AI Ethical Gap Analysis in Medical Practices Using Deductive Thematic Analysis

Abduladhim Ashtaiwi
abduladhim.ashtaiwi@aum.edu.kw
College of Engineering and Technology, American University of the Middle East, Kuwait

ABSTRACT

This study investigates ethical compliance in AI applications within the healthcare sector, focusing on alignment with established ethical frameworks from government and non-government organizations. Utilizing Deductive Thematic Analysis (DTA), this work analyzes publicly available documents from prominent AI healthcare companies to assess adherence to key ethical themes—privacy, transparency, fairness, accountability, and patient autonomy. The study introduces the Thematic Completeness Index (TCI), quantifying both theme coverage and depth. The findings indicate that while themes like fairness and privacy are moderately represented, their depth remains limited, suggesting a need for more thorough ethical practices. Diagnostics and imaging companies exhibited higher compliance than those in drug discovery. The results underscore the importance of adaptive regulatory frameworks and multi-stakeholder collaboration to bridge ethical gaps, ensuring AI-driven healthcare remains responsible and equitable.

KEYWORDS

AI Ethics, Healthcare Compliance, Ethical Frameworks, Privacy, Privacy, Transparency, Fairness, and Accountability.

1 INTRODUCTION

The evolution of artificial intelligence (AI) in medicine started in the late 1950s when early rule-based systems were used in healthcare. For example, expert systems like MYCIN emerged during that time, leveraging if-then rules to identify bacteria and recommend antibiotics. Advancements continued into the 1980s and 1990s as machine learning (ML) algorithms were slightly introduced to refine the decision-making processes in medical diagnostics. The late 1990s and early 2010s observed the rise of artificial neural networks (ANNs), deep-learning models, the internet of medical things (IoMT), and augmented reality (AR), marking the beginning of a new era of sophisticated AI applications in the medical sector. Building on these advancements, AI applications in healthcare are now expanding rapidly, with companies integrating these technologies into diagnostics, medical imaging, personalized medicine, drug discovery, patient management, predictive healthcare, and robotic surgeries.

There was no ethical enforcement of AI and ML in the medical sector until the late 1990s. From the late 1990s to the beginning of 2010s, there was an increase in ethical awareness; early regulations and discussions about them started to shape the field [1]. The discussion was followed by establishing formal regulatory frameworks along with robust ethical discussions [2]. In the mid-2010s, a global effort to harmonize these regulations became evident [3], despite varying approaches across different regions [4]. The late 2010s witnessed the integration of ethical AI principles into clinical practice and education [5] [6]. Currently, many organizations, like the world health organization (WHO) [7], UNICEF [8] and patient safety network (PSNet) [9] are evolving towards more patient-centered AI ethics, indicating a shift to prioritize the well-being and rights of patients in the development and application of AI in healthcare [10] [11].

Assessing AI ethical readiness and compliance presents significant challenges due to the complexity and diversity of ethical standards across various sectors and organizations. AI ethical readiness refers to how well published guidelines cover important ethical issues. It assesses whether these guidelines fully address key ethical concerns for AI use in the medical field. In contrast, compliance assesses the degree to which companies implement these guidelines in practice and adhere to the frameworks established by governmental and non-governmental organizations (GOs and NGOs).

The deductive thematic analysis (DTA) proposed in this study is a qualitative, theory-driven approach. It leverages natural language processing (NLP) to effectively explore the ethical themes across large text corpora. DTA evaluates the completeness of published AI ethical guidelines and the extent to which companies adhere to these established standards. DTA employs predefined themes and keywords derived from a comprehensive review of ethical frameworks and relevant literature. DTA employs the thematic completeness index (TCI) to quantify thematic presence within the corpus. TCI uses two key metrics: theme depth, which reflects the proportion of relevant keywords identified for each theme, and theme coverage, which measures the breadth of theme representation across the corpus. By integrating these metrics, TCI provides an overall evaluation of thematic alignment and the depth of ethical considerations in AI. DTA is an NLP-based framework that continuously assesses the ethical adherence in healthcare AI, helping stakeholders track and address ethical gaps as they emerge, supporting sustainable governance.

The remainder of this paper is organized as follows: Section 2 provides historical background and reviews related work. Section 3 outlines the Deductive Thematic Analysis (DTA) approach and describes the Thematic Completeness Index (TCI) used in this research. Section 4 details the methodology for data collection and ethical gap assessment. Section 5 presents the analysis of results, including thematic trends and corporate compliance findings. Section 6 discusses the impact of the identified ethical gaps and their implications for AI in healthcare. Finally, Section 7 offers concluding remarks and suggests directions for future research.

2 HISTORICAL BACKGROUND AND RELATED WORK

The integration of AI and ML into the healthcare sector has revolutionized medical practices and raised complex ethical issues.

2.1 History of AI Ethics in Medical Practice

The medical sector has a history of introducing strict regulations to address technology's inherited ethical issues. Figure 1 highlights the timeline evolution of the regulation applied in the healthcare sector. Beginning with regulatory inattention, the field saw a shift toward awareness and preliminary guidelines in the late 1990s, evolving into formal regulatory frameworks and robust ethical debates by the 2010s [2]. 2020 witnessed formal regulatory frameworks and ethical debates, reflecting a more structured approach to AI governance [12]. Recently, beyond 2020, a global divergence in regulatory approaches has been noted, along with efforts to combine international regulations [13]. The slight integration of ethical AI into clinical practices is expected to continue evolving in the future [14].

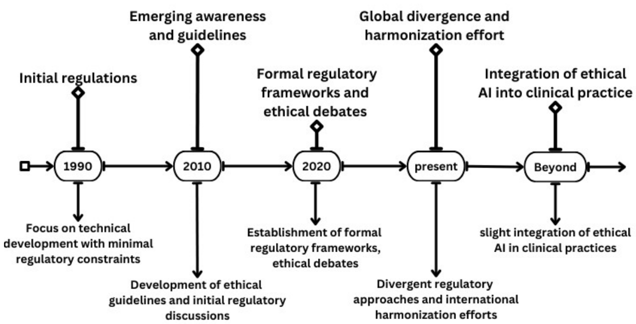

Figure 1: Evolution of regulation in the healthcare sector

2.2 Related work

Recent literature addresses the ethical integration of AI in healthcare, focusing on themes like transparency, accountability, and privacy. [15] identifies transparency and bias as critical challenges in AI-driven healthcare, emphasizing ethics throughout the lifecycle of AI applications. NIST's AI risk management framework provides a structured approach for managing AI risks with updates to maintain alignment with societal values [16]. Similarly, [17] advocates for policy frameworks that balance diagnostic accuracy and patient privacy in clinical AI systems. [18] propose a human-centric AI framework emphasizing global standards and adaptability to address biases and interpretability issues. [19] and [20] underscore the importance of liability frameworks and general data protection regulation (GDPR) compliance for enhancing trust and ethical accountability in healthcare AI. In governance, [13] suggests a model for ethical oversight of AI in clinical settings, while [21] focuses on equity and informed consent in Indian healthcare, underscoring regional factors. [22] examine the global gap between ethical AI principles and practical applications, stressing the need for governance that ensures robust ethical compliance.

3 DEDUCTIVE THEMATIC ANALYSIS (DTA)

DTA is a theory-driven approach used to assess AI ethical compliance in the medical field by identifying relevant themes and keywords derived from extensive reviews of governmental, non-governmental, and academic sources. Table 1 displays the list of predefined themes and their associated keywords utilized in this study. These themes were specifically generated, focusing on AI ethics in the medical sector. DTA employs NLP to identify ethical themes associated keywords across large text corpora.

Table 1: Predefined themes and their associated keywords.

Theme	Keywords
Privacy	privacy, data confidentiality, consent, data protection, patient rights, information security, data breach, anonymization, personal health information, data sharing, confidentiality breaches.
Transparency	transparency, explainability, disclosure, openness, AI understanding, algorithmic transparency, decision-making process, transparent reporting, data sources, model interpretability, user trust, ethical disclosure.
Fairness	fairness, bias, equitable access, discrimination, equality, algorithmic fairness, social justice, health disparities, equal treatment, bias mitigation, diversity, inclusive healthcare, equity.
Accountability	accountability, responsibility, ethical standards, liability, regulatory compliance, professional ethics, moral responsibility, governance, oversight, legal accountability, ethical oversight, standards adherence, audit trails.
Safety	safety, clinical validation, monitoring, adverse events, risk management, patient safety, medical errors, safety protocols, AI safety, clinical safety, safety assessments, quality control, health risk assessment.
Patient Autonomy	autonomy, informed decision-making, patient choices, self-determination, consent process, patient-centered care, ethical consent, decisional autonomy, patient empowerment, respect for autonomy, personal choices, autonomous decision-making.
Innovation and Progress	innovation, technological advancements, AI development, healthcare innovation, cutting-edge technology, research ethics, progress, breakthroughs, clinical research, technology adoption, innovative solutions.
Collaboration and Partnership	collaboration, partnership, stakeholder engagement, multi-disciplinary teams, public-private partnerships, cross-sector collaboration, teamwork, joint ventures, collaborative models, community involvement, stakeholder collaboration, cooperation.
Sustainability and Environmental Impact	sustainability, environmental impact, green healthcare, sustainable practices, eco-friendly, carbon footprint, sustainable development, energy efficiency, resource conservation, waste reduction, environmental sustainability, climate change.

3.1 Data preprocessing

Depending on the task, many data preprocessing steps are performed in NLP. **Tokenization** divides text into words or sentences, while **lowercasing** standardizes text case. **Stopwords** like "the" and "and" are removed to focus on meaningful content, and **punctuation** and **special characters** are eliminated. **Stemming** and **lemmatization** reduce words to their base forms. **Normalization** ensures consistent formatting, such as expanding contractions, while **text cleaning** removes URLs and other irrelevant artifacts.

3.2 Thematic Completeness Index (TCI)

TCI evaluates theme existence in a corpus against predefined themes (defined in Table 1). It uses two key metrics: Theme Depth (D_i), and Theme Coverage (C). D_i, where i denotes the i^{th} theme, is calculated as a percentage of the identified keywords within a theme (T) related to the total number of predefined keywords associated with that same theme T. This measure quantifies the completeness of keyword coverage within each thematic category. For a given theme T, let T_T be the total number of predefined keywords associated with a theme T, and F_T be the set of found keywords for the theme T_i. The D_{ith} theme depth for theme T_i is calculated as:

$$D_i = \left(\frac{|F_{T_i}|}{|T_{T_i}|}\right) \times 100\% \quad (1)$$

Where $\{0 \geq i \leq n\}$ and n is the number themes. Theme Coverage (C) is a metric used to quantify the extent to which predefined themes are represented within a corpus. It is calculated as the ratio of the number of found themes to the total number of predefined themes, expressed as a percentage. This metric provides an overview of how comprehensively the corpus addresses the full spectrum of themes. A higher theme coverage percentage indicates that a greater proportion of the predefined themes are represented by the data, suggesting a broader thematic alignment. Let: T_{total} be the total number of predefined themes, and T_{found} be the number of themes for which at least one keyword has been identified in the corpus. The theme coverage (C) is calculated as:

$$C = \left(\frac{T_{\text{found}}}{T_{\text{total}}}\right) \times 100\% \quad (2)$$

The TCI is defined as:

$$TCI = C \times \left(\frac{1}{n}\sum_{i=1}^{n} D_i\right) \quad (3)$$

Where the term $\frac{1}{n}\sum_{i=1}^{n} D_i$ represents the average theme depth of the n themes.

4 METHODOLOGY

The methodology outlined in Figure 2 presents a structured framework for AI Ethical Gap Analysis, employing DTA to assess the alignment between ethical standards and real-world AI applications in medical practices. The process begins with the aggregation of AI ethical guidelines and frameworks published by GOs and NGOs into a single comprehensive corpus. Hence, eight leading organizations are selected: the World Health Organization (WHO) [23], National Institute of Standards and Technology (NIST) [24], Food and Drug Administration (FDA) [25], United Nations Educational, Scientific and Cultural Organization (UNESCO) [26], Berkman Klein Center for Internet & Society (Harvard University) [27], Organization for Economic Co-operation and Development (OECD) [28], European Group on Ethics in Science and New Technologies (EGESnT) [29], Information Commissioner's Office (ICO) [30], and International Organization for Standardization (ISO) [31]. The ethical guidelines from these organizations were downloaded, compiled, and saved in a single file, *AI-Ethical-Corpus.txt.* The corpus undergoes the preprocessing phase, described in Section 3.1, to create a cleaned corpus named the Aggregated Cleaned Corpus (ACC). To extract deeper insights, text visualization techniques, including Word Clouds and bar charts, are applied.

Subsequently, Algorithm 1 is applied to identify the themes in the ACC corpus. After which Equations 1, 2, and 3 are applied to calculate TCI of the found themes. The calculated TCI value can then be used to identify gaps between established ethical standards and predefined ethical guidelines shown in Table 1.

As shown in the methodology depicted in Figure 2, the second approach is assessing how companies' practical implementations align with predefined ethical themes. First, Algorithm 2 is executed to find themes per company which then used to calculate TCI per company. Table 4 shows a sample of leading companies that span diverse AI applications within the medical sector. The list is not exhaustive; it is a sample of prominent companies at the forefront of implementing AI and ML in different medical practices. The table is organized into the following columns: "*Area*" (the medical domain where AI and ML are applied), "*Comp./Org. name*" (the name of the company or organization), "*Application*" (specific medical domain for AI and ML application), "*Ethical implications*" (ethical concerns arising from these applications), and "*TCI*" (Thematic Completeness Index).

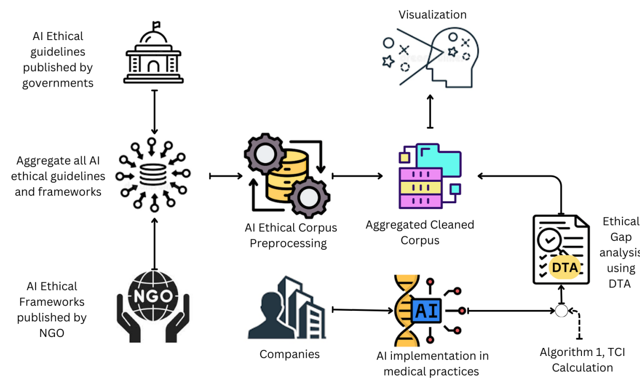

Figure 2: Methodology

Algorithm 1 Theme and Keyword Search Algorithm

Input: ACC, Predefined themes (Table 1)
Output: Found themes and keywords
$Stopwords \leftarrow$ English stopwords set; $lemmatizer \leftarrow$ WordNetLemmatizer
$words \leftarrow$ word_tokenize(ACC)
$cleaned\_words \leftarrow$ [lemmatizer.lemmatize(word.lower()) **for** word **in** words **if** word.lower() $\notin$ $stopwords$ **and** word $\notin$ punctuation]
$themes\_keywords \leftarrow$ dictionary with each $theme$ as an empty dictionary
for each $word$ in $cleaned\_words$ **do**
  for each $(theme, keywords)$ in Predefined themes (Table 1) **do**
    if $word \in keywords$ **then**
      Increment $themes\_keywords[theme][word]$
    end if
  end for
end for

Algorithm 2 List of Fount Themes and Keywords per Company's website

Input: The company's URL link
Output: Themes and keywords per company.
Extract all sub_URLs from the provided URL and save them in the *(sub_URL list.txt)* file
for each Sub_URL link found in *(sub_URL list.txt)* **do**
  Extract the text
  Append the extracted text to *(text_per_website.txt)* file
end for
text_per_website.txt will be used as input in Algorithm 1 to return found themes per company's website.

5 RESULTS

As illustrated in Figure 2, this study analyzes the findings from three perspectives: visualizing the ACC corpus through Word Cloud and Bar Chart, applying Deductive Thematic Analysis (DTA) to the ACC corpus, and using DTA to evaluate corporate AI ethical compliance. Each of these approaches is explored in the following sections.

5.1 AI Ethical Gap Analysis of Guidelines Published by GOs and NGOs

5.1.1 Gap Assessment using Word Cloud and Bar Chart. Figure 3 reveals an uneven distribution of keywords across ethical themes in healthcare. Fairness and accountability emerge as priorities, with high keyword counts for "fairness," "bias," "accountability," and "governance," highlighting efforts to address biases and enforce ethical governance in AI systems. Privacy and transparency are moderately represented, with terms like "privacy" and "explainability" indicating a focus on data protection and clear decision-making processes. While safety receives some emphasis, patient autonomy is notably less represented, suggesting that although risk management is prioritized, patient-centered care may require additional attention. Innovation and sustainability are the least emphasized themes, pointing to limited consideration of environmental impact and future technological advancement. Overall, the focus on fairness, accountability, privacy, and safety contrasts with gaps in autonomy, innovation, and sustainability, underscoring a need for a more balanced ethical approach in healthcare AI.

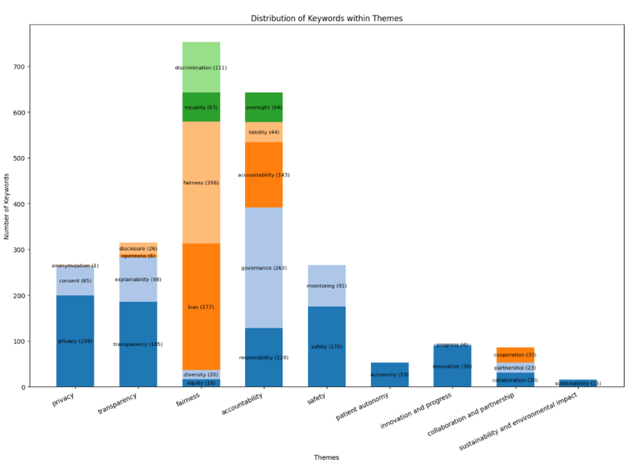

Figure 3: Themes and keywords found per GOs/NGOs (ACC) corpus

Figure 4 highlights frequently occurring terms in the ACC corpus, with keywords such as "AI," "system," "data," "model," "individual," and "principle" appearing prominently. The dominance of "AI" and "system" indicates a central focus on AI systems as an overarching subject. At the same time "data" and "model" reflect key technical components frequently discussed in the context of AI ethics. The prominence of "individual" and "principle" suggests an emphasis on the impact of AI systems on individuals and adherence to ethical principles. Words like "risk," "privacy," "protection," and "process" also appear, indicating concerns around data security, user privacy, and responsible AI deployment. The word cloud highlights ethical gaps in Patient Autonomy, Sustainability, and Innovation. Terms like "informed decision-making" for autonomy, "environmental impact" for sustainability, and innovation-related keywords are missing, suggesting these areas are underemphasized.

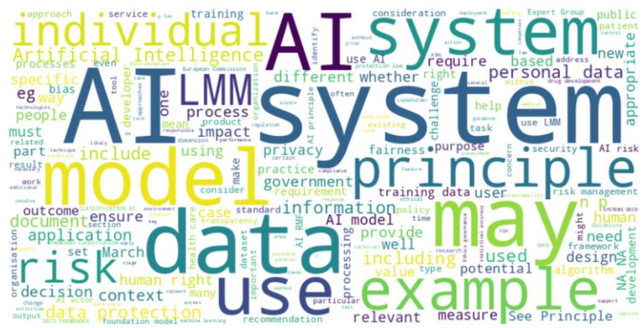

Figure 4: Word Cloud for ACC corpus

5.1.2 Gap Assessment using TDA. As explained in Section 3 DTA is applied to quantitatively assess the ethical gaps. In this section, as shown in Figure 2, DTA is used to evaluate the ethical gaps in the published frameworks from GOs/NGOs. Algorithm 1 is executed to find ethical themes and their associated keywords in the ACC. The results of this analysis are presented in Table2.

Table 2: Found themes and their associated keywords in the published GOs/NGOs frameworks

Theme	Total Key-words (Table 1)	Found Key-words	Frequency Count
Privacy	11	3	privacy (199), consent (65), anonymization (1)
Transparency	12	4	transparency (185), explainability (98), openness (6), disclosure (26)
Fairness	13	6	equity (16), diversity (20), bias (277), fairness (266), equality (63), discrimination (111)
Accountability	13	5	responsibility (128), governance (263), accountability (143), liability (44), oversight (64)
Safety	13	2	safety (175), monitoring (91)
Patient Autonomy	12	1	autonomy (53)
Innovation and Progress	10	2	innovation (90), progress (4)
Collaboration and Partnership	12	3	collaboration (30), partnership (23), cooperation (33)
Sustainability and Environmental Impact	12	1	sustainability (15)

Using Equation 1, the theme depth (D_i) for each theme T_i was calculated as follows: Privacy (27.27%), Transparency (33.33%), Fairness (46.15%), Accountability (38.46%), Safety (15.38%), Patient Autonomy (8.33%), Innovation and Progress (10.00%), Collaboration and Partnership (25.00%), and Sustainability and Environmental Impact (8.33%). The average theme depth across all themes was

23.58%. Given that each theme is represented within the corpus, the theme coverage (C) is calculated as 100%.

Consequently, using Equation 3, the thematic completeness index (TCI) was calculated as $23.58\% \times 100\% = 23.58\%$.

5.2 Evaluating Corporate Ethical Compliance

To assess whether AI implementations in the medical sector adhere to ethical guidelines, we execute Algorithm 2. It extracts ethical themes and keywords from company websites (see Algorithm 2 for details). Table 3 provides an example of the themes and keywords identified for Atomwise. This algorithm is also applied to all selected company websites to compile a list of ethical themes. Equations 1, 2, and 3 are applied to calculate the TCI for each company, with the results displayed in Table 4.

Table 3: Fount Themes and Keywords in Atomwise's website

Theme	**Total Key-words (Table 1)**	**Found Key-words**	**Frequency Count**
Privacy	11	2	privacy (34), consent (13)
Transparency	12	1	disclosure (1)
Fairness	13	1	bias (2)
Accountability	13	0	-
Safety	13	1	safety (5)
Patient Autonomy	12	0	-
Innovation and Progress	10	0	-
Collaboration and Partnership	12	2	partnership (2), collaboration (2)
Sustainability and Environmental Impact	12	0	-

6 ETHICAL GAP ANALYSIS AND IMPACT

The word cloud Figure 4 reveals ethical gaps, particularly in Patient Autonomy, Sustainability, and Innovation. Terms like "informed decision-making" are absent, indicating a lack of focus on patient empowerment in AI-driven decisions. Sustainability is underrepresented, with no mention of "environmental impact," reflecting insufficient attention to AI's long-term effects.

Figure 3 reveals several critical concerns that could significantly impact the responsible use of AI in healthcare. In **privacy**, missing elements such as *data protection* and *patient rights* highlight insufficient safeguards, while **transparency** lacks focus on *algorithmic transparency* and *user trust*, potentially reducing clarity in AI decision-making. **Fairness** covers bias but underrepresents *diversity* and *equity*, raising concerns about inclusive healthcare outcomes. **Accountability** misses essential aspects like *ethical standards* and *regulatory compliance*, and **safety** lacks attention to *clinical validation* and *patient safety*, risking the reliability of AI systems. **Patient autonomy** is underdeveloped, with limited emphasis on *informed decision-making* and *ethical consent*, which diminishes patient control in AI-driven care. Additionally, gaps in **innovation**, **collaboration**, and **sustainability**, especially regarding *research ethics* and *environmental impact*, pose long-term risks. These gaps, if unaddressed, could undermine trust, lead to biased outcomes, and compromise the ethical and sustainable use of AI in healthcare.

The TCI calculation (23.58%), in the ACC corpus shows that while all themes are mentioned (100% coverage), their depth is limited.

Table 4: Sample of different medical services

Area	Comp./Org. name	Application	Ethical implication	TCI
Diagnostics and Imaging	Aidoc [32]	Analyzes medical imaging in real time to help radiologists prioritize urgent cases	1) Potential for unequal treatment outcomes due to AI biases,2) Privacy and security of patient data, 3) Over-reliance on AI risking misdiagnosis, 4) Requirement for human-verifiable AI decisions, 5 Patient consent versus immediate data sharing needs, and 6) Dependence on technology in critical diagnoses.	12.87%
	Zebra Medical Vision [33]	Provides radiologists with AI tools to detect various medical conditions in images.		12.87%
	Viz.ai [34]	Detects and alerts stroke and other acute events in imaging.		10.94%
Clinical Workflow	Notable Health [35]	Automates administrative tasks in healthcare, like patient intake.	1) Genetic data privacy and bias, 2) Ethical access to genetic treatments, 3) Oncology data equity via AI, 4) Predictive models' impact on insurance, and 5) Accuracy in healthcare analytics.	6.66%
	Nuance [36]	AI-driven clinical documentation and speech recognition solutions.		8.46%
	TEMPUS [37]	Using AI to analyze data, personalizing cancer treatment with their extensive genomic database.		13.73%
Drug Discovery	Atomwise [38]	AI for small molecule drug discovery, focusing on molecular binding prediction.	1) Ethics and verification in AI drug discovery, 2) Data privacy and AI in treatment decisions, 3) AI efficiency vs. scientific and ethical rigor, and 4) Ethics of AI targeting aging and drug effects.	6.5%
	BenevolentAI [39]	Understands diseases and discovers new treatments by analyzing data.		12.01
	Exscientia [40]	Accelerates drug discovery process with AI.		4.81%
	Insilico Medicine [41]	AI for drug discovery, focusing on aging and other diseases.		4.88%

This indicates that each theme is touched on but not explored thoroughly, signaling a need for more in-depth discussion.

The TCI calculated for corporations shown in Table 4 highlights how companies align with ethical standards, with TCI scores ranging from 4.81% (Exscientia) to 13.73% (TEMPUS), revealing significant ethical gaps. Companies in diagnostics and imaging showed better adherence to themes like privacy and fairness, while the drug discovery sector lagged, particularly in privacy, bias, and consent. An average TCI of 9.37% highlights a substantial ethical gap in addressing AI ethics in healthcare.

Limitations

This study has several limitations. Primarily, it relies on thematic keyword analysis using NLP, which, while insightful, may not capture the nuanced application of ethical principles in practice. Additionally, the scope is limited to publicly available documents, potentially excluding internal practices that could offer a more comprehensive view. Future research incorporating direct surveys or interviews with AI developers, healthcare professionals, and regulatory bodies could provide a richer understanding of how these ethical principles are practically applied. Finally, the ethical gap analysis is based on a limited sample of prominent AI healthcare companies, which may not fully represent the sector. Expanding the sample to include smaller organizations and a wider range of geographic regions would improve the generalizability of these findings.

While TCI provides a robust model for ethical gap assessment, it has limitations. Keyword-based NLP analysis may miss some nuanced contexts, and TCI's general approach may not capture all domain-specific details. Despite these limitations, TCI is a practical, scalable tool that delivers actionable insights to advance ethical compliance.

7 CONCLUSION

This study presents an ethical gap analysis of AI applications in healthcare, revealing significant disparities between published guidelines and corporate practices in privacy, transparency, fairness, and accountability. While ethical themes are widely represented, their depth is limited, with critical areas such as patient autonomy, innovation, and sustainability underemphasized. Corporate compliance varies, with diagnostics companies showing moderate adherence and drug discovery firms displaying notable gaps, especially in privacy and bias.

These findings underscore the need for adaptive regulatory frameworks and stronger collaboration between developers, healthcare providers, and regulatory bodies to enhance accountability. Addressing these gaps will be essential for establishing AI as a trustworthy and ethical tool in healthcare.

The evolving nature of AI ethics requires dynamic compliance mechanisms. TCI's adaptable, NLP-based framework offers continuous assessment of ethical adherence in healthcare AI, helping stakeholders track and address ethical gaps as they emerge, supporting sustainable governance.

REFERENCES

[1] H. Salehi and R. Burgueño, "Emerging artificial intelligence methods in structural engineering," *Engineering Structures*, vol. 171, pp. 170–189, Sep. 2018.

[2] J. Morley, "The debate on the ethics of ai in health care: A reconstruction and critical review," Open Science Framework, Tech. Rep., Nov. 2019.

[3] H. Kluge, J. M. Martín-Moreno, N. Emiroglu, G. Rodier, E. Kelley, M. Vujnovic, and G. Permanand, "Strengthening global health security by embedding the international health regulations requirements into national health systems," *BMJ Global Health*, vol. 3, no. Suppl 1, p. e000656, Jan. 2018.

[4] F. Pesapane, C. Volonté, M. Codari, and F. Sardanelli, "Artificial intelligence as a medical device in radiology: Ethical and regulatory issues in europe and the united states," *Insights into Imaging*, vol. 9, no. 5, pp. 745–753, Oct. 2018.

[5] V. H. Buch, I. Ahmed, and M. Maruthappu, "Artificial intelligence in medicine: Current trends and future possibilities," *British Journal of General Practice*, vol. 68, no. 668, pp. 143–144, Mar. 2018.

[6] S. Graham, C. A. Depp, E. Lee, C. Nebeker, X. Tu, H.-C. Kim, and D. V. Jeste, "Artificial intelligence for mental health and mental illnesses: An overview," *Current Psychiatry Reports*, vol. 21, no. 11, 2019.

[7] WHO Ethical, "Ethics and governance of artificial intelligence for health," https://www.who.int/publications-detail-redirect/9789240029200, 2021, accessed: 2024-02-01.

[8] UNICEF Ethical, "Policy guidance on ai for children | unicef office of global insight & policy," https://www.unicef.org/globalinsight/reports/policy-guidance-ai-children, 2020, accessed: 2024-02-01.

[9] PSNet Ethics, "Home | psnet," https://psnet.ahrq.gov/, 2019, accessed: 2024-02-01.

[10] J. Shaw, F. Rudzicz, T. Jamieson, and A. Goldfarb, "Artificial intelligence and the implementation challenge," *Journal of Medical Internet Research*, vol. 21, no. 7, p. e13659, Jul. 2019.

[11] A. Vellido, "Societal issues concerning the application of artificial intelligence in medicine," *Kidney Diseases*, vol. 5, no. 1, pp. 11–17, 2019.

[12] M. D. McCradden, J. A. Anderson, E. A. Stephenson, E. Drysdale, L. Erdman, A. Goldenberg, and R. Z. Shaul, "A research ethics framework for the clinical translation of healthcare machine learning," *The American Journal of Bioethics*, vol. 22, no. 5, pp. 8–22, May 2022.

[13] K. P. Reddy, M. Satish, A. Prakash, S. M. Babu, P. P. Kumar, and B. S. Devi, "Machine learning revolution in early disease detection for healthcare: Advancements, challenges, and future prospects," pp. 638–643, Oct. 2023.

[14] K. Spector-Bagdady, V. Rahimzadeh, K. Jaffe, and J. Moreno, "Promoting ethical deployment of artificial intelligence and machine learning in healthcare," *The American Journal of Bioethics*, vol. 22, no. 5, pp. 4–7, May 2022.

[15] S. Pasricha, "Ai ethics in smart healthcare," *IEEE Consumer Electronics Magazine*, vol. 12, no. 4, pp. 12–20, Jul. 2023.

[16] E. Tabassi, "Artificial intelligence risk management framework (ai rmf 1.0)," National Institute of Standards and Technology (U.S.), Gaithersburg, MD, Tech. Rep. NIST AI 100-1, Jan. 2023, accessed: 2024-08-11. [Online]. Available: http://nvlpubs.nist.gov/nistpubs/ai/NIST.AI.100-1.pdf

[17] S. Yadav, P. Mane, V. K. Swarnkar, S. K. Rawandale, A. S. Patil, K. S. Katke, and N. Bhat, "The role of ai in healthcare policy development and management," in *Proceedings of the 2023 International Conference on Artificial Intelligence for Innovations in Healthcare Industries (ICAIIHI)*, Dec. 2023, pp. 1–6.

[18] S. Nasir, R. A. Khan, and S. Bai, "Ethical framework for harnessing the power of ai in healthcare and beyond," *IEEE Access*, vol. 12, pp. 31 014–31 035, 2024.

[19] P. Kumar, S. Chauhan, and L. K. Awasthi, "Artificial intelligence in healthcare: Review, ethics, trust challenges & future research directions," *Engineering Applications of Artificial Intelligence*, vol. 120, p. 105894, Apr. 2023.

[20] M. Mohammad Amini, M. Jesus, D. Fanaei Sheikholeslami, P. Alves, A. Hassanzadeh Benam, and F. Hariri, "Artificial intelligence ethics and challenges in healthcare applications: A comprehensive review in the context of the european gdpr mandate," *Machine Learning and Knowledge Extraction*, vol. 5, no. 3, pp. 1023–1035, Aug. 2023, accessed: 2024-10-26. [Online]. Available: https://www.mdpi.com/2504-4990/5/3/53

[21] A. K. Saini, R. Yadav, S. S. Shekhawat, P. Vats, S. L. Yadav, A. P. Singh, and S. S. Biswas, "Ai in healthcare: Navigating the ethical, legal, and social implications for improved patient outcomes," in *Proceedings of the 2023 International Conference on Data Science and Network Security (ICDSNS)*. IEEE, Jul. 2023, pp. 1–8, accessed: 2024-10-26. [Online]. Available: https://ieeexplore.ieee.org/document/10245763/

[22] L. N. Tidjon and F. Khomh, "The different faces of ai ethics across the world: A principle-to-practice gap analysis," *IEEE Transactions on Artificial Intelligence*, vol. 4, no. 4, pp. 820–839, Aug. 2023, accessed: 2024-05-25.

[23] W. E. Forum, "9 ethical ai principles for organizations to follow," Jun. 2021, accessed: 20-July-2024. [Online]. Available: https://www.weforum.org/agenda/2021/06/ethical-principles-for-ai/

[24] E. Tabassi, "Artificial intelligence risk management framework (ai rmf 1.0)," National Institute of Standards and Technology (U.S.), Gaithersburg, MD, Tech. Rep. NIST AI 100-1, Jan. 2023, accessed: 2024-07-20.

[25] N. S. Arden, A. C. Fisher, K. Tyner, L. X. Yu, S. L. Lee, and M. Kopcha, "Industry 4.0 for pharmaceutical manufacturing: Preparing for the smart factories of the future," *International Journal of Pharmaceutics*, vol. 602, p. 120554, Jun. 2021, accessed: 2024-07-20.

[26] UNESCO, "Recommendation on the ethics of artificial intelligence," 2021, accessed: 20-July-2024. [Online]. Available: https://www.unesco.org/en/articles/recommendation-ethics-artificial-intelligence

[27] J. Fjeld, N. Achten, H. Hilligoss, A. Nagy, and M. Srikumar, "Principled artificial intelligence: Mapping consensus in ethical and rights-based approaches to principles for ai," Rochester, NY, Jan. 2020, accessed: 20-July-2024. [Online]. Available: https://doi.org/10.2139/ssrn.3518482

[28] O. for Economic Co-operation and D. (OECD), "Oecd framework for the classification of ai systems," 2022, accessed: 20-July-2024.

[29] E. Commission, "European group on ethics in science and new technologies," Jun. 2024, accessed: 20-July-2024. [Online]. Available: https://research-and-innovation.ec.europa.eu/strategy/support-policy-making/scientific-support-eu-policies/european-group-ethics_en

[30] I. C. O. (ICO), "Guidance on ai and data protection," Jul. 2024, accessed: 20-July-2024. [Online]. Available: https://ico.org.uk/for-organisations/uk-gdpr-guidance-and-resources/artificial-intelligence/guidance-on-ai-and-data-protection/

[31] I. O. for Standardization (ISO), "Artificial intelligence," Jul. 2024, accessed: 20-July-2024. [Online]. Available: https://www.iso.org/sectors/it-technologies/ai

[32] Aidoc, "Always on healthcare ai," 2024, accessed: 16-July-2024. [Online]. Available: https://www.aidoc.com/

[33] Z. M. Vision, "Zebra medical vision website," 2024, accessed: 16-July-2024. [Online]. Available: http://www.zebra-med.com/

[34] Viz.ai, "Ai-powered care coordination," 2024, [Online; accessed 16-July-2024]. [Online]. Available: https://www.viz.ai/

[35] N. Health, "The ai platform for healthcare operations," 2024, accessed: 16-July-2024. [Online]. Available: https://www.notablehealth.com/

[36] N. Communications, "Conversational ai for healthcare and customer engagement," 2024, accessed: 16-July-2024. [Online]. Available: https://www.nuance.com/index.html

[37] Tempus, "Ai-enabled precision medicine," 2024, accessed: 21-August-2024. [Online]. Available: https://www.tempus.com/

[38] Atomwise, "Home page," 2024, accessed: 16-July-2024. [Online]. Available: https://www.atomwise.com

[39] BenevolentAI, "Ai drug discovery | ai pharma," 2024, accessed: 16-July-2024. [Online]. Available: https://www.benevolent.com/
[40] Exscientia, "Exscientia | ai drug discovery | pharmatech," 2024, accessed: 16-July-2024. [Online]. Available: https://www.exscientia.com/
[41] I. Medicine, "Main page," 2024, accessed: 16-July-2024. [Online]. Available: https://insilico.com