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Assessing the accuracy and consistency of ChatGPT in clinical pharmacy management: A preliminary analysis with clinical pharmacy experts worldwide

Zahraa Al-Dujaili [a], Sarah Omari [b], Jey Pillai [a], Achraf Al Faraj [a,*]

[a] College of Pharmacy, American University of Iraq – Baghdad (AUIB), Baghdad, Iraq
[b] Department of Epidemiology and Population Health, American University of Beirut (AUB), Beirut, Lebanon

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ABSTRACT

Background: ChatGPT conversation system has ushered in a revolutionary new era of information retrieval and stands as one of the fastest-growing platforms. Clinical pharmacy, as a dynamic discipline, necessitates an advanced comprehension of drugs and diseases. The process of decision-making in clinical pharmacy demands accuracy and consistency in medical information, as it directly affects patient safety.

Objective: The objective was to evaluate ChatGPT's accuracy and consistency in managing pharmacotherapy cases across multiple time points. Additionally, input was gathered from global clinical pharmacy experts, and the agreement between ChatGPT's responses and those of clinical pharmacy experts worldwide was assessed.

Methods: A set of 20 cases of pharmacotherapy was entered into ChatGPT at three different time points. Reliability analysis was performed using inter-rater reliability to measure the accuracy of the output generated by ChatGPT at each time point. Test-retest reliability was performed to measure the consistency of the output generated by ChatGPT across the three time points. Pharmacy expert performance was evaluated, and the overall results were compared.

Results: ChatGPT achieved a hit rate of 70.83% at week 1, 79.2% at week 3, and 75% at week 5. The percent agreement between weeks 1 and 3 was 79.2%, whereas it was 87.5% between weeks 3 and 5, and 83.3% between weeks 1 and 5. In contrast, accuracy rates among clinical pharmacy experts showed considerable variation according to their geographic location. The highest agreement between clinical pharmacist responses and ChatGPT responses was observed at the last time point examined.

Conclusions: Overall, the analysis suggested that ChatGPT is capable of generating clinically relevant pharmaceutical information, albeit with some variation in accuracy and consistency. It should be noted that clinical pharmacy experts worldwide may provide varying degrees of accuracy depending on their expertise. This study highlights the potential of AI chatbots in clinical pharmacy.

1. Introduction

In November 2022, ChatGPT (Generative Pre-Trained Transform) ushered in a new era of information retrieval.[1] ChatGPT is the prototype of a novel artificial intelligence (AI) chatbot developed by OpenAI that has taken the world by storm in recent months. In its first few months of availability, more than 100 million users conversed with its deep-learning algorithms, which were trained using massive amounts of data to generate human-like responses.[2–4] The concept of algorithm amplification has been used to improve ChatGPT's learning models with human feedback, resulting in better contextual understanding.[5] OpenAI's GPT is the first in a series of highly scaled language models that belong to the family of large language models known as autoregressive language models.[6] The powerful, breakthrough technology of conversational AI is on the rise, and it is expected to improve even better with additional training, optimization, and function.[7,8] ChatGPT may be the first model to better represent the combination of clinical knowledge and conversational interaction and be able to provide coherent and informative responses on medical topics. However, for this to be beneficial, ChatGPT must perform comparably to a human in assessing medical knowledge and reasoning for patient safety.[2]

It is worth noting that drug-related issues represent a significant

* Corresponding author. College of Pharmacy, American University of Iraq – Baghdad (AUIB), Airport Road, Baghdad, 10023, Iraq.
E-mail address: achraf.alfaraj@gmail.com (A. Al Faraj).

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global burden for patients and health systems. Clinical pharmacy is a dynamic health science discipline whose mission is to optimize drug therapy and prevent disease through interventions such as medication reconciliation, targeted education, and minimizing polypharmacy.[9,10] Although the role of clinical pharmacy has progressed over the past decade, it remains underdeveloped in various parts of the world.[11] Nevertheless, clinical pharmacy is a term that encompasses various definitions and is understood differently throughout the world. For some, it is closely associated with "patient care," while others associate it more with "managing the appropriate use of medicines".[12] However, bridging clinical expertise and knowledge to improve medication management with information technology is one way to increase the efficiency and effectiveness of organizational operations.[13] With continued advances in clinical practice, it is critical to provide accurate drug-related information to the end user for clinical decision making.[14] AI, machine learning and deep learning will be the future of healthcare, including application to medication management.[15] Developments are underway to help in many areas, such as selecting drug therapy, monitoring adherence, and alerting patients to potential drug-drug interactions or adverse events. When developing and implementing AI tools, it is important to ensure that the data collected and used are meaningful, up-to-date, and consistent.[13]

In a previous study of the performance and risk associated with using ChatGPT to answer 50 drug-related questions, which was assessed by six senior hospital pharmacists, it was found that only 13 of 50 responses were substantively accurate and contained enough information to initiate treatment without risk to the patient. In addition, ChatGPT responses varied over time when entered repeatedly, and only three of 12 responses were consistent, indicating little to no reproducibility.[16] In addition, experts have conducted online conversations using ChatGPT as case studies and found that diagnoses provided by ChatGPT are often incomplete. For example, when patients present common symptoms such as fever, ChatGPT recommends antipyretics but has difficulty assessing other underlying conditions such as infections.[17] Therefore, determining the accuracy of output from AI chatbots is critical for health and medical communication, as accurate information is important for clinical practice and patient safety. To date, the main objective of this study has been to evaluate the potential utility of an AI chatbot for pharmacotherapy case management in clinical pharmacy. To evaluate the capabilities of the AI chatbot, several pharmacotherapy cases were developed covering a wide range of medical specialties. These were designed with brief scenarios, each followed by relevant questions to simulate real-world clinical scenarios. The accuracy and consistency of ChatGPT-generated interpretations were assessed at three time points, each two weeks apart. In a second step of this research, clinical pharmaceutical experts from different countries and continents were consulted about the same twenty pharmacotherapy cases and the agreement between ChatGPT output and those of clinical pharmaceutical experts from around the world was assessed.

2. Methods

2.1. Study design and setting

In this study design, a preliminary analysis consisted of twenty pharmacotherapy cases, each with 2–4 questions (48 questions in total), were generated in February 2023 using a computer-assisted consultation format (Supplementary Data 1). These were developed covering a wide range of medical specialties, including infectious diseases, cardiovascular disease and stroke, obstetrics and gynecology, endocrinology, urology, clinical cessation, pulmonary disease, and mental disorders. Decision making for each case was based on evidence-based recommendations and clinical pharmacy practice guidelines, which can be found in Supplementary Data 2. Cases were designed by a clinical pharmacy expert, a board-certified pharmacotherapy specialist with extensive clinical hospital experience, with brief scenarios, each followed by relevant questions to simulate real-world clinical scenarios. In addition, these cases were carefully reviewed for validity and reliability by a panel of five clinical pharmacy experts with extensive experience, each with more than ten years of clinical pharmacy experience. The review process included a thorough evaluation of the content of each case, to ensure its accuracy and relevance. The clinical pharmacists who had participated in the pilot study were excluded from the final analysis to ensure feasibility.

2.2. Accuracy of ChatGPT outputs and consistency over time

First, the accuracy and consistency of ChatGPT-generated interpretations were evaluated at three time points, each two weeks apart. For each case, a new chat session was started (without any questions having been asked previously in the session). This was to prevent previous output on a particular case from influencing the model's response. In addition, questions about the corresponding pharmacotherapy case were entered into ChatGPT-3.5 (OpenAI, L.L.C., San Francisco, CA, USA) as part of an ongoing conversation in the same chat session. Each question was tested at three different time points (weeks 1, 3, and 5) with a two-week interval between February and March 2023. The twenty pharmacotherapy cases with all prompts can be found in Supplementary Data 3.

Two other senior clinical pharmacists who are experts in the field, independently rated the ChatGPT-generated responses based on two criteria: Accuracy and Completeness (Table 1). In this study, accuracy was defined as the correctness of the outputs, while completeness referred to the comprehensiveness of the responses. Each of the 48 case responses received a numerical score based on the rubrics listed in Table 2. It is worth noting that there were no discrepancies between raters.

Reliability analysis was conducted to assess both inter-rater reliability and test-retest reliability. Inter-rater reliability was used to evaluate the agreement between the ChatGPT -generated results at each time point. Test-retest reliability was used to measure the consistency of ChatGPT-generated results across the three time points.

2.3. Evaluation of clinical pharmacy experts' answers

In a second step, clinical pharmacy experts from different countries and continents were consulted on the same twenty pharmacotherapy cases. The computerized consultation format was shared with twenty clinical pharmacy experts from around the world at one point in time. To ensure an unbiased evaluation process, clinical pharmacy experts were contacted independently through professional networks of universities in different countries. It is important to note that none of these experts are authors of the present work and that they agreed to be consulted for the twenty cases of pharmacotherapy. For the evaluation of the expert

Table 1
Scoring rubric for rating answers generated by ChatGPT.

	Complete answer provided	Incomplete answer provided
Correct answer stated	The answer provided was comprehensive, responding to all the branches of the prompt, and a correct and accurate answer was given as per the answer key.	The answer provided was not comprehensive: it only answered some of the prompts and not all of them. However, for the parts answered, the answer was correct. Alternatively, the score can also be given when the response is partially correct, partially incorrect.
Incorrect answer stated/No specific answer stated	The prompt was completely addressed, but the answers provided are incorrect.	The prompt was neither completely addressed, nor were the answers provided correct.

Table 2
Scoring guide for answers generated by ChatGPT.

	Complete answer provided	Incomplete answer provided
Correct answer stated	2	1
Incorrect answer stated/No specific answer stated	0	0

responses, each of the 48 case scenarios was scored either 0 (incorrect) or 1 (correct).

2.4. Agreement between ChatGPT output and clinical pharmacy experts' response

The final step was to assess the agreement between ChatGPT results and those of clinical pharmacy experts from around the world. Percent agreement was calculated to assess the agreement between each expert's response and ChatGPT at each time point. These coefficients were then described in terms of their range and distribution across countries.

2.5. Bias

The aim of this study was to explore the agreement between ChatGPT and clinical pharmacy experts. The selection criteria for clinical pharmacy experts who participated in the consultation was based on a transparent selection set indicating desired expertise and experience. These selection criteria were listed in the computerized consultation form (Supplementary Data 1 and 4). These criteria ensured that the selected experts had the necessary knowledge and skills relevant to the research objectives.

2.6. Statistical methods

All analyses were conducted using Stata software (version 14; 2015). The assessment of inter-rater reliability and test-retest reliability was performed using Kappa test. In order to evaluate the accuracy of both ChatGPT responses and those provided by the twenty clinical pharmacy experts, the correctness rate of each item was calculated. To examine the agreement between the responses across the three time points (weeks 1, 3, and 5), the kappa statistic was computed and interpreted at the 0.05 significance level.

3. Results

3.1. Accuracy of ChatGPT outputs and consistency over time

The accuracy of ChatGPT outputs for pharmacotherapy cases was first assessed at three specific time points: week 1, week 3, and week 5. At week 1, ChatGPT achieved a hit rate of 70.83%. This rate increased to 79.2% in the third week and decreased to 75% in the fifth week. The agreement between ChatGPT-generated scores was then examined at each time point. Interestingly, the percentage agreement between the first and third week was only 79.2%, while it was 87.5% between the third and fifth week. The percentage agreement between weeks 1 and 5 was 83.3%. All kappa statistics were significant, indicating moderate positive agreement between each pair of ChatGPT assessments across the three time points (Table 3).

Table 3
Percent Agreement (PA) and Kappa statistic between ChatGPT ratings across three timepoints (week 1, week 3, and week 5). *: P-value<0.05.

		ChatGPT w1	ChatGPT w1
ChatGPT w3	PA	79.2%	87.5%
	Kappa	**0.45***	**0.647***
ChatGPT w5	PA	83.3%	-
	Kappa	**0.579***	-

3.2. Evaluation of expert answers

On average, clinical pharmacy experts had an accuracy rate of 69.2% which fluctuated between 47.9% and 93.8%. The average rate by geographic residence of clinical pharmacy experts was 72.5%, 68.3%, and 67.7% for Europe, North America, and Asia, respectively. The frequency of the correct answer to the question of clinical pharmacy experts in pharmacotherapeutic consultation is shown in Table 4.

3.3. Agreement between ChatGPT output and clinical pharmacy experts' response

Table 5 shows a matrix of the results in terms of percentage agreement between the responses of each clinical pharmacy expert and ChatGPT at each time point. When assessing ChatGPT outputs in week 1, agreement was only found with E10 (USA) and E15 (USA) (Kappa = 0.294 and 0.556 respectively). On the other hand, more clinical pharmacy expert agreement was found with ChatGPT outputs at week 3, where a significant Kappa statistic was found with E7, E8, E9, E10, E12, E15, E16, and E19 ranging between 0.26 and 0.62. All these clinical pharmacy experts are from USA except for E9 who is from Lebanon, E12 from Sweden, and E16 from Belgium. Finally, the most clinical pharmacy expert agreement with ChatGPT was found at week 5 with significant Kappa statistics found with each of E8, E10, E12, E14, E15, E17, E18, E19, AND E20, ranging between 0.27 and 0.43. All the clinical Pharmacy experts are from USA except for E16 who is from Belgium.

4. Discussion

The main objective of the current study was to evaluate the potential utility of an AI chatbot for pharmacotherapy case management in clinical pharmacy. As mentioned earlier, this study provides an assessment of the performance of ChatGPT in different areas of pharmacotherapy. To date, there are few studies documenting the use and various aspects of ChatGPT in pharmacy and healthcare settings. Nevertheless, ChatGPT can help with medication management by providing dosing instructions and information about potential side effects and interactions.[18] Ensuring accuracy and consistency in the pharmaceutical context is critical for patient safety.[19] In light of this context, data from the current study

Table 4
Frequency of expert correct answers per question (n = 20).

Question	Count (%)	Question	Count (%)
Q1	15 (75)	Q25	2 (10)
Q2	4 (20)	Q26	19 (95)
Q3	10 (50)	Q27	19 (95)
Q4	12 (60)	Q28	19 (95)
Q5	17 (85)	Q29	11 (55)
Q6	18 (90)	Q30	13 (65)
Q7	13 (65)	Q31	20 (100)
Q8	13 (65)	Q32	15 (75)
Q9	4 (20)	Q33	11 (55)
Q10	17 (85)	Q34	13 (65)
Q11	18 (90)	Q35	14 (70)
Q12	19 (95)	Q36	20 (100)
Q13	19 (95)	Q37	4 (20)
Q14	19 (95)	Q38	13 (65)
Q15	11 (55)	Q39	10 (50)
Q16	20 (11)	Q40	12 (60)
Q17	20 (11)	Q41	14 (70)
Q18	19 (95)	Q42	16 (80)
Q19	15 (75)	Q43	15 (75)
Q20	10 (50)	Q44	13 (65)
Q21	20 (11)	Q45	17 (85)
Q22	16 (80)	Q46	2 (10)
Q23	17 (85)	Q47	5 (25)
Q24	9 (45)	Q48	12 (60)

Table 5
Percent Agreement (PA) and Kappa statistics for each clinical pharmacy expert rating with ChatGPT ratings at the three timepoints (week 1, week 5, and week 5).

Country		E1	E2	E3	E4	E5	E6	E7	E8	E9	E10
		USA	India	USA	France	Denmark	Canada	USA	USA	Lebanon	USA
ChatGPT w1	**PA (%)**	68.8%	60.4%	60.4%	60.4%	56.3%	66.7%	62.5%	68.8%	58.3%	70.8%
	Kappa	0.193	0.165	0.222	−0.123	0.14	0.042	0.129	0.259	0.104	**0.294***
ChatGPT w3	**PA (%)**	68.8%	64.6%	56.3%	72.9%	52.1%	72.9%	70.8%	72.9%	66.7%	75.0%
	Kappa	0.086	0.236	0.146	0.077	0.064	0.148	**0.276***	**0.307***	**0.262***	**0.339***
ChatGPT w5	**PA (%)**	68.8%	64.6%	56.3%	56.3%	60.4%	68.8%	66.7%	72.9%	62.5%	75.0%
	Kappa	0.143	0.244	0.143	−0.97	0.224	0.091	0.2	**0.333***	0.182	**0.368***
Country		E11	E12	E13	E14	E15	E16	E17	E18	E19	E20
		Kuwait	Sweden	India	USA	USA	Belgium	Qatar	Kuwait	USA	Germany
ChatGPT w1	**PA (%)**	58.3%	60.4%	58.3%	58.3%	81.3%	68.8%	70.8%	72.9%	62.5%	70.8%
	Kappa	0.032	0.222	0.11	−0.053	**0.556***	0.016	0.152	0.232	0.194	0.152
ChatGPT w3	**PA (%)**	62.5%	64.6%	60.4%	70.8%	85.4%	81.3%	79.2%	77.1%	66.7%	79.2%
	Kappa	0.069	**0.308***	0.189	0.176	**0.627***	**0.234***	0.259	0.219	**0.262***	0.259
ChatGPT w5	**PA (%)**	66.7%	64.6%	56.3%	75.0%	77.1%	77.1%	79.2%	77.1%	66.7%	79.2%
	Kappa	0.2	**0.306***	0.106	**0.333***	**0.436***	0.185	**0.333***	**0.29***	**0.273***	**0.333***

PA: Percent agreement*p-value<0.05.

suggested that accuracy in pharmacotherapy case processing varies over time. Although ChatGPT made initial progress, accuracy either leveled off or later declined slightly. The moderately positive consistency of results across the three time points (Table 3) indicated that ChatGPT was able to understand context and engage in coherent conversations about pharmacotherapy issues and reflected the promise of ChatGPT for providing comprehensive pharmaceutical information.[19] Compared to a previous study, the benefits and risks associated with ChatGPT were examined using a real-world sample of 50 drug-related questions. This study showed that ChatGPT answered the majority of questions incorrectly or partially incorrectly. These results indicated that the practicality of using AI applications for drug-related information remains questionable due to challenges such as inaccurate content, lack of references, and lack of reproducibility.[16]

Second, the hit rate of clinical pharmacy experts was 69.2%, with a range of variation among the twenty participants from 47.9% to 93.8%. This variation suggests differences in individual expertise and specific clinical pharmacy practices and principles across regions. On average, experts from Europe had the highest hit rate, followed by those from North America and Asia. The United Kingdom Clinical Pharmacy Association defines clinical pharmacy as the comprehensive field that encompasses the knowledge, skills, and attitudes pharmacists need to actively contribute to patient care. According to the European Society of Clinical Pharmacy, it is a medical specialty that promotes the safe and effective use of medical devices and medicines.[12] The American College of Clinical Pharmacy, on the other hand, defines clinical pharmacy in shorthand as the branch of pharmacy concerned with the science and practice of the use of medicines.[20,21] The practice of clinical pharmacy follows the philosophy of pharmaceutical care; it combines a compassionate attitude with professional therapeutic knowledge, experience, and judgment to ensure the best possible outcome for the patient.[12] Some countries in the Middle East have attempted to adopt the principles of clinical pharmacy from the United States.[22] Further research with larger samples is needed to fully understand the factors contributing to these differences and to identify possible strategies to improve clinical pharmacy practice.

Furthermore, results showed that agreement between clinical pharmacy experts and ChatGPT varied at different time points. At baseline, in week 1, agreement was limited, but increased in weeks 3 and 5. However, it is important to note that ChatGPT is neither a licensed medical professional nor a live system. It generates results based on learned data and may not always have access to the latest information or current evidence-based recommendations and guidelines for clinical pharmacy practice.[19] In contrast to the current study, a previous study examined the performance of ChatGPT on the pharmacist licensure examination in Taiwan. The results showed that ChatGPT-3.5 did not pass the pharmacist licensure examination in Taiwan. Specifically, graphical questions, chemical formulas, and tables were excluded from evaluation in this study. Despite these limitations, AI has the potential to improve rapidly through the use of Deep Learning.[5] In addition, a previous cross-sectional study examined the ability of ChatGPT to provide high-quality, insightful answers to patient questions using a public and unidentifiable database of questions from a public social media forum. Chatbot answers were generated by entering the original question into a new session (with no previous questions asked in the session). This study demonstrated that ChatGPT generates high-quality and insightful responses to patient questions in an online forum and illustrates the strengths of using AI in healthcare communications. However, investigation in the clinical setting is recommended, including the use of the chatbot to generate answers that can be reviewed by physicians.[23]

Finally, the current study highlighted certain limitations of ChatGPT, such as performing irrelevant pharmacokinetic calculations and lacking clinical considerations and human judgment (ie, the third question of the first case; Supplementary Data). However, despite these limitations, ChatGPT provided a coherent and comprehensive set of responses. Consequently, it could serve as a supportive patient safety tool, especially given its status as an unlicensed pharmacist. Nonetheless, the current study underscores the importance of considering ChatGPT as a valuable adjunct to human clinical expertise. The results highlight the potential utility of AI chatbot in the clinical setting, and further exploration of this technology in healthcare is warranted. Although AI chatbot can provide additional information and insight, it should never replace the expertise and clinical judgment of clinical pharmacy experts.[24]

5. Strength and weakness

The objective of the current study was to analyze the ability of ChatGPT to provide comprehensive clinical pharmacy information. The study design allowed direct interaction between ChatGPT and human experts in pharmacotherapy case management. To prevent algorithm amplification, cases were created and validated by a panel of clinical pharmacy experts, and cases were not based on previously published cases. The limitation of the current study could result from potential bias in participant selection. As there were no specific inclusion criteria for clinical pharmacy experts, certain characteristics might not be adequately represented. In addition, the hit rate of clinical pharmacy experts varied considerably among the twenty participants. Further research with larger samples may be needed to fully understand the factors contributing to the differences and identify potential strategies to improve clinical pharmacy practice. Longitudinal studies with longer

observation periods could also provide a more comprehensive understanding. It should be noted, however there is a paucity of literature on the use and various aspects of ChatGPT in clinical pharmacy, making direct comparison of the current findings difficult.

6. Conclusions

Two key research questions were addressed: the accuracy and consistency of ChatGPT and the agreement between ChatGPT and clinical pharmacy experts. The overall analysis suggests that ChatGPT can generate coherent, comprehensive, and clinically relevant pharmaceutical information, although accuracy and consistency vary somewhat. Despite its promising capabilities, the study pointed to certain limitations of ChatGPT, such as irrelevant pharmacokinetic calculations and a lack of clinical reasoning. Further studies with longer evaluation periods and larger samples are needed to gain a more comprehensive understanding of ChatGPT's performance in clinical pharmacy practice and to fully explore and exploit the possibilities of AI technology in the pharmaceutical field. In addition, further research is also needed to understand the factors contributing to individual and geographic differences among clinical pharmacy experts and to identify strategies to improve clinical pharmacy practice on a global scale. Overall, the study provides valuable insights into the potential applications of ChatGPT in clinical pharmacy and highlights the importance of a collaborative approach between ChatGPT and human expertise to ensure optimal patient care, emphasizing the complementary role of AI chatbot assistants alongside human clinical expertise.

Ethics statement

The study was an analysis of pharmacotherapy consultations conducted by ChatGPT and clinical pharmacy experts worldwide, and no human subjects were included. Consequently, formal institutional review board approval was not required.

CRediT author statement

Zahraa Al-Dujaili: Methodology, Validation, Investigation, Resources, Data Curation, Writing - Original Draft, Visualization. Sarah Omari: Formal analysis. Jey Pillai: Methodology. Achraf Al Faraj: Conceptualization, Data Curation, Writing - Review & Editing, Visualization, Supervision, Project administration.

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Ethics statement

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Declaration of competing interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sapharm.2023.08.012.

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