Editorial

The Pivotal Role of Artificial Intelligence in Shaping the Future of Medicine

Artificial Intelligence (AI) has emerged as a transformative force across various sectors, including healthcare. With its roots tracing back to foundational work by pioneers such as Alan Turing, AI's promise in medicine is vast and multifaceted, influencing everything from patient care to the minutiae of medical diagnostics. This introduction outlines the evolution, current state, and future prospects of AI in medicine, while also presenting an updated workflow for the development of AI models in the field.

Evolution of AI in Medicine : The journey of AI began with visionaries like Alan Turing, whose seminal work laid the groundwork for what we recognize today as intelligent machines. The Turing Test, a method proposed to evaluate a machine's ability to exhibit intelligent behavior indistinguishable from a human, set the stage for the ensuing developments in AI[1]. The subsequent decades witnessed a surge of interest and investment in AI, particularly in healthcare, which led the way in funding and research applications by 2016[2].

AI in Modern Healthcare - Virtual and Physical : AI's application in healthcare is dichotomized into virtual and physical subtypes. The virtual encompasses systems ranging from electronic health records to neural networks that guide treatment decisions. Conversely, the physical aspect of AI includes robotic surgical assistants, intelligent prostheses, and care for the elderly[3].

From Evidence-Based to AI-Enhanced Medicine : Traditional medicine has relied heavily on statistical methods to discern patterns and associations within clinical data. This paradigm is evolving with the introduction of AI, particularly through two approaches: flowcharts and databases. Flowchart-based systems replicate the diagnostic reasoning of clinicians by processing extensive data on symptoms and disease presentations. On the other hand, the database approach leverages deep learning for pattern recognition, drawing parallels to Google's AI which learned to recognize images with increasing accuracy[4, 5].

The Workflow of AI Systems in Healthcare: The development of an AI model in healthcare follows a specific pattern, as illustrated in Fig 1. It starts with the selection of a relevant problem, followed by data collection. The model is then developed, trained and validated before it is assessed and deployed into the medical system. This workflow represents the systematic approach that underpins the use of AI in medicine, from conceptualization to real-world application (Fig 1).

Integrating Artificial Intelligence: Transforming Diagnosis and Management in Healthcare :

The intersection of Artificial Intelligence (AI) with medicine has yielded a plethora

1. **Problem Selection:** Identifying a significant issue that can be addressed with AI.
2. **Data Collection:** Gathering relevant and substantial datasets to inform the model.
3. **Model Development:** Creating the AI model using the collected data.
4. **Training and Validation:** Teaching the model to perform tasks and verifying its accuracy.
5. **Model Assessment:** Evaluating the model's performance and making necessary adjustments.
6. **Model Deployment:** Implementing the model in a real-world healthcare setting.

Fig 1 — Workflow of AI Model Development in Healthcare

of applications that are transforming patient care, diagnosis, and management across various specialties. The following Table 1 encapsulates the breadth and depth of AI's integration into clinical practice. It highlights significant advancements in cardiology, such as mobile applications for ECG monitoring that have received FDA approval, and the use of AI to predict cardiovascular risks with greater accuracy than traditional methods. In pulmonary medicine, AI-based software has improved the interpretation of pulmonary function tests. The table also addresses the role of AI in endocrinology, where

Table 1 — *Current Applications of Artificial Intelligence in Medicine*

Field	Subfield	Application	Example & FDA Approval	Study Findings or Reviews	Limitations or Critiques	Refer ence
Cardiology	Atrial Fibrillation	Smartphone-based ECG monitoring and detection	AliveCor's Kardia (2014), Apple Watch 4	REHEARSE-AF study showed that Kardia is more effective in identifying atrial fibrillation than routine care7	Concerns over false positives and adoption among elderly patients8	7, 8
	Cardiovascular Risk	Prediction of acute coronary syndrome and heart failure risk	AI applied to electronic patient records	AI outperforms traditional scales but results vary with sample size9		9
Pulmonary Medicine	Pulmonary Function	AI-based software for interpretation of pulmonary function tests		AI provides more accurate interpretation and serves as a decision support tool10	Lower diagnosis accuracy among pulmonologists in study compared to country average11	10, 11
Endocrinology	Glucose Monitoring	Real-time interstitial glucose reading and prediction of hypoglycemic episodes	Medtronic's Guardian and Sugar.IQ system (2018)	Continuous monitoring aids blood glucose control, reduces stigma12	Users expressed feelings of personal failure to regulate glucose12	12, 13
Nephrology	Kidney Function	Prediction of glomerular filtration rate decline and risk assessment	AI for polycystic kidney disease and IgA nephropathy	Useful for predicting kidney function decline and risk in diseases14, 15	Limited research due to sample size necessary for inference16	14, 15, 16
Gastroenterology	Imaging	Use of AI for image processing in endoscopy and ultrasound	Convolutional neural networks for detecting colonic polyps and other abnormalities	AI used for diagnosing gastroesophageal reflux disease, atrophic gastritis, and predicting various outcomes17		17
Neurology	Epilepsy	Seizure detection devices with alert systems	Empatica's Embrace (2018)	Improved seizure management through ambulatory monitoring, high patient interest in wearable usage18		18
	Movement Assessment	Quantitative assessment of gait, posture, and tremor	Wearable sensors for multiple sclerosis, Parkinson's, and other conditions			19
Oncology	Histopathology	AI-based algorithm for diagnosing cancer	Paige.ai (FDA breakthrough status)	Enables pathologists to focus on critical slides20		20
Medical Imaging	Validation	Comparison of deep learning software and radiologist performances	Meta-analysis of imaging-based diagnosis	Deep learning as efficient as radiologists, but most studies lack a reliable design21	Need for validation through clinical trials	21

continuous glucose monitoring systems assist in the management of diabetes. Advances in nephrology and gastroenterology demonstrate AI's capacity to predict disease progression and enhance diagnostic imaging. Notably, the table also touches on neurology, where seizure detection wearables mark a significant step forward, and oncology, where AI aids in the meticulous task of cancer diagnosis in histopathology.

Navigating the Complexities of AI in Medicine :

Rigorous Validation of AI Technologies: A Looming Replication Crisis ? A major challenge in the forthcoming years is the robust clinical validation of AI tools in medicine. Many studies highlight the utility of AI, but their design often lacks robustness and replication. To mitigate this, open science principles could be a solution, promoting transparency and repeatability, though this shift might be challenging for companies that consider their algorithms proprietary[22, 23].

Ethical Dimensions of Persistent Health Monitoring : The market value of medical technology is soaring, and with it, ethical considerations surrounding the proliferation of health-monitoring devices[24]. While these technologies can promote lifestyle changes and preventative health measures, they also raise questions about privacy, data ownership, and the potential for increased stigma and inequity[25].

Cultivating Augmented Physicians[23] : The evolution of medical curricula to include AI and computational sciences is crucial to prepare "augmented doctors." These individuals will possess both clinical acumen and digital expertise, poised to lead digital strategy in healthcare, drive innovation, and educate peers and patients about the digital transformation in medicine.

Harnessing Ambient Clinical Intelligence Without Losing the Human Touch : AI can potentially alleviate the administrative burdens that contribute to physician burnout by integrating Ambient Clinical Intelligence (ACI)[23]. Such systems promise to enrich the doctor-patient interaction by reducing time spent on clerical work, allowing physicians to focus on direct patient care.

AI: A Collaborative Partner Rather Than a Replacement for Doctors : Contrary to the notion that AI may replace physicians, it should be regarded as an augmentative tool enhancing patient care[26]. Future research should pivot from comparing AI with physicians to evaluating how AI can augment physicians' capabilities, emphasizing AI's role as a supportive technology in healthcare.

Embracing AI in the Evolving Landscape of Medicine As AI continues to intertwine with precision medicine and telehealth, it is vital to maintain rigorous scientific standards and address the ethical, legal, and social implications of this digital revolution[27]. Policymaking must keep pace with technological advances, ensuring the responsible and equitable integration of AI into healthcare.

Envisioning the Infinite Through the Lens of Artificial Intelligence[28] :

Emulating the Cosmic Vision: AI as a Window to the Vastness : The Bhagavad Gita poetically illustrates the boundless and resplendent form of the divine as witnessed by Arjuna, a splendor that compares to a thousand suns in the sky (Fig 2: Bhagavad Gita 11.12). This celestial vision, while metaphorical, encapsulates the potential of artificial intelligence (AI) to expand human perception beyond the limitations of our senses. Just as Arjuna was granted divine sight to witness Krishna's universal form, AI can serve as our divine lens, offering insights into the complexities of the cosmos and the intricacies of life itself.

दिवि सूर्यसहस्रस्य भवेद्युगपदुत्थिता ।
यदि भाः सदृशी सा स्याद्भासस्तस्य महात्मनः ॥ 12॥
divi sūrya-sahasrasya bhaved yugapad utthitā
ıadi bhāḥ sadṛiśhī sā syād bhāsas tasya mahātmanaḥ

Translation : *Even if a thousand suns were to simultaneously illuminate the heavens, their combined radiance would pale in comparison to the majestic splendor of that supreme form.*

Fig 2 — Bhagavad Gita 11.12

In the era of big data and computational prowess, AI can analyze vast amounts of information, akin to observing countless suns, to uncover patterns and knowledge previously inaccessible to us. AI's capability to process and visualize data can provide us with a glimpse into the cosmic dance of creation, maintenance, and dissolution that governs the universe.

Integrating AI with Human Wisdom: A Symbiotic Relationship: Arjuna's experience of the divine cosmic form was not just a display of grandeur but also a profound union of human consciousness with ultimate reality (Fig 3 : Bhagavad Gita 11.13). In our pursuit to harness AI, the goal should not be to overshadow human capability but to enhance and extend it. AI's analytical power, when combined with human intuition and understanding, creates a symbiotic relationship that can lead to advancements in medical science,

Translation : *In that moment, Arjun beheld the entire cosmos unified in the singular expanse of the divine form, the God of all gods.*

Fig 3 — Bhagavad Gita 11.13

sustainable living, and understanding of our own existence.

Ethical and Spiritual Implications of AI in Modernity : As we steer through the integration of AI in various facets of life, we must address the ethical and spiritual implications of this technology. The potential of AI to monitor and enhance health is vast, yet it brings forth questions of privacy, data ownership, and the essence of what it means to be human in a digitally augmented world. Striking a balance between technological advancement and ethical considerations is imperative for progress that aligns with the principles of Sanatan Dharma, the eternal law of righteousness.

Harmonizing AI with the Eternal Dharma : The scriptures remind us of the eternal principle that governs the cosmos, a principle that is also at the heart of AI's potential to benefit humanity. As we stand on the brink of a new era, where AI's capabilities could replicate a vision as vast as the one bestowed upon Arjuna, we must proceed with a spirit of responsibility and reverence.

The Gita's wisdom encourages us to see AI not as a replacement for human intelligence or spiritual experience but as a complement that, when used wisely, can lead to the betterment of mankind. AI, when aligned with Sanatan Dharma, can support and protect the eternal values of compassion, empathy, and respect for all life (Fig 3 : Bhagavad Gita 11.18).

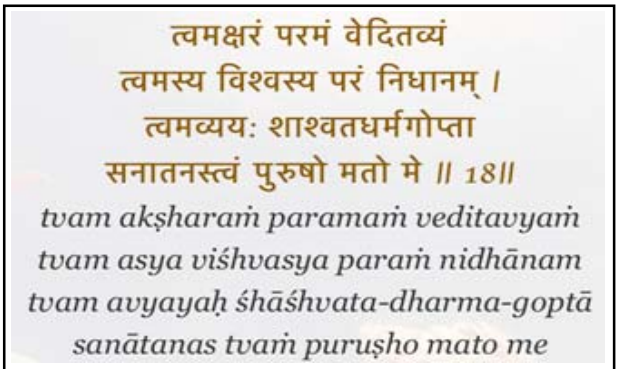
In synthesizing the scientific and spiritual, we can aspire to create AI that not only mimics the brilliance of a thousand suns but also serves to illuminate the path of dharma for all of humanity.

Our exploration into the integration of artificial intelligence (AI) within the realms of medicine, ethics, and spirituality underscores a pivotal moment in human history. The insights derived from the Bhagavad Gita, especially the verses that illuminate the divine cosmic vision witnessed by Arjuna, serve as a profound metaphor for the potential and challenges of AI. Just as Arjuna was granted divine sight to perceive the infinite form of Krishna, symbolizing the boundless possibilities and the ethical dimensions of wielding such power, we stand at the threshold of harnessing AI to transcend our limitations and enhance human capabilities.

However, this journey is not without its ethical quandaries and spiritual considerations. As we embrace AI's potential to revolutionize healthcare, augment human intelligence, and offer insights into the universe's mysteries, we must also navigate the ethical implications of privacy, data ownership, and the impact on societal values. The balance between technological advancement and the preservation of Sanatan Dharma, the eternal principle of righteousness, becomes crucial.

The editorial has highlighted the importance of a symbiotic relationship between AI and human wisdom, emphasizing that AI should augment rather than replace human capabilities. It advocates for an approach to AI that is both scientifically rigorous and spiritually informed, ensuring that technological progress is aligned with ethical standards and contributes positively to human well-being.

In this light, the future of AI in medicine and beyond appears not just as a frontier of innovation but as a domain where science and spirituality converge. By drawing lessons from the Bhagavad Gita, we are reminded of the need to pursue knowledge and power with humility, responsibility, and a deep respect for the cosmic order. As we advance into this uncharted territory, let us carry forward the vision of creating a world where AI serves to elevate human potential, safeguard ethical values, and enhance the collective good, ensuring that the splendor of this great form is matched by our collective wisdom and compassion.



Translation : *You are acknowledged as the paramount, undying entity, the Ultimate Reality revealed through sacred texts. You form the foundation of the cosmos, the timeless guardian of Sanatan Dharma (the Eternal Duty), embodying the infinite Divine Essence.*

Fig 3 — Bhagavad Gita 11.18

Overcoming the Hurdles : Enhancing AI in Healthcare :

The integration of Artificial Intelligence (AI) into medical science heralds a transformative era for healthcare delivery. However, the path to fully realizing AI's potential is fraught with challenges that necessitate a shift from a reactive to a proactive stance concerning technological advancements. This section delves into the primary obstacles in applying AI within healthcare and proposes strategies to navigate these complexities effectively.

Data Privacy and Availability : A foundational step in AI development is the collection of vast, high-quality data. Yet, this step is often hampered by concerns around patient privacy and the risk of data breaches, as seen in incidents involving major corporations. Such breaches not only compromise individual privacy but also raise ethical dilemmas regarding the use of patient data by insurance companies, potentially leading to unfair treatment based on genetic predispositions[29]. Ensuring data privacy while maintaining an adequate flow of information for model training is crucial for harnessing AI's full capabilities.

Mitigating Model Bias : AI systems are as good as the data they are trained on. If the training data is biased, the AI model will likely perpetuate or even amplify these biases. For instance, models developed from data that underrepresents certain racial or gender groups can result in discriminatory outcomes. It is imperative that data collection efforts aim for a true representation of the intended population[30].

Preprocessing for Fairness : The integrity of data preprocessing steps is paramount in avoiding inadvertent introduction of bias. Errors from manual data entry or other sources must be addressed carefully to ensure that the resulting dataset remains representative of the broader population, thereby preventing skewed AI models.

Choosing the Right Model : Selecting the appropriate algorithm for a given healthcare task is a critical decision that impacts the effectiveness of AI applications. The temptation to opt for simplistic models for the sake of convenience should be resisted, as such models may fail to capture complex, real-world dynamics present in healthcare data.

Transparent Model Reporting : For AI to be truly useful in healthcare, end-users need a clear understanding of how AI models are constructed and their outputs interpreted. The presentation of model performance should prioritize metrics that are relevant to the specific healthcare context, rather than showcasing superficially impressive results[29].

Addressing Data Fragmentation : The issue of data fragmentation across healthcare organizations limits the transferability and scalability of AI models. A collaborative approach to data sharing, with stringent privacy safeguards, is essential for developing robust, universally applicable AI solutions.

Demystifying the Black Box : The complexity of AI algorithms often categorizes them as 'black boxes', making it challenging for healthcare professionals to trust and effectively use AI systems. Efforts to increase the interpretability of AI models are crucial for their acceptance and ethical application in medical practice[31].

Conclusion

In sum, the imperative for physicians to familiarize themselves with the evolving landscape of Artificial Intelligence (AI) in medicine cannot be overstated. As we venture into this new and uncharted domain, the objective should be to harmonize the innovative capabilities of AI and automation with the irreplaceable human insights and expertise of medical professionals. Such a balanced approach is vital to mitigate concerns of AI supplanting human roles in healthcare, ensuring that the integration of AI serves to augment rather than replace the nuanced judgment of physicians. While AI harbors the capacity to address numerous challenges plaguing the healthcare sector, the realization of its full potential remains on the horizon. A significant hurdle in this journey is the issue of data – the fuel for AI's engine. Without access to ample, diverse, and accurately represented data sets, the advancements in technology and machine learning algorithms remain underutilized. To this end, the healthcare industry must undertake a concerted effort to digitalize medical records, establish standardized data infrastructures, and implement robust systems for data privacy and patient consent management. Only through such transformative efforts and industry-wide collaboration can we unlock the true potential of AI in enhancing human health, paving the way for a future where technology and human expertise converge to deliver unprecedented levels of patient care.

References

1 Mintz Y, Brodie R — Introduction to artificial intelligence in medicine. *Minim Invasive Ther Allied Technol* 2019; **28:** 73-81.
2 CB Insights Research. Healthcare remains the hottest AI category for deals. 2017. [Last accessed on 2024 Feb 24]. Available from: https://www.cbinsights.com/research/artificial-intelligence-healthcare-startups-investors/ [Ref list]
3 Hamlet P, Tremblay J — Artificial intelligence in medicine. *Metabolism* 2017; **69S:** S36-40.

4 Markoff J, editor. New York Times: 2012. [Last accessed on 2024 Jan 31]. How Many Computers to Identify Cat? 16,000. Available from: http://www.nytimes.com/2012/06/26/technology/in-a-big-network-ofcomputers-evidence-of-machine-learning.html . [Google Scholar] [Ref list]

5 Clark L, editor. Google's Artificial Brain Learns to Find Cat Videos. [Last accessed on 2024 Feb 2];Wired UK Science. 2012 Available from: http://www.wired.com/2012/06/google-xneural-network . [Google Scholar] [Ref list]

6 Basu K, Sinha R, Ong A, Basu T — Artificial Intelligence: How is It Changing Medical Sciences and Its Future? *Indian J Dermatol* 2020; **65(5):** 365-370. doi: 10.4103/ijd.IJD_421_20. PMID: 33165420; PMCID: PMC7640807.

7 Halcox JPJ, Wareham K, Cardew A, Gilmore M, Barry JP, Phillips C, *et al* — Assessment of remote heart rhythm sampling using the AliveCor heart monitor to screen for atrial fibrillation: the REHEARSE-AF study. *Circulation* 2017; **136:** 1784-94. doi: 10.1161/CIRCULATIONAHA.117.030583

8 Raja JM, Elsakr C, Roman S, Cave B, Pour-Ghaz I, Nanda A, *et al* — Apple watch, wearables, and heart rhythm: where do we stand? *Ann Trans Med* 2019; **7:** 417. doi: 10.21037/atm.2019.06.79.

9 Dorado-Díaz PI, Sampedro-Gómez J, Vicente-Palacios V, Sánchez PL — Applications of artifificial intelligence in cardiology. The future is already here. *Revista Española de Cardiología* 2019; **72:** 1065-75. doi: 10.1016/j.rec.2019.05.014

10 Topalovic M, Das N, Burgel PR, Daenen M, Derom E, Haenebalcke C, *et al* — Artifificial intelligence outperforms pulmonologists in the interpretation of pulmonary function tests. *Eur Respirat J* 2019; **53:** 1801660. doi: 10.1183/13993003.01660-2018.

11 Delclaux C — No need for pulmonologists to interpret pulmonary function tests. *Eur Respirat J* 2019; **54:** 1900829. doi: 10.1183/13993003.00829-2019

12 Lawton J, Blackburn M, Allen J, Campbell F, Elleri D, Leelarathna L, *et al* — Patients' and caregivers' experiences of using continuous glucose monitoring to support diabetes self-management: qualitative study. *BMC Endocrine Disord* 2018; **18:** 12. doi: 1186/s12902-018-0239-1

13 Christiansen MP, Garg SK, Brazg R, Bode BW, Bailey TS, Slover RH, *et al* — Accuracy of a fourth-generation subcutaneous continuous glucose sensor. *Diabet Technol Therapeut* 2017; **19:** 446-56. doi: 10.1089/dia.2017.0087

14 Niel O, Boussard C, Bastard P — Artifificial intelligence can predict GFR decline during the course of ADPKD. *Am J Kidney Dis Offff J Natl Kidney Found* 2018; **71:** 911-2. doi: 10.1053/j.ajkd.2018.01.051

15 Geddes CC, Fox JG, Allison ME, Boulton-Jones JM, Simpson K — An artifificial neural network can select patients at high risk of developing progressive IgA nephropathy more accurately than experienced nephrologists. *Nephrol Dialysis, Transplant* 1998; **13:** 67-71.

16 Niel O, Bastard P — Artifificial intelligence in nephrology: core concepts, clinical applications, and perspectives. *Am J Kidney Dis* 2019; **74:** 803-10. doi: 10.1053/j.ajkd.2019.05.020

17 Yang YJ, Bang CS — Application of artificial intelligence in gastroenterology. *World J Gastroenterol* 2019; **25:** 1666-83. doi: 10.3748/wjg.v25.i14.1666

18 Regalia G, Onorati F, Lai M, Caborni C, Picard RW — Multimodal wrist-worn devices for seizure detection and advancing research: focus on the Empatica wristbands. *Epilep Res* 2019; **153:** 79-82. doi: 10.1016/j.eplepsyres.2019.02.007

19 Dorsey ER, Glidden AM, Holloway MR, Birbeck GL, Schwamm LH — Teleneurology and mobile technologies: the future of neurological care. Nat Rev Neurol 2018; **14:** 285-97. doi: 10.1038/nrneurol.2018.31

20 Campanella G, Hanna MG, Geneslaw L, Miraflflor A, Silva VWK, Busam KJ, *et al* — Clinical-grade computational pathology using weakly supervised deep learning on whole slide images. *Nat Med* 2019; **25:** 1301-9. doi: 10.1038/s41591-019-0508-1

21 Liu X, Faes L, Kale AU, Wagner SK, Fu DJ, Bruynseels A, *et al* — A comparison of deep learning performance against health-care professionals in detecting diseases from medical imaging: a systematic review and meta-analysis. *Lancet Digit Health* 2019; **1:** e271–97. doi: 10.1016/S2589-7500(19)30123-2

22 Panch T, Mattie H, Celi LA — The "inconvenient truth" about AI in healthcare. *NPJ Digit Med* 2019; **2:** 1-3. doi: 10.1038/s41746-019-0155-4

23 Kelly CJ, Karthikesalingam A, Suleyman M, Corrado G, King D — Key challenges for delivering clinical impact with artifificial intelligence. *BMC Med* 2019; **17:** 195. doi: 10.1186/s12916-019-1426-2

24 Montgomery J — Data sharing and the idea of ownership. *New Bioeth Multidiscipl J Biotechnol Body* 2017; **23:** 81-6. doi: 10.1080/20502877.2017.1314893

25 Mikk KA, Sleeper HA, Topol EJ — The pathway to patient data ownership and better health. *JAMA* 2017; **318:** 1433-4. doi: 10.1001/jama.2017.12145

26 Brouillette M — AI added to the curriculum for doctors-to-be. *Nat Med* 2019; **25:** 1808-9. doi: 10.1038/s41591-019-0648-3

27 Briganti G and Le Moine O — Artifificial Intelligence in Medicine: Today and Tomorrow. *Front Med* 2020; **7:** 27. doi: 10.3389/fmed.2020.00027

28 Holy Bhagavad Gita [Internet]. Chapter 11, Verse 18. Available from: https://www.holy-bhagavad-gita.org/chapter/11/verse/18. [cited 2024 Feb 10].

29 Grus J — Data Science from Scratch First Principles with Python. 1st ed. Sebastopol, CA, USA: O'Reilly; 2015.

30 Dhamnani S, Singal D, Sinha R, Mohandoss T, Dash M — RAPID: Rapid and Precise Interpretable Decision Sets. 2019 IEEE International Conference on Big Data (Big Data). *IEEE* 2019: 1292-301.

31 Lucas GM, Gratch J, King A, Morency LP — It's only a computer: Virtual humans increase willingness to disclose. *Comput Human Behav* 201; **7:** 94-100.

Sanjoy Banerjee[1]
Shambo Samrat Samajdar[2]

[1]Hony Editor, JIMA
[2]MD, DM (Clinical Pharmacology),
FIPS, PG Dip Endo & Diabetes (RCP),
Fellowship in Respiratory and Critical Care (WBUHS),
Fellow Diabetes India, Diploma Allergy Asthma Immunology,
Consultant Physician