

## NARRATIVE REVIEW

## A comprehensive exploration of artificial intelligence in orthopaedics within lower-middle-income countries: a narrative review

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### Abstract

Integrating Artificial Intelligence (AI) in orthopaedic within lower-middle-income countries (LMICs) promises landmark improvement in patient care. Delving into specific use cases—fracture detection, spine imaging, bone tumour classification, and joint surgery optimisation—the review illuminates the areas where AI can significantly enhance orthopaedic practices. AI could play a pivotal role in improving diagnoses, enabling early detection, and ultimately enhancing patient outcomes—crucial in regions with constrained healthcare services. Challenges to the integration of AI include financial constraints, shortage of skilled professionals, data limitations, and cultural and ethical considerations. Emphasising AI's collaborative role, it can act as a complementary tool working in tandem with physicians, aiming to address gaps in healthcare access and education. We need continued research and a conscientious approach, envisioning AI as a catalyst for equitable, efficient, and accessible orthopaedic healthcare for patients in LMICs.

**Keywords:** Artificial Intelligence, Orthopaedics, Health Services, Patient Care, Bone Neoplasms, Physicians, precision medicine; predictive analysis

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### Introduction

Artificial intelligence (AI) is the science of using algorithms to replicate cognitive processes of a human brain, such as problem-solving and knowledge application. Under the umbrella of AI, machine learning

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(ML), deep learning, and natural language processing (NLP) are particularly useful in healthcare.<sup>1</sup> ML is a statistical method used to create models based on available data. ML is particularly helpful in precision medicine as it can collate information from multiple sources and suggest the most suitable treatment for the patient based on individual context. Instead of being explicitly programmed to perform a task, ML systems use data to improve their performance over time. The most complex form of ML is represented by deep learning, which involves neural networks with numerous layers of features to extract and process data to predict outcomes.<sup>2</sup> NLP interprets human language and can be used for speech recognition, message understanding, and translation.<sup>3</sup>

AI has a broad range of applications in the healthcare system, ranging from processing genetic information to scheduling appointments, reading radiographs, and analysing big data. Although AI is expensive to implement in resource-limited settings, a lot of work is being done on the use of AI in Asia and Africa. This review aims to highlight the opportunities for successfully integrating AI into orthopaedics in lower-middle-income countries (LMICs) and understand the factors behind its current lag in implementation.

### Methods

For this review, we searched through articles in the English language from PUBMED, Scopus, Science Direct, and Google Scholar, along with reports from notable organizations such as the World Health Organization. There were no restrictions based on the dates of publication or type of AI. All relevant studies addressing the use of AI in Orthopaedics and/or LMICs were included in the review. There were no strict exclusion criteria, and applicable information from all the eligible articles was synthesized in this review. The articles were collected, and the review was written from October to November 2023. All articles published at the time of writing (November 2023) were included. The review was primarily done at the Aga Khan University, Karachi, Pakistan. LMICs were defined based on the World Bank's income classification.<sup>4</sup>

The review was done in collaboration at Aga Khan University, Karachi, Pakistan, Dow University of Health Sciences, Karachi, Pakistan, and University of California Davis Health, Sacramento, California, USA.

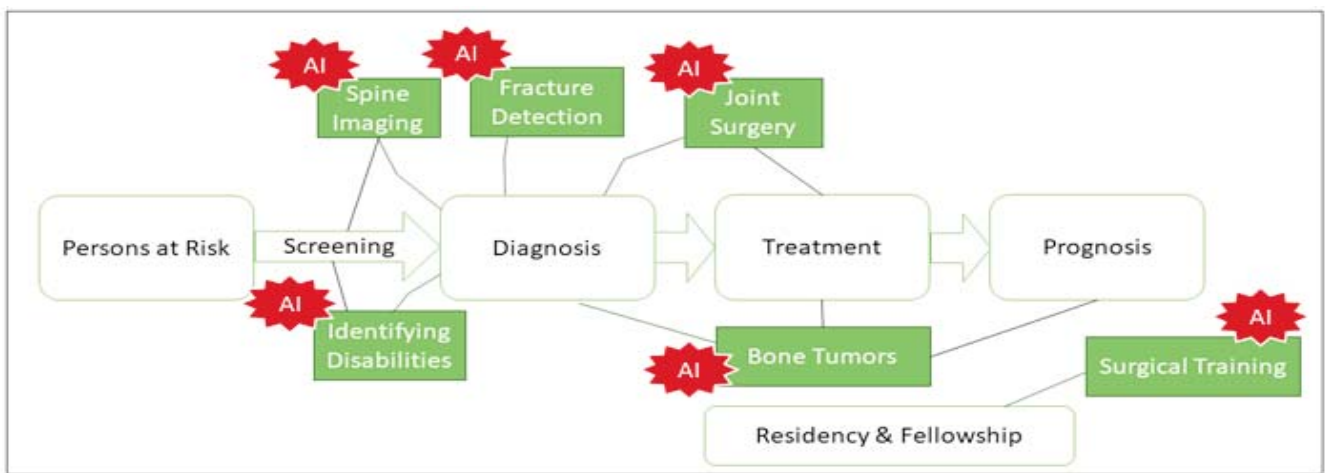
**AI for Orthopaedics in LMICs**

AI, although currently very expensive and developed for high-income countries, is a promising transformative healthcare solution for LMICs in the long term. In Pakistan, a mere 11.3% of medical students and doctors had practical experience with AI in 2022.<sup>5</sup> In contrast, India showcases a more active embracement of AI across diverse healthcare domains, including medical imaging, surgical robot management, wearable sensors, and virtual

assistants.<sup>6</sup> In Orthopaedics, AI can be used in LMICs for fracture detection, musculoskeletal imaging, joint surgery, implant modelling, surgical training, scribes, and identifying disabilities. (Figure and Table)

**Fracture Detection**

Studies report that AI performance in fracture detection is at par with clinicians, with the difference in pooled sensitivity and specificity for humans and recognising fractures from x-rays and computed tomography (CT) scans reported to be statistically insignificant.<sup>7</sup> When aided by AI, clinicians have a 10.4% higher sensitivity and a 6.3-second reduction in time to detect fracture.<sup>8</sup> Current AI models for fracture detection have shown promising



**Figure:** Use of AI in Clinical Pathway of Orthopaedics in LMICs.

**Table:** Review at a Glance: AI in Orthopaedics in LMICs.

**AI Applications in Orthopaedics**

**Fracture Detection:** Promising results in improving sensitivity and reducing detection time. Crucial in emergency trauma cases, enhancing patient outcomes and relieving workloads.

**Spine Imaging:** Assistance in reading radiology scans for spinal imaging with higher accuracy in identifying abnormalities.

**Bone Tumours:** Diagnosing benign versus malignant tumours, offering personalised treatment plans. Aids in therapeutic planning, guiding biopsies, and predicting treatment responses

**Joint Surgery:** Improving accuracy and personalisation of surgical planning. AI models also show proficiency in identifying and classifying orthopaedic implant models, providing valuable support in revision surgeries.

**Identifying Disabilities:** Potential in identifying various neuro-muscular disorders, augmenting diagnostic processes compared to traditional clinical data. Applications in classifying disorders and gene cluster identification.

**Surgical Training:** Remote surgical training, particularly beneficial in inaccessible locations, improving the quality of care. Simulation-based training and three-dimensional presurgical planning.

**Challenges**

**Financial Constraints:** High cost of AI technologies  
**Shortage of Skilled Professionals:** Scarcity of proficient AI professionals  
**Data Limitations:** Limited and unstructured healthcare data  
**Cultural and Ethical Considerations:** Patient privacy, consent, data safety

**Future Prospects**

**Enhanced Orthopaedic Care:** Improved diagnoses and early detection  
**Multidisciplinary Approach:** Cost reductions, risk detection, and treatment prediction  
**Training Healthcare Professionals:** Bridging the skills gap, self-sufficiency in medical expertise.

AI: Artificial Intelligence

results as an adjunct to clinicians, but we still need more data and fine-tuning before they can be used with minimal input from a clinician.

This support is crucial to physicians working in LMICs, especially those who are attending to emergency trauma patients. The reduced time and increased accuracy can lead to improved patient outcomes and relieve the workload in busy emergency rooms of public hospitals, which could save lives. This would be particularly important for triage in disaster management, for example after an earthquake.

### Spine Imaging

Reading radiology scans accurately and timely is a challenge in public sector hospitals in LMICs due to the shortage of radiologists. AI offers a practical solution to reduce time and improve the accuracy of radiology reports. D'Antoni et al.<sup>9</sup> have evaluated the role of AI in spinal imaging, particularly addressing lower back pain. Interobserver variability in reading Magnetic Resonance Imaging (MRI) for disc abnormality is reported at around 50%,<sup>10</sup> while AI is reported to be accurate by up to 80%.<sup>11</sup> A notable example from Vietnam showcases the application of machine learning to predict the risk of osteoporosis in women over 50 years of age.<sup>12</sup> The study not only underscores the feasibility of utilising machine learning in LMICs but also highlights the competitive performance of the models developed with a precision score greater than 0.55, outperforming the reference models. These contrasting experiences emphasise the importance of context-specific considerations, data availability, and technical expertise in shaping the current state of AI implementation in healthcare across LMICs.

### Bone Tumours

Multidisciplinary oncological care and expertise are major challenges in LMICs, and AI can provide solutions that can be implemented across multiple centres. Hence, patients presenting to centres with low expertise and lacking interdisciplinary care could also be treated using AI's access to the latest knowledge to make personalised oncological treatment plans for each patient.

Ong et al.<sup>13</sup> advocates for the proficiency of AI-based radiomics in diagnosing benign versus malignant tumours. The study reported AI having a sensitivity of 0.63-1.00 and a specificity of 0.73-0.96 when compared with the gold standard (histopathology) for differentiating between various types of tumours such as benign, malignant, metastatic, and multiple myeloma. The Area Under Curve (AUC) was reported at 0.73 - 0.96, which is interpreted as good-to-excellent in differentiating benign versus malignant lesions. Apart from diagnosis, these models also assist in therapeutic

planning, especially neoadjuvant chemotherapy, guiding biopsies, classifying tumours, and predicting treatment responses,<sup>14</sup> leading to improved holistic management of musculoskeletal tumours.<sup>13</sup> AI's diagnostic accuracy for classifying tumours was significantly higher than that of four doctors (0.853 vs. 0.794).<sup>14</sup>

### Joint Surgery

In the domain of joint surgery, Magan et al.<sup>15</sup> posit that integrating AI into surgical planning can improve accuracy and personalized surgical plans, yielding improved results after knee arthroplasty. Additionally, Klontzas et al.<sup>16</sup> demonstrated the efficacy of AI in predicting factors associated with severe early joint space narrowing. This study reported achieving an area under the curve of 69.9% in predicting severe joint space narrowing based on age and anatomical hip parameters.

Accurate identification of implants is important in the preoperative planning of revision surgeries. In the realm of implant models, insights from a systematic review by Ren et al.<sup>17</sup> underscore the proficiency of AI in classifying orthopaedic implant models from radiographs with an overall accuracy of 0.804 to 1.0. Notably, when pitted against the expertise of three surgeons, the AI model demonstrated a similar level of accuracy in performance. Another study by Patel et al.<sup>18</sup> highlighted that the AI model for orthopaedic implant identification performed superior to five orthopaedic specialists with an accuracy of 98.9% vs. 76.1%. Karnuta et al.<sup>19</sup> demonstrated that their deep learning system was able to discriminate between 9 implant models with an accuracy of 97.4% and classify the models at a speed of 0.02 seconds per image.

### Identifying Disabilities

Furthermore, in the realm of identifying disabilities, a cross-sectional study by Takahashi et al.<sup>20</sup> reported the capability of AI to identify individuals with locomotive syndrome, showcasing its potential to augment diagnostic processes compared to traditional clinical data. Pineros-Fernandez et al.<sup>21</sup> noted high precision across various AI applications in classifying neuromuscular disorders using muscle magnetic resonance with precision ranging from 88 to 99%. Furthermore, Tran et al.<sup>22</sup> developed a model to identify gene clusters in different muscle diseases and noted an accuracy of 90% in classifying hereditary myopathies. These findings highlight the diverse applications of AI across various facets of neuromuscular disorders, promising advancements in diagnostics, education, and healthcare efficiency.

### Surgical Training

Satopathy et al.<sup>23</sup> highlight the use of AI in providing

remote surgical training to those in inaccessible locations which can increase the quality of care. St. Mart et al.<sup>24</sup> advocated for the transformative potential of AI in orthopaedic education, particularly in the domain of surgical training. The integration of AI promises to revolutionise the learning experience for orthopaedic practitioners with the help of simulation-based training and employing a didactic approach.<sup>25</sup> Multiple AI-enabled visualisation devices can offer three-dimensional presurgical planning and surgical simulation.<sup>26</sup>

### Challenges to using AI in Orthopaedics in LMICs

There would continue to remain a stark disparity between the quality of healthcare being provided in LMICs and high-income countries, with LMICs lacking resources, adequate training of doctors, strong organisational structure, and financial protection to patients. Within LMICs, countries such as India, Iran, Pakistan, and Egypt are already leading in the development and implementation of ML. Although many of these projects are not very robust, lack appropriate validation, and are trained on smaller sets of data,<sup>27</sup> but it is a good starting point. The challenges to incorporating AI in orthopaedics in LMICs can be broadly classified into financial constraints, shortage of skilled professionals, data limitations, concerns among patients and healthcare providers, and cultural and ethical considerations.

### Financial Constraints

The confluence of advanced medical technologies and financial implications underscores the need for a balanced approach—one that harnesses the transformative power of AI while mitigating the risk of widening socioeconomic gaps in healthcare accessibility. The financial burden associated with AI technologies presents a significant hurdle in introducing them in LMICs. While relatively more affordable or even free AI tools like ChatGPT exist, they may lack the computational capabilities and purpose-built functionality of their pricier counterparts. The specialized hardware and software required for the implementation of AI in medical settings, along with reliable access to high-speed internet amplifies the financial strain, especially in rural healthcare settings where such resources may be most revolutionary. Beyond the cost of installation, infrastructure maintenance, and staff training are significant financial considerations that need to be addressed.

Overcoming these financial constraints requires strategic planning, international collaborations, and innovative solutions to ensure that the benefits of AI in orthopaedics are accessible to all, irrespective of economic disparities. A silver lining to the issue of highly-priced AI tools is that new technology is usually very expensive at first but as it

becomes more widely available, cheaper variants are obtainable. However, with continued improvement and efficient incorporation of AI, the estimated cost saved per day can go up to \$17,881 per day per hospital, in the US.<sup>28</sup>

### Shortage of Skilled Professionals

The integration of AI in orthopaedics necessitates a comprehensive training programme for orthopaedic professionals and associated healthcare teams to effectively feed data and utilize information provided by the AI. Similarly, quality assurance and technical support teams require specialised training. However, the scarcity of proficient AI professionals in LMICs poses a significant obstacle, making the recruitment and retention of skilled personnel a formidable financial and logistical challenge. For example, 92% of Pakistanis claim to have never used a desktop, laptop, or tablet.<sup>29</sup> However, the groundwork to increase the number of AI professionals has been initiated by a few LMICs.<sup>30</sup>

### Data Limitations

Theoretically, more healthcare data should be available in LMICs<sup>31</sup> due to larger populations, but a major problem is the lack of usable large-scale patient record databases.<sup>32</sup> Most hospitals either completely lack documentation or do not have a robust and reliable central repository.<sup>33</sup> Moreover, experts have cautioned against the use of large secondary datasets for model development due to the potential introduction of hidden biases. Consequently, the extensive and diverse datasets crucial for training AI algorithms remain elusive. While models trained in other countries may be considered, they fall short in providing context-specific insights tailored to the unique characteristics of the Pakistani population. This data gap extends to other LMICs, further complicating the effective implementation of AI in orthopaedic healthcare.

The multifaceted nature of orthopaedic diagnoses requires data from various sources, including X-rays, MRIs, CT scans, and clinical examinations. Clinical examinations are crucial in diagnoses but there is limited evidence of AI performing clinical examinations in orthopaedics. A study assessing the competency of general practitioners in Pakistan revealed a concerning trend—most lacked structured training and exhibited gaps in knowledge and skills.<sup>34</sup> Given that general practitioners often serve as the first point of contact for musculoskeletal complaints and often interpret X-rays and splints, the data contributed by them for training AI models may carry inherent flaws. Moreover, the need to include intricate and complex anatomical structures poses a formidable challenge in developing highly specific Orthopaedic AI algorithms. Ensuring these algorithms can adapt to the variations in human anatomy from individual to individual, while

accommodating for differences in judgements of different clinicians, further compounds the intricacy of the task. This is particularly important for diseases not prevalent in developed countries, such as tuberculosis of the bone and joints.

### Cultural and Ethical Considerations

The incorporation of AI into healthcare demands careful consideration of cultural and ethical norms. According to Bicer et al.,<sup>35</sup> patient privacy, consent, data safety, data monitoring, bias, and accountability are some of the ethical concerns surrounding the use of AI in orthopaedic practice. The potential for breaches in patient data and privacy through cybercrime activities, such as hacking, introduces significant concerns. There may also be ethical concerns surrounding the risk of overreliance on AI, potentially diminishing the use of clinical judgment and human intuition.

AI algorithms must be attuned to patient preferences and comfort levels, with the ultimate decision-making authority resting in the hands of the physician. To navigate accountability-related issues, physicians must take the lead in handling cases, with AI providing input. The delicate balance between harnessing the benefits of AI and upholding cultural and ethical values underscores the need for meticulous attention and thoughtful implementation in healthcare systems. As AI integrates further into the healthcare system, balancing clinicians' astute and knowledge as opposed to AI's suggestions might also be challenging, particularly in medico-legal cases.

### Future Prospects

Despite the myriad challenges, the pursuit of the benefits and precision offered by AI models in orthopaedics remains a worthwhile endeavor. AI stands as a beacon for enhanced orthopaedic care in LMICs, promising improved diagnoses and early detection of conditions. Timely intervention facilitated by AI can lead to significantly improved outcomes, particularly in regions where access to healthcare services is limited.

The long-term impact of AI extends to possible cost reductions in treatment. By providing accurate diagnoses and treatment plans, AI minimizes the need for secondary opinions, thereby streamlining the decision-making process. Its multidisciplinary approach further reduces the necessity for various specialties in a single case. Additionally, risk detection and treatment prediction contribute to a substantial reduction in financial burdens associated with complications and adverse events. This, in turn, allows for targeted interventions and efficient resource allocation.

AI applications, including virtual reality simulations, emerge as valuable tools in training healthcare professionals in orthopaedics. This not only enhances the skills of local doctors but also lessens the reliance on opinions from professionals in developed countries. By bridging the skills gap, AI becomes a catalyst for self-sufficiency in medical expertise within LMICs.

### Limitations

This review must be read considering its limitations. The absence of a systematic literature search, limiting to English language articles, and not assessing risk of bias of the included literature may introduce an element of subjectivity. Future studies should focus on implementing AI tools in LMIC healthcare, to provide a better picture of the opportunities and challenges in this area

### Conclusion

This narrative review offers an exploration of the multifaceted landscape surrounding the implementation of AI in orthopaedics in LMICs. Despite the resource constraints faced by LMICs, the substantial efforts required for AI integration prove to be a valuable investment, given the myriad benefits it can yield. However, acknowledging the inherent limitations stemming from data availability challenges and varying opinions among healthcare professionals and patients, a judicious approach is warranted. AI, rather than standing alone, should be viewed as a complementary tool, working in tandem with the insights and expertise provided by physicians. This collaborative approach ensures a nuanced and balanced integration of AI into the orthopaedic healthcare landscape of LMICs.

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### References

- Davenport T, Kalakota R. The potential for artificial intelligence in healthcare. *Future Healthc J* 2019;6:94-8. doi: 10.7861/futurehosp.6-2-94
- Pettit RW, Fullem R, Cheng C, Amos CI. Artificial intelligence, machine learning, and deep learning for clinical outcome prediction. *Emerg Top Life Sci* 2021;5:729-45. doi: 10.1042/ETLS20210246. [ahead of print]
- Joshi AK. Natural language processing. *Science* 1991;253:1242-9. doi: 10.1126/science.253.5025.1242
- The World Bank. The World by Income and Region. [Online] 2022 [Cited 2023 November 20]. Available from URL: <https://datatopics.worldbank.org/world-development-indicators/the-world-by-income-and-region.html>
- Ahmed Z, Bhinder KK, Tariq A, Tahir MJ, Mehmood Q, Tabassum MS, et al. Knowledge, attitude, and practice of artificial

- intelligence among doctors and medical students in Pakistan: A cross-sectional online survey. *Ann Med Surg (Lond)* 2022;76:e103493. doi: 10.1016/j.amsu.2022.103493
6. Stanly M. AI in Indian healthcare sector: Promises and challenges. [Online] 2023 [Cited 2023 November 20]. Available from URL: <https://indiaai.gov.in/article/ai-in-indian-healthcare-sector-promises-and-challenges>
  7. Kuo RYL, Harrison C, Curran TA, Jones B, Freethy A, Cussons D, et al. Artificial Intelligence in Fracture Detection: A Systematic Review and Meta-Analysis. *Radiology* 2022;304:50-62. doi: 10.1148/radiol.211785
  8. Guermazi A, Tannoury C, Kompel AJ, Murakami AM, Ducarouge A, Gillibert A, et al. Improving Radiographic Fracture Recognition Performance and Efficiency Using Artificial Intelligence. *Radiology* 2022;302:627-36. doi: 10.1148/radiol.210937
  9. D'Antoni F, Russo F, Ambrosio L, Bacco L, Vollero L, Vadalà G, et al. Artificial Intelligence and Computer Aided Diagnosis in Chronic Low Back Pain: A Systematic Review. *Int J Environ Res Public Health* 2022;19:5971. doi: 10.3390/ijerph19105971
  10. Alomari RS, Corso JJ, Chaudhary V, Dhillion G. Lumbar Spine Disc Herniation Diagnosis with a Joint Shape Model. In: Yao J, Klinder T, Li S, eds. *Computational Methods and Clinical Applications for Spine Imaging*. Lecture Notes in Computational Vision and Biomechanics, vol 17. Cham, Switzerland: Springer International Publishing Switzerland, 2014; pp 87-98. Doi: 10.1007/978-3-319-07269-2\_8.
  11. Joshi RS, Lau D, Ames CP. Artificial intelligence for adult spinal deformity: current state and future directions. *Spine J* 2021;21:1626-34. doi: 10.1016/j.spinee.2021.04.019
  12. Bui HM, Ha MH, Pham HG, Dao TP, Nguyen TT, Nguyen ML, et al. Predicting the risk of osteoporosis in older Vietnamese women using machine learning approaches. *Sci Rep* 2022;12:20160. doi: 10.1038/s41598-022-24181-x
  13. Ong W, Zhu L, Tan YL, Teo EC, Tan JH, Kumar N, et al. Application of Machine Learning for Differentiating Bone Malignancy on Imaging: A Systematic Review. *Cancers (Basel)* 2023;15:1837. doi: 10.3390/cancers15061837
  14. Park CW, Oh SJ, Kim KS, Jang MC, Kim IS, Lee YK, et al. Artificial intelligence-based classification of bone tumors in the proximal femur on plain radiographs: System development and validation. *PLoS One* 2022;17:e0264140. doi: 10.1371/journal.pone.0264140
  15. Magan AA, Kayani B, Chang JS, Roussot M, Moriarty P, Haddad FS. Artificial intelligence and surgical innovation: lower limb arthroplasty. *Br J Hosp Med (Lond)* 2020;81:1-7. doi: 10.12968/hmed.2020.0309
  16. Klontzas ME, Volitakis E, Aydingöz Ü, Chlapoutakis K, Karantanas AH. Machine learning identifies factors related to early joint space narrowing in dysplastic and non-dysplastic hips. *Eur Radiol* 2022;32:542-50. doi: 10.1007/s00330-021-08070-x
  17. Ren M, Yi PH. Artificial intelligence in orthopedic implant model classification: a systematic review. *Skeletal Radiol* 2022;51:407-16. doi: 10.1007/s00256-021-03884-8
  18. Patel R, Thong EHE, Batta V, Bharath AA, Francis D, Howard J. Automated Identification of Orthopedic Implants on Radiographs Using Deep Learning. *Radiol Artif Intell* 2021;3:e200183. doi: 10.1148/ryai.2021200183
  19. Karnuta JM, Shaikh HJF, Murphy MP, Brown NM, Pearle AD, Nawabi DH, et al. Artificial Intelligence for Automated Implant Identification in Knee Arthroplasty: A Multicenter External Validation Study Exceeding 3.5 Million Plain Radiographs. *J Arthroplasty* 2023;38:2004-8. doi: 10.1016/j.arth.2023.03.039
  20. Takahashi S, Nonomiya Y, Terai H, Hoshino M, Ohyama S, Shintani A, et al. Artificial intelligence model to identify elderly patients with locomotive syndrome: A cross-section study. *J Orthop Sci* 2023;28:656-61. doi: 10.1016/j.jos.2022.01.010
  21. Piñeros-Fernández MC. Artificial Intelligence Applications in the Diagnosis of Neuromuscular Diseases: A Narrative Review. *Cureus* 2023;15:e48458. doi: 10.7759/cureus.48458
  22. Tran A, Walsh CJ, Batt J, Dos Santos CC, Hu P. A machine learning-based clinical tool for diagnosing myopathy using multi-cohort microarray expression profiles. *J Transl Med* 2020;18:454. doi: 10.1186/s12967-020-02630-3
  23. Satapathy P, Hermis AH, Rustagi S, Pradhan KB, Padhi BK, Sah R. Artificial intelligence in surgical education and training: opportunities, challenges, and ethical considerations - correspondence. *Int J Surg* 2023;109:1543-4. doi: 10.1097/JS9.0000000000000387
  24. St Mart JP, Goh EL, Liew I, Shah Z, Sinha J. Artificial intelligence in orthopaedics surgery: transforming technological innovation in patient care and surgical training. *Postgrad Med J* 2023;99:687-94. doi: 10.1136/postgradmedj-2022-141596
  25. Varas J, Coronel BV, Villagrán I, Escalona G, Hernandez R, Schuit G, et al. Innovations in surgical training: exploring the role of artificial intelligence and large language models (LLM). *Rev Col Bras Cir* 2023;50:e20233605. doi: 10.1590/0100-6991e-20233605-en
  26. Park JJ, Tiefenbach J, Demetriades AK. The role of artificial intelligence in surgical simulation. *Front Med Technol* 2022;4:e1076755. doi: 10.3389/fmedt.2022.1076755
  27. Adeoye J, Akinshipo A, Koohi-Moghadam M, Thomson P, Su YX. Construction of machine learning-based models for cancer outcomes in low and lower-middle income countries: A scoping review. *Front Oncol* 2022;12:e976168. doi: 10.3389/fonc.2022.976168
  28. Khanna NN, Mairdarkar MA, Viswanathan V, Fernandes JFE, Paul S, Bhagawati M, et al. Economics of Artificial Intelligence in Healthcare: Diagnosis vs. Treatment. *Healthcare (Basel)* 2022;10:2493. doi: 10.3390/healthcare10122493.
  29. Gallup Pakistan. Pakistan's Foremost Research Lab. [Online] 2023 [Cited 2023 November 20]. Available from URL: <https://gallup.com.pk/>
  30. The Nation. 100,000 graduates to be given AI training in next 5 years. News release. The Nation Media Centre. [Online] 2023 [Cited 2023 November 20]. Available from URL: <https://www.nation.com.pk/27-May-2023/100-000-graduates-to-be-given-ai-training-in-next-5-years>
  31. Finnegan A, Potenziani DD, Karutu C, Wanyana I, Matsiko N, Elahi C, et al. Deploying machine learning with messy, real world data in low- and middle-income countries: Developing a global health use case. *Front Big Data* 2022;5:e553673. doi: 10.3389/fdata.2022.553673
  32. Chanh HQ, Ming DK, Nguyen QH, Duc TM, Phuoc An L, Trieu HT, et al. Applying artificial intelligence and digital health technologies, Viet Nam. *Bull World Health Organ* 2023;101:487-92. doi: 10.2471/BLT.22.289423
  33. Anamta R. Impact of electronic medical records in improving the quality of healthcare services provided in Pakistan hospitals. *Baqai J Health Sci* 2015;18:16-20.
  34. Farazdaq H, Gilani JA, Qureshi A, Khan UI. Needs assessment of

general practitioners in Pakistan: A descriptive cross-sectional survey. *J Family Med Prim Care* 2022;11:7664-70. doi: 10.4103/jfmpc.jfmpc\_1167\_22

35. Kaya Bicer E, Fangerau H, Sur H. Artificial intelligence use in orthopedics: an ethical point of view. *EFORT Open Rev* 2023;8:592-6. doi: 10.1530/EOR-23-0083

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