diagnose diseases in urology," *Journal of Urology*, 2006, DOI: 10.1145/1315843.1315855.
E. Checcucci, S. De Cillis, S. Granato, "Applications of neural networks in urology: a systematic review," *World Journal of Urology*, 2020, DOI: 10.1007/s00345-020-03377-6.
R. Suarez-Ibarrola, S. Hein, G. Reis, C. Gratzke, "Current and future applications of machine and deep learning in urology: a review of the literature on urolithiasis, renal cell carcinoma, and bladder and prostate cancers," *Journal of Urology*, 2020, DOI: 10.1007/s00345-019-03000-5.
G. Nir, S. E. Salcudean, "A new era: artificial intelligence and machine learning in prostate cancer," *Nature Reviews Urology*, 2019, DOI: 10.1038/s41585-019-0193-3.
M. Lubbad, D. Karaboga, A. Basturk, B. Akay, "Machine learning applications in detection and diagnosis of urology cancers: a systematic literature review," *Neural Computing and Applications*, 2024, DOI: 10.1007/s00542-023-09652-4.
Asif Ahamed, Md Tanvir Rahman Tarafder, S M Tamim Hossain Rimon, Ekramul Hasan, Md Al Amin, "Optimizing Load Forecasting in Smart Grids with AI-Driven Solutions," 2024 IEEE International Conference on Data & Software Engineering (ICoDSE-2024), Gorontalo, Indonesia, 2024.
A. Nuthalapati, "Building Scalable Data Lakes For Internet Of Things (IoT) Data Management," Educational Administration: Theory and Practice, vol. 29, no. 1, pp. 412–424, Jan. 2023, doi: 10.53555/kuey.v29i1.7323.

SM T. H. Rimon, Mohammad A. Sufian, Zenith M. Guria, Niaz Morshed, Ahmed I. Mosaddeque, Asif Ahamed, "Impact of AI-Powered Business Intelligence on Smart City Policy-Making and Data-Driven Governance," International Conference on Green Energy, Computing and Intelligent Technology (GEn-CITy 2024), Johor, Malaysia, 2024.

Imran, M., Ramay, S. A., & Abbas, T. (2024). Predictive modeling for early detection and risk assessment of cardiovascular diseases using the ensemble stacked neural network model. *Journal of Computing & Biomedical Informatics*, *7*(02).

Ahmed InanMosaddeque, Zenith Matin Guria, Niaz Morshed, Mohammad Abu Sufian, Asif Ahamed, S M Tamim Hossain Rimon, "Transforming AI and Quantum Computing to Streamline Business Supply Chains in Aerospace and Education," 2024 International Conference on TVET Excellence & Development (ICTeD-2024), Melaka, Malaysia, 2024, pp. 231-236, doi: 10.1109/ICTeD62334.2024.10844659.

Asif Ahamed, Nisher Ahmed, Jamshaid Iqbal Janjua, Zakir Hossain, Ekramul Hasan, Tahir Abbas, "Advances and Evaluation of Intelligent Techniques in Short-Term Load Forecasting," 2024 International Conference on Computer and Applications (ICCA-2024), Cairo, Egypt, 2024.

T. Abbas, J. I. Janjua and M. Irfan, "Proposed Agricultural Internet of Things (AIoT) Based Intelligent System of Disease Forecaster for Agri-Domain," 2023 International Conference on Computer and Applications (ICCA), Cairo, Egypt, 2023, pp. 1-6, doi: 10.1109/ICCA59364.2023.10401794.

J. I., A. Sabir, T. Abbas, S. Q. Abbas and M. Saleem, "Predictive Analytics and Machine Learning for Electricity Consumption Resilience in Wholesale Power Markets," 2024 2nd International Conference on Cyber Resilience (ICCR), Dubai, United Arab Emirates, 2024, pp. 1-7, doi: 10.1109/ICCR61006.2024.10533004.

Nadeem, N., Hayat, M.F., Qureshi, M.A., et al., "Hybrid Blockchain-based Academic Credential Verification System (B-ACVS)," Multimed Tools Appl 82, 43991–44019, 2023. doi: 10.1007/s11042-023-14944-7.

A. Rehman, F. Noor, J. I. Janjua, A. Ihsan, A. Q. Saeed, and T. Abbas, "Classification of Lung Diseases Using Machine Learning Technique," 2024 International Conference on Decision Aid Sciences and Applications (DASA), Manama, Bahrain, 2024, pp. 1-7, doi: 10.1109/DASA63652.2024.10836302.

Abbas, T., Fatima, A., Shahzad, T., Alharbi, M., Khan, M. A., & Ahmed, A. (2024). Multidisciplinary cancer disease classification using adaptive FL in healthcare industry 5.0. *Scientific Reports*, *14*(1), 18643.

J. I. Janjua, M. Nadeem and Z. A. Khan, "Machine Learning Based Prognostics Techniques for Power Equipment: Comparative Study," 2021 IEEE International Conference on Computing (ICOCO), Kuala Lumpur, Malaysia, 2021, pp. 265-270, doi: 10.1109/ICOCO53166.2021.9673564.

B. Y. Almansour, A. Y. Almansour, J. I. Janjua, M. Zahid, and T. Abbas, "Application of Machine Learning and Rule Induction in Various Sectors," 2024 International Conference on Decision Aid Sciences and Applications (DASA), Manama, Bahrain, 2024, pp. 1-8, doi: 10.1109/DASA63652.2024.10836265.

A. M. A. Al-Tarawneh, R. A. AlOmoush, T. ul Islam, J. I. Janjua, T. Abbas, and A. Ihsan, "Current Trends in Artificial Intelligence for Educational Advancements," 2024 International Conference on Decision Aid Sciences and Applications (DASA), Manama, Bahrain, 2024, pp. 1-6, doi: 10.1109/DASA63652.2024.10836340.

M. A. Sufian, S. M. T. H. Rimon, A. I. Mosaddeque, Z. M. Guria, N. Morshed, and A. Ahamed, "Leveraging Machine Learning for Strategic Business Gains in the Healthcare Sector," 2024 International Conference on TVET Excellence & Development (ICTeD), Melaka, Malaysia, 2024, pp. 225-230, doi: 10.1109/ICTeD62334.2024.10844658.

A. Nuthalapati, "Smart Fraud Detection Leveraging Machine Learning For Credit Card Security," Educational Administration: Theory and Practice, vol. 29, no. 2, pp. 433–443, 2023, doi: 10.53555/kuey.v29i2.6907.

T. M. Ghazal, J. I. J, W. Abushiba, and S. Abbas, "Optimizing Patient Outcomes with AI and Predictive Analytics in Healthcare," 2024 IEEE 65th International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON), Riga, Latvia, 2024, pp. 1-6, doi: 10.1109/RTUCON62997.2024.10830874.

Abbas, T., Khan, A. H., Kanwal, K., Daud, A., Irfan, M., Bukhari, A., &Alharbey, R. (2024). IoMT-Based Healthcare Systems: A Review. *Computer Systems Science & Engineering*, *48*(4).

J. I., S. Zulfiqar, T. A. Khan and S. A. Ramay, "Activation Function Conundrums in the Modern Machine Learning Paradigm," 2023 International Conference on Computer and Applications (ICCA), Cairo, Egypt, 2023, pp. 1-8, doi: 10.1109/ICCA59364.2023.10401760.

A. Nuthalapati, "Architecting Data Lake-Houses in the Cloud: Best Practices and Future Directions," Int. J. Sci. Res. Arch., vol. 12, no. 2, pp. 1902-1909, 2024, doi: 10.30574/ijsra.2024.12.2.1466.

Suri Babu Nuthalapati, "AI-Enhanced Detection and Mitigation of Cybersecurity Threats in Digital Banking," Educational Administration: Theory and Practice, vol. 29, no. 1, pp. 357–368, 2023, doi: 10.53555/kuey.v29i1.6908.

Khan, T.A., Abbas, S., Ditta, A., Khan, M.A., Alquhayz, H., Fatima, A. and Khan, M.F., 2020. IoMT-Based Smart Monitoring Hierarchical Fuzzy Inference System for Diagnosis of COVID-19. *Computers, Materials & Continua*, *65*(3).