

Bioethical challenges in the integration of artificial intelligence in transplant surgery 4.0: A scoping review

Nicolás Lozano-Suarez¹ , Julia Andrea Gomez-Montero¹ , Maritza Jiménez-Gómez¹ , Santiago Cabas¹ , Nicolás Giron-Londoño² , Andrea García-López¹ , and Fernando Giron-Luque^{1,3}

Abstract

Introduction: The integration of artificial intelligence (AI) into transplant surgery offers potential benefits, including enhanced precision and personalized patient care. However, these advancements raise critical ethical issues that must be addressed to ensure responsible implementation. This scoping review and bibliometric analysis explore the literature on the ethical considerations associated with the application of AI in transplant surgery.

Methods: Following Joanna Briggs Institute and PRISMA-ScR guidelines, we conducted a systematic search of databases, including PubMed, Scopus, Science Direct, JSTOR, LILACS, IEEE, and GreyNet from 2013 to 2025. We identified articles that discussed ethical implications in English or Spanish. Data were charted using *Rayyan* (Rayyan Systems Inc., Doha, Qatar) and analyzed with *Biblioshiny*. One reviewer reviewed each article twice to ensure accuracy.

Results: Our search identified 6824 records, of which 16 studies met the selection criteria. The bibliometric analysis revealed a significant increase in scholarly output on AI ethics in transplantation since 2020. Key ethical concerns comprehend dehumanization of medical care, limitations in AI interpretability, and erroneous decision-making. The potential benefits highlighted include improved donor-recipient matching and personalized patient care. However, the need for human oversight in AI applications is emphasized mitigating risks such as patient dehumanization and biased decision-making.

Conclusion: This review is the first to comprehensively map the ethical landscape of AI integration in transplant surgery. It identifies both the potential and the significant ethical challenges of these technologies. Future research should focus on developing frameworks for ethical AI implementation and ensuring that advancements in AI contribute to equitable and just healthcare practices.

Keywords

Medical ethics, transplantation, artificial intelligence, operative surgical procedures, machine learning

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Introduction

The ongoing advancement of scientific knowledge and the introduction of novel technologies have significantly impacted the field of medicine.¹ Among these innovations, artificial intelligence (AI) has emerged as a pivotal development, influencing both daily clinical practice in surgery and the publication of scientific evidence on the subject.² AI potential in medicine is immense, providing advanced diagnostic tools, personalized treatment plans, and enhanced patient outcomes using predictive analytics and machine learning algorithms.³ The integration of AI promises to revolutionize various medical fields, including surgery and transplantation, by increasing efficiency, accuracy, and the overall quality of care.⁴

Despite the significant benefits that AI brings to health-care, its application raises several ethical and social concerns. Issues such as data privacy, algorithmic bias, and the

¹Department of Transplant Research, Colombiana de Trasplantes, Bogotá, Colombia

²Faculty of Medicine, Universidad del Rosario, Bogotá, Colombia

³Department of Transplant Surgery, Colombiana de Trasplantes, Bogotá, Colombia

Corresponding author:

Andrea García-Lopez, Department of Transplant Research, Colombiana de Trasplantes, Av Carrera, 30 No. 47 A-74, Bogotá, Colombia.
Email: aegarcia@colombianadetrasplantes.com



transparency of AI decision-making processes are critical areas of concern.⁵ These ethical dilemmas have profound implications for patient trust, informed consent, and the equitable distribution of medical resources.⁶ Addressing these concerns is essential to ensure the responsible and ethical use of AI in healthcare settings, preventing potential misuse and ensuring that the benefits are accessible to all patients.⁷

In the field of transplantation, the incorporation of AI has been progressively expanding, yielding significant influences on aspects such as donor-recipient matching, surgical strategizing, and postoperative care.^{3,4,8} However, the implementation of AI in transplantation also presents distinct challenges. These encompass the requirement for high-quality data, the risk of algorithmic inaccuracies, and the ethical implications of automated decision-making.^{5,9} Despite its growing use, comprehensive studies on the ethical aspects of AI in transplantation are lacking.^{1,10} This gap highlights the need for further research to ensure the ethical and effective integration of AI in transplantation. The aim of this study is to identify and analyze the ethical considerations and dilemmas associated with AI in transplant surgery.

Methodology

Study design

A scoping review and bibliometric analysis were conducted. The review mapped and categorized the existing literature, identifying prevalent themes and gaps in the current understanding of medical ethics issues in transplantation. This article followed the recommendations of the Joanna Briggs Institute for Scoping Reviews¹¹ and was reported in alignment with the PRISMA-ScR guidelines.¹² The PRISMA-ScR checklist is provided in Supplemental Appendix 1. As this scoping review aimed to map the existing literature, no critical appraisal of individual sources of evidence was performed, in accordance with JBI guidance. No protocol was registered for this scoping review.

Selection criteria

The inclusion criteria for studies in this review were articles published within the last 10 years (2013–2025) that fully or partially address the ethical implications of using AI in transplantation. Texts must be available in English or Spanish. The exclusion criteria exclude editorial discussions, commentaries, abstracts conference summaries, and articles unavailable in full text.

Data sources and search strategy

On 29 May 2025, a systematic search was conducted across multiple databases including PubMed, Scopus, Science Direct, JSTOR, LILACS, IEEE, and GreyNet. The search

used keywords spanning three domains: AI, Ethics, and Transplantation. Detailed search strategies can be found in Supplemental Appendix 2.

Studies eligibility

Following the initial screening, which was conducted by a minimum of two reviewers selected from a pool of four (NL, NG, JAG, and AG), all articles meeting the preliminary inclusion criteria proceeded to a full-text review. This subsequent review was performed independently by two reviewers (NL and NG). In instances of disagreement, a third reviewer was appointed to adjudicate; however, no discrepancies were identified at this stage.

Data extraction was likewise carried out independently by the same two reviewers (NL and NG), utilizing a standardized and pilot-tested extraction instrument. Any discrepancies identified during data extraction were addressed through discussion and consensus between the reviewers, with recourse to a third-party adjudicator if necessary.

Data extraction

To facilitate data collection, the research team developed and piloted a data extraction tool on several articles to ensure its efficacy before application. This tool was utilized to systematically gather data across two distinct dimensions: bibliometric analysis and scoping review elements. For the bibliometric analysis, the extracted data included author, journal, and publication information. For the scoping review, the tool captured detailed information such as study type, source of information, data collection dates, study population, applications of AI, benefits, risks and ethical dilemmas of AI, ethical principles discussed, as well as proposed solutions or requirements. All data extraction was meticulously performed by NLS, who conducted a thorough full-text review of each included article at least twice at separate times to ensure comprehensive data accuracy and reliability. This dual-phase approach ensured consistency and validity in the data compilation process.

Statistical analysis

Given the nature of the study, the bibliometric data were analyzed using the R-based *Biblioshiny* application, available at <https://bibliometrix.org/>. This analysis provided descriptive statistics such as frequencies, percentages, and rankings, highlighting the publication trends and distributions. For the scoping review, we applied an inductive approach with thematic analysis to deeply understand the qualitative data. This method enabled the systematic identification and theme interpretation emerging directly from the data, ensuring a comprehensive analysis of the ethical implications of AI in transplantation.

Ethical considerations

This review strictly adheres to ethical standards in handling published data, ensuring proper attribution to all sources, and avoiding the misuse of proprietary information. Although this is a literature-based study and does not involve primary human or animal subjects, it has still been approved by the Colegio Mayor de Nuestra Señora del Rosario Ethics Committee (DVO005 1836-CV1518) to ensure all ethical requirements are met.

Results

In this review, 6824 records were identified from various databases. After removing 666 duplicate records, 6158 records were screened. Of these, 6107 were excluded based on abstract and title information. A total of 51 records were sought for retrieval, with two not retrieved. A further eligibility assessment was conducted on the remaining 49 reports, excluding 33 more records due to article type and content. Ultimately, 16 studies met all selection criteria and were included in the review, view detailed Prisma in Figure 1.

Bibliometric analysis

Our bibliometric analysis reveals a significant increase in scholarly output on the topic of ethics of AI in transplantation from 2020 to 2025, reflecting a growing interest in this intersection of fields and a steady increase in publications; before 2020 we did not find articles related. However, the average number of citations per article peaked in 2020 at over 22 citations per article and has since declined, suggesting the natural process of more citations with more time since publication. The main countries of the scientific publications were the United States, Sweden, Italy, Spain, Australia, Germany, and Singapore. Figure 2 compiles the bibliometric analysis results.

Figure 2 illustrates the trends in annual scientific production and the average number of citations per year from 2020 to 2025, focusing on AI ethics in transplants. Graph A shows a gradual increase in the number of published articles: one article in 2020 and 2021, followed by three in 2022 and 2025 (until May), and four publications on the central topic in 2023 and 2024. Conversely, Graph B displays a downward trend in the average annual citations. In 2020, the average was 22.6 citations. However, in the subsequent years, the number of citations significantly decreased to three in 2021, four in 2022, and dropped again to 1.5 in 2023. In 2024, output remained steady with a modest citation impact. In 2025, articles were published but not yet cited, likely due to limited time. This suggests that although there has been a steady increase in the number of published articles, their impact, as measured by the number of citations, is likely to grow over time.

The comparative analysis presented in Figure 3 assesses 10 institutions based on the volume of academic and/or scientific articles published on the ethics of AI in transplantation. Johns

Hopkins University stands out prominently with about 10 publications, followed by Mayo Clinic and Granada with six and five articles. University of Oxford, Duke University, Massachusetts Institute of Technology, Monash University, and New York University each contributed three articles to the field. Murdoch Children's Research Institute and the National University of Singapore concluded the list with two publications each, positioning them lower in the ranking concerning the evaluated central theme.

Figure 4 depicts a global map of scientific production concerning the ethics of AI in transplantation. The United States stands out as the primary contributor, representing a total of 30 publications. Followed by Spain, Italy, and Austria with eight, six, and five publications, respectively. Finally, other countries such as Singapore, Germany, and Sweden show fewer than three articles published on the primary research theme.

Findings from the scoping review

The articles presented display common trends regarding the possible benefits and outcomes AI could offer when implemented into the transplant allocation system. The 16 included articles highlight the impact of precision medicine and how AI shift decision-making from being “experience based” to “data-driven.” While the implementation of patient-specific decision-making is a common theme, the way it impacts the patients varies across articles. Table 1 presents a summary of the articles included. A more detailed version is available in the Supplemental Appendix 3. Thirteen out of the 16 articles demonstrate how AI provides an unbiased analysis of the patients' case, aiming to offer the best possible care by considering factors like drug interactions, dosing, monitoring schedules, and a long-term graft survival plan (Table 2). In contrast, the remaining three articles focus on how AI-driven precision medicine can ensure ethical justice and fairness for all patients on the waiting list. This includes prioritizing placement and assessing the overall match potential between patients and donors, which is argued to reduce long-term postoperative rejection of the organ.

Ethical dilemmas in AI and transplantation

Despite the clear advantages of AI in the field of transplantation, its use and implementation raise several ethical dilemmas and conflicts:

Dehumanization of medical care

A prominent concern is that the integration of AI into clinical practice may render the care process less personal and more mechanistic, potentially diminishing empathy and patient-centered communication. As AI systems prioritize accuracy and objectivity, they may overlook individual patient nuances. Therefore, it is essential that healthcare

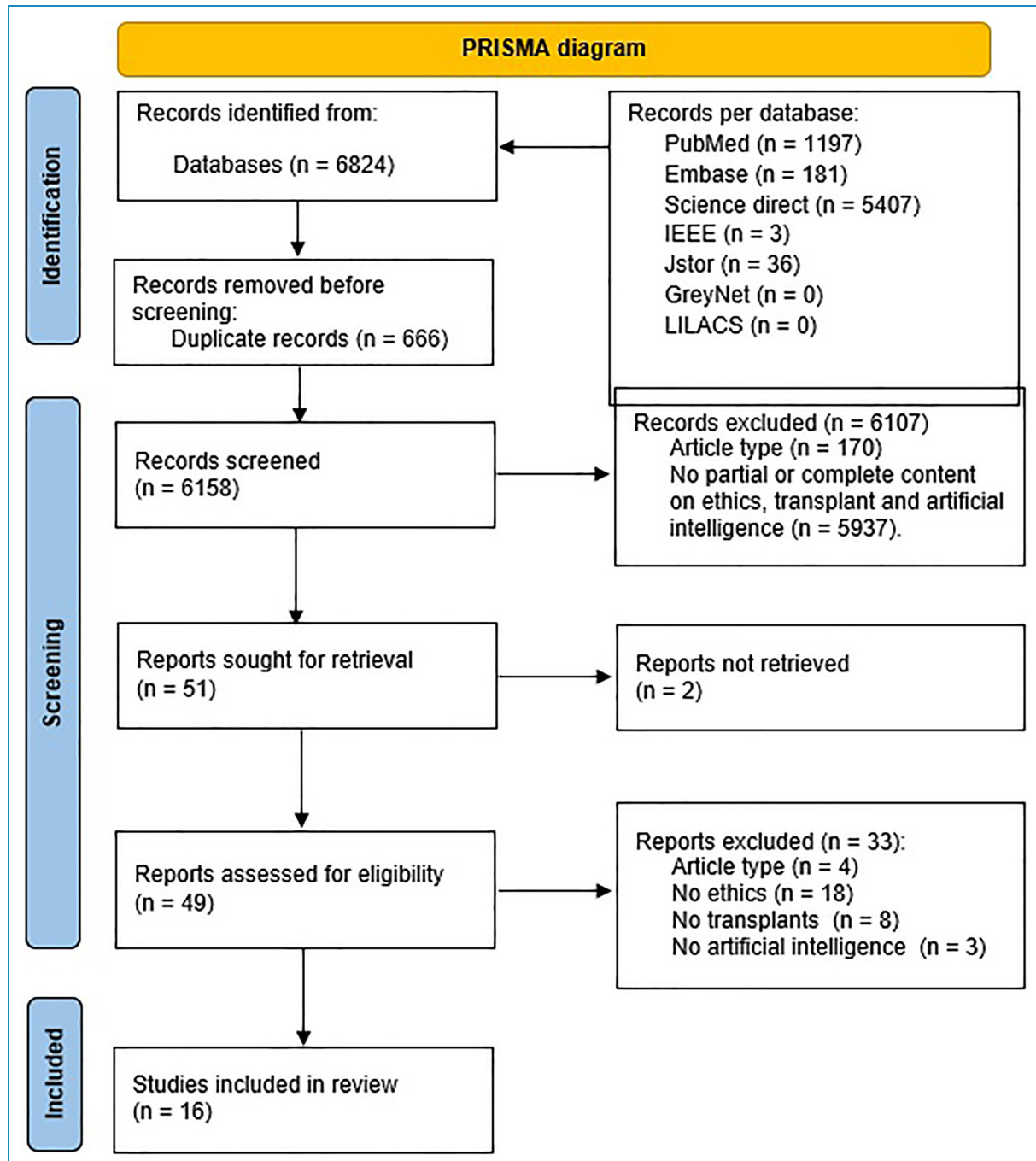


Figure 1. PRISMA flow diagram for the selection of studies in the scoping review.

professionals not only understand the AI decision-making process but also contextualize its outputs within a humane and individualized patient-clinician relationship.²³

Challenges in AI interpretation and trust

The broader accessibility and adoption of AI necessitate a clear understanding of its development and application. This issue has two primary dimensions. First, the transparency and

explainability of AI models are often insufficiently addressed, which can significantly hinder their clinical applicability.¹³ Second, the lack of clarity in how these tools are reported and understood may foster mistrust among both patients and clinicians. This includes phenomena such as algorithmic aversion, where reluctance to rely on automated systems impedes their adoption. Furthermore, questions of accountability arise—for instance, in the event of an adverse outcome, to what extent can responsibility be attributed to the AI system?

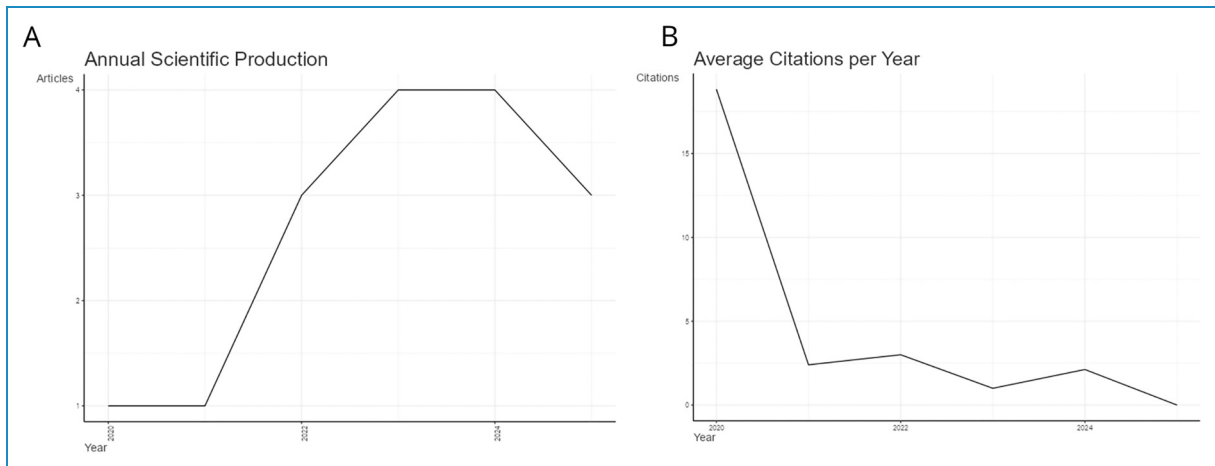


Figure 2. Trends in annual scientific production and average citations per year (2020–2025): (a) annual scientific production, (b) average citations per year.

Erroneous decision-making and data bias

AI may also contribute to erroneous medical decisions, particularly when trained on low-quality or non-representative datasets. Since the accuracy of AI predictions is closely tied to the quality of the input data, biased or incomplete datasets can lead to inequities in diagnosis, treatment access, and outcomes. These limitations underscore the importance of ensuring data representativeness and fairness in AI design. Additionally, biases inherent in the data, coupled with privacy and security concerns related to sensitive health information, pose further risks. Addressing these issues is critical to maintaining trust and integrity within healthcare systems. AI tools must therefore be developed and implemented with strict attention to data quality, equity, and privacy, to support fair, accurate, and ethically responsible decision-making in transplantation. Table 2 summarizes the key ethical concerns identified.

Discussion

This scoping review is the first to comprehensively explore the ethical considerations associated with the integration of AI in transplant surgery. Our analysis highlights the increasing scholarly interest in this intersection, with a significant rise in publications between 2013 and 2025. The review identifies several critical ethical dilemmas, including concerns about data privacy, algorithmic bias, and the transparency of AI decision-making processes. Despite these challenges, the literature also points to substantial potential benefits, such as improved precision in donor-recipient matching and enhanced patient outcomes through personalized care. The findings underscore the necessity for a balanced approach that maximizes the advantages of AI technologies while addressing their ethical implications to ensure equitable and just application in transplant surgery.

The articles presented posing similar trends regarding possible risks and benefits surrounding the implementation of AI for allocating organs used for transplants, highlighted by the fact that most, if not all, sources display very common and highly debated barriers and obstacles AI faces in nearly all applications seen in the medical world.²⁴ The most contested dilemma revolves around whether AI's "data-driven" decision-making is biased or unbiased.^{3,7,8,10,13,14,16–22} This concern arises because the automation of organ allocation could potentially place patients at risk of dehumanization. This issue is not only addressed in the 16 articles meeting the review criteria but also discussed in supplementary and alternative sources, which emphasize it as a principal argument against current AI utilization. It is crucial to acknowledge that while this barrier in AI development is extensively debated, a grey area persists in medical and scientific knowledge regarding how AI automation might contribute to the perceived "dehumanization" of patients.¹⁰ The empirical assessment of whether these potential consequences outweigh the benefits remains an area requiring further investigation (Table 2).

Another major trend seen in all articles is the possible solutions AI poses for organ allocation, nine out of the 16 articles reviewed that fit the criteria suggested a "Human-supervised AI," in other words, experts suggest that whatever AI is implemented in the future to facilitate organ allocations, donor matching, and patient care, among other uses should be supervised by a human being that follows the AI decision making to mitigate discrimination and dehumanization of patients.²⁵ Although the suggestions made are logical and even necessary to guarantee ethical justice as well as the patient's rights, especially for populations at risk, this means that before actually implementing AI there needs to be a deeper and better understanding of the needs and challenges faced currently in the organ allocation system around the world, this can allow the scientific

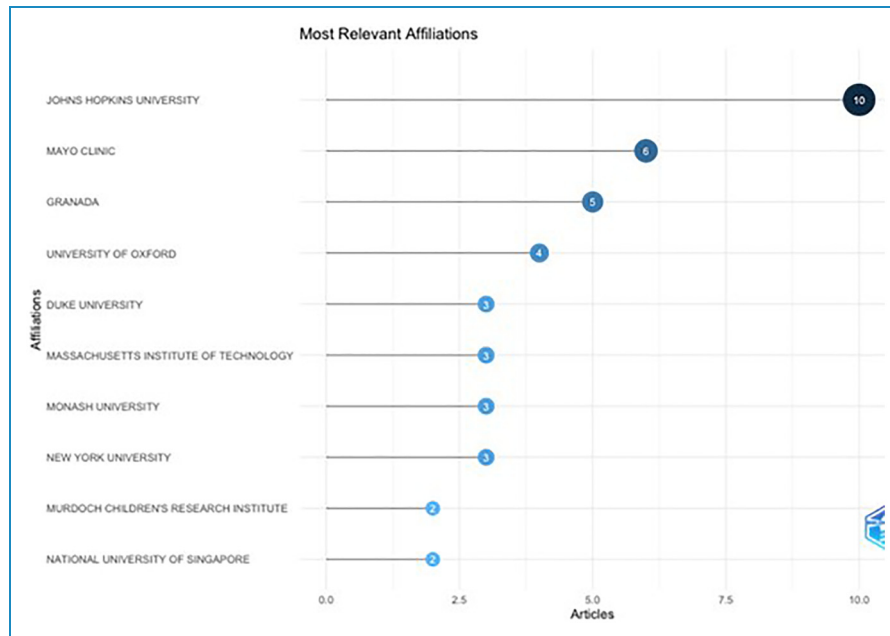


Figure 3. Top 10 institutions based on the volume of academic/scientific articles on the ethics of artificial intelligence in transplantation.

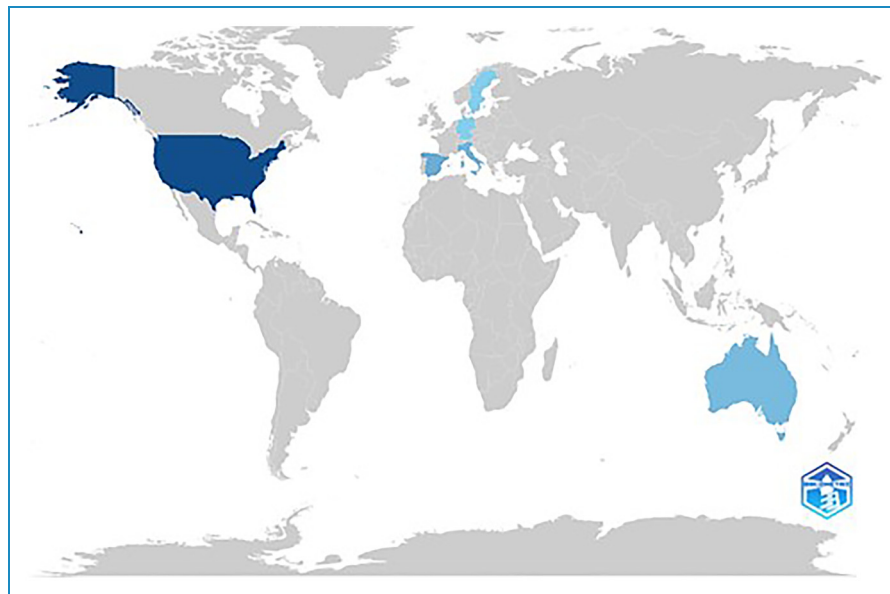


Figure 4. Global map of scientific production concerning the ethics of artificial intelligence in transplantation.

community to have a better understanding on how AI could be used to lessen the burden and challenges faced nowadays. The main objective that should be reviewed, researched, and discussed is whether we need “human supervised AI” or “Machine assisting AI” or in other words, do we currently need automated AI that does everything for us or AI that facilitates challenging aspects of organ allocation but has no influence on the process itself, this is a debate that experts cannot decide upon (Table 2).

Exploring alternative research papers there is a clear underdevelopment of the ethical considerations of AI not only in kidney transplant but transplants overall. Since the topic is rather innovative, there isn’t much expansion regarding possible multidisciplinary considerations as seen in other technological advancements like surgery 4.0 or machine-assisted medicine. The most relevant article that discusses AI applications focuses on the utility AI could bring to transplants in a clinical/patient-care aspect

Table 1. Key bibliometric characteristics of the reviewed studies about the integration of artificial intelligence (AI) in transplant surgery from 2013 to 2023.

Authors, year, country	Journal	Journal quartile	Journal h-index	Study type	Source	Total citations	Total views
Drezga-Kleiminger et al. (2023), ¹⁰ United Kingdom, Australia, and Singapore.	BMC Medical Ethics	Q1	54	Cross-sectional	Primary	0	1046
Garcia Valencia et al. (2023), ⁵ USA	Healthcare (Basel, Switzerland)	Q2	48	Review	Secondary	7	2250
Papalexopoulos et al. (2022), ¹³ USA	Journal of Law and the Biosciences	Q1	26	Review	Primary	10	1868
Clement et al. (2021), ⁷ United States and Sweden	Frontiers in Immunology	Q1	190	Rapid Review	Secondary	12	4200
Rueda et al. (2022), ³ Spain	AI and Society	Q1	39	Review	Secondary	8	4117
Schattenberg et al. (2023), ¹ Germany and USA	Updates in Clinical Hepatology	Q1	194	Review	Secondary	4	124
Balsano et al. (2021), ¹⁴ Italy and France	Digestive and Liver Disease	Q1	100	Systematic review	Secondary	18	34
Freedman et al. (2020), ⁸ USA	Artificial Intelligence	Q1	161	Review	Secondary	112	46
Strauss et al. (2023), ¹⁵ USA	Hepatology Communications	Q1	41	Qualitative cross-sectional	Primary	1	10
Olawade et al. (2024), ¹⁶ United Kingdom	Current Research in Translational Medicine	Q2	70	Review	Secondary	5	66
Gong et al. (2024), ¹⁷ China	International Journal of Medical Informatics	Q1	141	Bibliometric analysis	Secondary	0	44
Clark et al. (2024), ¹⁸ United Kingdom	Journal of Cardiothoracic Surgery	Q2	61	Review	Secondary	12	68
Fuchs et al. (2024), ¹⁹ Germany	Children	Q2	56	Review	Secondary	0	1341
Gatsinga et al. (2025), ²⁰ Singapore	Transplantation Proceedings	Q3	93	Review	Secondary	0	13
Salybekov et al. (2025), ²¹ Kazakhstan	Journal of Clinical Medicine	Q1	132	Review	Secondary	1	716
Pruinelli et al. (2025), ²² United States	BMC Medical Informatics and Decision-Making	Q1	107	Systematic review	Secondary	0	33

instead of an organ allocation aspect. There is a notable scarcity of articles that discuss ethical considerations of AI in the specific use of transplants, opting for a wider, more general approach to AI in large topics like general surgery.

The World Journal of Transplantation (WJT) and Current Opinion in Transplantation (COT) are two of the most relevant and detailed papers available today that discuss AI applications in transplants. The WJT evaluates AI performance

Table 2. Summary of findings on artificial intelligence (AI) applications in organ transplantation.

Topic	Number of articles	Ethical issues discussed	Recommendations
AI applications	Thirteen ^{1,3,5,7,8,10,13–15,18–20,22}	Data-driven support Improvement of clinical precision Artificial intelligence-supported clinical decision Predictive models for organ allocation Patient education and effective communication Data analysis and research in kidney transplantation Optimized evaluation of rescued organs Predictive modeling and risk stratification	Balance between top-down and bottom-up approaches Development of explainable AI systems Interpretability and explainability Use as a tool and not final decision maker Comparative effectiveness studies Generalization and external validation
Benefits	Ten ^{1,5,8,10,13–17,20}	Improvement of equity and justice Efficiency in policy exploration Accurate prediction Large amounts of information analysis Stakeholder empowerment Optimization of patient outcomes Ensuring patient understanding	Mandatory reporting of patient population composition Background sensitivity Bias mitigation Continuous evaluation of effectiveness and clinical impact Patient perspectives and engagement
Risks and ethical dilemmas of AI	Twelve ^{1,3,5,7,8,10,13–16,20,22}	Dehumanization of the medical process Data quality and model assumptions Transparency and standardization Responsibility and accountability (legal) Perpetuating inequities and injustice Trust in the healthcare system Failure to capture complex information Challenges of privacy and patient data protection Training and acceptance of AI	Implementation of access controls and authentication Collaborative approach and multidisciplinary integration Long-term patient outcome evaluation and feedback loop Optimization of integration with electronic health records (EHRs)
Regulations or norms	Five ^{5,8,14,18,21}	Effective guidelines and regulations Comprehensive and high-quality databases Standards for development, validation, and use of AI	Considering alternatives Measuring cost-effectiveness evaluation Development of regulatory standards Human oversight
Requirements or needs	Seven ^{5,10,16,17,19,21,22}	Frameworks and regulations Standardization of best practices in AI User experience and acceptance	Training medical professionals in AI Involvement of decision-makers and patients Ethical standards for fairness and equity

in kidney transplants in six machine learning categories ranging from radiological evaluation, graft survival predictions, and even optimization of immunosuppressive dosage. Unfortunately, as with most other papers that share the

topic, they limit themselves to superficial discussions regarding ethical considerations and focus the study on evaluating efficiency and success in clinical trials. On the other hand, COT evaluates possible AI algorithms and

programming models and offers a critical perspective of modern biostatistics focusing on the challenges faced when creating a suitable AI system for a complex topic such as organ transplants. The article gives detailed insight into AI models and the possible benefits it could offer, yet it falls under the same issues regarding the absence of a deep debate of ethical challenges faced when implementing AI into the organ allocation system.^{17,20–22,26,27}

Applications of AI in transplant

The integration of AI in transplantation is transforming various aspects of patient care and operational efficiency. Our review identified several key applications: organ allocation and assignment where AI algorithms optimize organ matching and distribution, considering ethical and clinical considerations such as pathological classification of organs at organ procurement.^{17,20–22} This application enhances fairness and reduces human error by incorporating predictive models that consider both donor and recipient factors. In Clinical Decision Support, AI systems are utilized to enhance decision-making in transplant contexts, integrating clinical decision support systems (CDSS) that leverage big data to provide precise, personalized recommendations and improve medication management post-transplant.^{15–17,20–22} Patient care and education benefits from AI through tools like chatbots that enhance patient communication and understanding, support linguistic and cultural needs, and offer personalized care management plans supervised by the medical professionals.¹⁸ Enhancing physician communication focuses on using AI to improve interactions between nephrologists and decision-makers, ensuring clearer, more effective communication and facilitating the nephrologist administration and assistant activities.²¹

Lastly, data analysis and predictive modeling for transplant outcomes uses AI to develop predictive models that forecast post-transplant graft survival, assess risks associated with rescued organs, and predict outcomes in conditions such as cirrhosis, thereby significantly improving clinical outcomes.^{16–22} Each of these applications demonstrates the potential of AI to not only streamline processes but also to deepen the understanding and effectiveness of transplant procedures and patient management.¹⁴

Case studies of bioethical dilemmas

The review by Dale et al.²⁸ underscores how risk-based algorithms in organ allocation often embed inconsistent ethical values, raising critical concerns about fairness and the potential for unjust prioritization criteria that may disproportionately affect vulnerable patient populations. On the other hand, Murray et al.²⁹ demonstrate that even sophisticated AI tools, such as large language models, can replicate or amplify allocation inequities if fairness metrics are not systematically evaluated—emphasizing the ongoing need

for ethical auditing and stakeholder-informed model design. Also, the study by Drezga-Kleiminger et al.¹⁰ highlights that while AI promises efficiency in organ allocation, public attitudes reflect strong reservations about replacing human judgment with automated decisions, particularly due to fears of dehumanization and loss of transparency. Finally, a human rights-based analysis by Lebrecht³⁰ reveals that the adoption of AI in transplantation must be grounded in legal and ethical safeguards, as unregulated algorithmic allocation may contravene principles of equity and non-discrimination across European healthcare systems. Together, these findings reinforce the necessity of incorporating practical, context-sensitive safeguards and maintaining human oversight to ensure that AI in transplantation aligns with principles of equity, justice, and public trust.

Bibliometric trends analysis

The bibliometric trends observed in our review are consistent with prior analyses that underscore the geographic concentration of research in AI and transplantation. He et al.,³¹ in a 30-year bibliometric analysis, found that research output in this field is largely dominated by institutions in high-income countries, particularly the United States, reflecting enduring disparities in access to scientific infrastructure and innovation. Similarly, Patil et al.³² noted a lack of global collaboration and underrepresentation of low- and middle-income countries in the ethical and legal discourse on transplantation. These findings point to a critical need for more inclusive research agendas and international cooperation to ensure that ethical standards, technological developments, and policy frameworks around AI in transplantation reflect diverse global perspectives and healthcare realities. Moreover, the dominance of North American and European institutions may shape which ethical concerns are most visible—often reflecting priorities and assumptions relevant to resource-rich settings—while potentially overlooking issues more salient in under-resourced or structurally vulnerable contexts.

Methodological quality of included studies

Although a formal quality appraisal was not performed, a descriptive assessment of the methodological features revealed both strengths and limitations across the included studies. Notably, two studies employed systematic review methodologies, adhering to structured search strategies and predefined inclusion criteria, which enhanced the transparency and reproducibility of their findings. Additional strengths included clearly defined research aims and the application of mixed or qualitative methods in a subset of studies, contributing valuable insights into complex ethical dynamics. However, most studies were narrative reviews or retrospective analyses with limited empirical data. None employed randomized or interventional designs, and those

involving primary data tended to rely on small samples. These limitations underscore the early stage of research in this field and the need for more rigorous, prospective studies to support evidence-based ethical guidance for AI implementation in transplantation.

Gaps for future research

The integration of AI in transplantation highlights a critical need for dedicated regulatory standards and ethical frameworks, given the specific demands and implications of this medical field. The literature reveals a notable deficiency in real-world studies examining the application of AI tools in actual patient care scenarios. This gap underscores the urgency for comprehensive research focused on practical, clinical implementations to better understand how these technologies affect patient outcomes. Additionally, there is a pressing need for legal reviews and adaptations within legal frameworks to ensure that AI deployment in transplantation aligns with both current and emerging legal standards. Despite the extensive publications on AI, the field of ethical considerations in transplantation remains relatively underexplored. This area offers significant opportunities for deep investigations into ethical nuances, aiming to enhance the conscientious application of AI, ensuring it upholds patient welfare and promotes equity in healthcare outcomes.^{5,10,16,17,19,21,22}

Recommendations

The risks related to dehumanization, algorithmic opacity, and trust emphasize the importance of a well-defined ethics-by-design framework for integrating AI into transplant surgery. This approach should prioritize explainability, ensure that all technology-supported recommendations are reviewed by qualified clinicians, address bias and fairness from the outset, and clarify responsibilities within clinical teams. Safeguarding patient autonomy is essential and requires adapting informed consent processes to reflect the role and limitations of these tools. We also emphasize the importance of involving diverse stakeholders in development and implementation, maintaining strict data protection standards, integrating new systems without disrupting clinical workflows, and setting up mechanisms for ongoing evaluation. Finally, a clear and thoughtful consent process should inform patients about the involvement of algorithmic tools, explain their purpose and boundaries, outline associated risks and safeguards, reaffirm the central role of human judgment, allow for questions or refusal, and document patient preferences transparently.

Limitations

This scoping review has several limitations. Although an extensive and systematic search was conducted, only

sixteen studies met the inclusion criteria, limiting the breadth of the analysis. A key reason for exclusion was that many articles addressed only two of the three required domains—AI, Ethics, and Transplantation—without explicitly covering all three, which may have led to the omission of potentially relevant discussions. Additionally, the language restriction to English and Spanish may have excluded pertinent literature in other languages. While the review intended to include studies on robotics and simulation, no eligible articles on these technologies were identified, either due to their absence in the literature or the limitations of the search strategy. Lastly, given the fast pace of technological innovation, relevant new studies may have been published after the data collection date.

Conclusion

This review represents the first comprehensive effort to systematically map the ethical landscape surrounding the integration of AI into transplant surgery. By analyzing current literature, technological developments, and ethical discourse, it highlights not only the transformative potential of AI—including improved precision, enhanced decision-making, and optimized resource allocation—but also the significant ethical challenges that accompany its implementation. These include issues of bias and fairness, data privacy, informed consent, algorithmic transparency, and the potential erosion of human oversight and accountability in clinical decisions.

The findings underscore an urgent need for interdisciplinary collaboration in the development of robust ethical frameworks that can guide the responsible deployment of AI in transplant surgery. Future research should aim to create actionable guidelines and policy recommendations that anticipate ethical dilemmas before they arise and promote systems that are not only technically sound but also socially responsive. This includes prioritizing patient safety, inclusivity, and equity, especially in contexts where healthcare disparities are already prevalent. Ultimately, advancing AI in transplant surgery must be aligned with broader commitments to justice, trustworthiness, and human-centered care in medicine.

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ORCID iDs

Nicolás Lozano-Suarez  <https://orcid.org/0000-0003-2851-5105>

Julia Andrea Gomez-Montero  <https://orcid.org/0000-0001-6220-500X>

Maritza Jiménez-Gómez  <https://orcid.org/0009-0000-1543-8345>

Santiago Cabas  <https://orcid.org/0009-0002-1437-3978>

Nicolás Giron-Londoño  <https://orcid.org/0009-0001-3506-6451>
 Andrea García-López  <https://orcid.org/0000-0002-3940-1413>

Ethical considerations and consent to participate

This study is a literature-based scoping review and did not involve direct interaction with human participants or the use of identifiable personal data. Nevertheless, the protocol was formally reviewed and approved by the Colegio Mayor de Nuestra Señora del Rosario Ethics Committee (DVO005 1836-CV1518) to ensure compliance with ethical research standards.

Author contributions

NL: study design and conception, data acquisition, data analysis and interpretation, writing the manuscript, and critical review. AG: study design and conception, data acquisition, data analysis and interpretation, writing the manuscript, and critical review. MJ: data analysis and interpretation, writing the manuscript, and critical review. SC: data analysis and interpretation, writing the manuscript, and critical review. NG: data acquisition, data analysis and interpretation, writing the manuscript, and critical review. AG: study design and conception, data acquisition, data analysis and interpretation, and critical review. FG: study design and conception, and critical review.

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Data availability statement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Supplemental material

Supplemental material for this article is available online.

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