BMJ Health & Care Informatics

Perioperative application of chatbots: a systematic review and meta-analysis

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To cite: Lin S-J, Sun C-Y, Chen D-N, *et al*. Perioperative application of chatbots: a systematic review and meta-analysis. *BMJ Health Care Inform* 2024;**31**:e100985. doi:10.1136/bmjhci-2023-100985

► Additional supplemental material is published online only. To view, please visit the journal online (https://doi.org/10.1136/bmjhci-2023-100985).

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Received 01 December 2023
Accepted 02 April 2024

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ABSTRACT

Background and objectives Patient–clinician communication and shared decision-making face challenges in the perioperative period. Chatbots have emerged as valuable support tools in perioperative care. A simultaneous and complete comparison of overall benefits and harm of chatbot application is conducted.

Materials MEDLINE, EMBASE and the Cochrane Library were systematically searched for studies published before May 2023 on the benefits and harm of chatbots used in the perioperative period. The major outcomes assessed were patient satisfaction and knowledge acquisition. Untransformed proportion (PR) with a 95% CI was used for the analysis of continuous data. Risk of bias was assessed using the Cochrane Risk of Bias assessment tool version 2 and the Methodological Index for Non-Randomised Studies.

Results Eight trials comprising 1073 adults from four countries were included. Most interventions (n=5, 62.5%) targeted perioperative care in orthopaedics. Most interventions use rule-based chatbots (n=7, 87.5%). This meta-analysis found that the majority of the participants were satisfied with the use of chatbots (mean proportion=0.73; 95% CI: 0.62 to 0.85), and agreed that they gained knowledge in their perioperative period (mean proportion=0.80; 95% CI: 0.74 to 0.87).

Conclusion This review demonstrates that perioperative chatbots are well received by the majority of patients with no reports of harm to-date. Chatbots may be considered as an aid in perioperative communication between patients and clinicians and shared decision-making. These findings may be used to guide the healthcare providers, policymakers and researchers for enhancing perioperative care.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Chatbots are prevailing in medical care, with great potential helping patients and healthcare providers.

WHAT THIS STUDY ADDS

⇒ The study conducts a systematic evaluation of chatbot interventions in perioperative care to find high majority of people are satisfied and have acquired knowledge. Other measures provide an insight into recent clinical application of chatbots.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This study could help healthcare providers, policymakers and researchers to properly implement chatbot systems to improve perioperative care considering the limitations recognised.

INTRODUCTION

Background

Perioperative communication remains a major challenge in healthcare settings. Postoperative regret and patient dissatisfaction are unfavourable situations. Despite advancements in surgical techniques, anaesthesia and perioperative care, these problems can still occur and affect patient outcomes.

The collection of patient data through preoperative assessment and consultation (PAC) can reduce postoperative complications.[1] PAC aims to reduce surgery-related and anesthesia-related risks, improve perioperative care quality and obtain informed consent for anaesthesia.[2] Qualities of PAC including communication, education and shared decision-making are associated with patient regret. Especially, patients are at higher risk of regret when they are less involved in the medical decision-making process.[3] However, challenges persist in data collection and shared decision-making, including knowledge gap between patients and physicians, time and personnel constraint and miscommunication due to sensitive information. These dilemmas can hinder the provision of effective consultations and deliberation.[4–6] Chatbots offer advantages of providing higher feasibility levels and response rates, visualised results and improved patient–clinician communication.[7–10] Such channels reduce complications, promote shared decision-making and uphold patients' rights and interests.

Chatbots and perioperative care

The perioperative period, encompassing the preoperative, intraoperative and postoperative phases, is a critical time for patients to make informed decisions and actively participate in their care.[11] Chatbots, which simulate human conversations, have emerged as valuable tools in perioperative care, revolutionising interactions between healthcare providers and patients.[12 13]

In the 1960s, ELIZA, the first chatbot, was developed by Joseph Weizenbaum at Massachusetts Institute of Technology.[14] With advancements in natural language processing, artificial intelligence (AI) and computing power, conversational agents, also known as chatbots, have emerged as versatile tools in medicine. These computer programmes simulate human-like conversation and have offer versatile applications in healthcare, such as screening for health conditions, counselling and providing at-home health management support.[15]

Research on chatbots has increased substantially since the year 2000. From 2015 to 2020, the output of search results from Scopus for the keywords 'chatbot', 'conversational agents' and 'conversation system' increased by 128%.[16] Chatbots have been successfully employed for various medical purposes,[17 18] such as type 2 diabetes risk reduction,[19 20] sleep quality improvement,[21] asthma knowledge acquisition,[22] and depression relief.[23]

Recently, researchers have explored their possible application in perioperative care.[24] Powered by AI or healthcare information retrieval systems, chatbots exhibit promise as decision support tools, serving to assist physicians and patients rather than replace medical professionals.[25] They bridge communication gaps by engaging with patients, delivering timely educational content, and providing tailored support.

The use of chatbots in the perioperative period has increased rapidly, with their proved abilities of pain management,[26] orthopaedic patient follow-up[27] and treatment adherence enhancement.[28] The widespread use of ChatGPT[29] has promoted calls for a comprehensive evaluation of the perioperative application of chatbots to guide future development and implementation efforts.[30] This is the first systematic review and meta-analysis to conduct a simultaneous and complete comparison of overall benefits and harm of perioperative chatbots. Our finding aims to provide valuable insights for healthcare providers, policymakers and researchers for enhancing chatbot system application in perioperative care.

METHODS

Protocol and registration

This systematic review conducted was designed and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement[31] and AMSTAR (Assessing the methodological quality of systematic reviews) 2 Guidelines.[32] The protocol was registered on International Platform of Registered Systematic Review and Meta-analysis Protocols database (INPLASY Number: INPLASY202370080) and Research Registry (UIN: reviewregistry1706).[33]

Search strategy

We conducted a comprehensive search of electronic databases, including MEDLINE, EMBASE and the Cochrane Library, from their inception to May 2023. The search strategy involved using free text and search strings related to two groups of core concepts. The first group encompassed keywords related to bidirectional chatbots, such as 'chatbot', 'conversational agent' and 'conversational system'. The second group included keywords related to the perioperative period, such as 'surgery,' 'intervention,' 'preoperative,' 'postoperative,' or 'perioperative'. Keywords were organised using the following three approaches: (1) To search for all terms that begin with a keyword, the word is typed followed by an asterisk (*) (eg, surgery* for surgery and surgeries). (2) Keywords within one group are combined using the OR operator (eg, 'chatbot' OR 'conversational agent'). (3) Keywords across different groups are linked using the AND operator (eg, 'chatbot' AND 'perioperative' AND 'intervention').

Inclusion and exclusion criteria

Three independent reviewers screened the titles and abstracts of identified articles and then assessed full-text articles for eligibility. To ensure the relevance and quality of the included studies, we applied the following inclusion criteria: (1) treatment focusing on invasive treatment, surgery or anaesthesia; (2) studies using any form of bidirectional chatbots (eg, messenger, short messaging service or websites); (3) studies reporting original data from randomised trials, clinical trials or observational studies; (4) studies reporting qualitative or quantitative results on interventions (chatbots); (5) English articles published from January 2019 to May 2023 and (6) interventions focusing on the perioperative period. Additionally, reviews and meta-analyses were screened for potentially eligible articles.

The exclusion criteria were as follows: (1) protocols rather than studies; (2) non-surgical and non-invasive treatment, such as physiological monitoring, chemical therapy, routine clinical procedures and treatment without a perioperative component; (3) studies that only focused on unidirectional short message service; (4) studies whose measures only focused on mental health, health behaviours or physiological data instead of perioperative care outcomes, or (5) non-English-language publications.

Participants

Eligible studies were those conducted on adult patients who had undergone or scheduled to undergo any surgical or invasive intervention; intervention in those studies are conversational agents (chatbots). Surgical interventions encompassed surgeries across various specialties, such as vascular surgery, urology, orthopaedics, anesthesiology and radiology. The selected eight articles were conducted in patients who underwent physical interventions such as ureteroscopy for kidney stones, primary total hip replacement for osteoarthritis, breast biopsy, hip arthroscopy for femoroacetabular impingement syndrome, anaesthesia before elective orthopaedic surgery and treatment for lower extremity superficial venous reflux disease.

Interventions and comparators

The intervention in this study involved the implementation of a chatbot applications for perioperative care. A chatbot was defined as a computer software application that permits two-way conversation (through text, speech or a combination of both) between a human user and a computer programme. No restrictions were placed on chatbot platforms or interfaces.

In three included comparative articles, comparators included routine procedures such as traditional preoperative assessment, consultation and postoperative follow-up delivered via face-to-face outpatient clinics by physicians.

Data extraction and conversion

Data from the selected studies were extracted using a standardised data extraction form.[34] The following information was collected: study characteristics (eg, author, year of publication, country and study design), participant characteristics (eg, demographics, surgical procedure type and sample size), chatbot intervention features (eg, technology platform and intervention time point) and perioperative outcomes (eg, data on satisfaction, knowledge acquisition and adherence). These extracted data were collated, cross-checked by other authors, and compared.

In patients' self-reports or questionnaires, a chatbot's assistance that improved patients' understanding of a procedure was defined as enhancing knowledge acquisition. For ease of comprehension and systematic representation, the authors converted the data on satisfaction and knowledge to a standardised Likert-5 scale ranging from 1 to 5. Additionally, data on the proportion of participants providing a rating of 4–5 were extracted for further analysis of untransformed proportions.

Statistical analysis

Quantifiable data were collected from patients' self-reports or questionnaires. Meta-analysis of four and three articles was performed for assessing satisfaction and knowledge acquisition respectively. The meta-analysis was conducted using Review Manager V.5.4 (RevMan, V.5.4.1, the Cochrane Collaboration, 2020) and Open Meta-Analyst software.[35] The effect size was calculated using untransformed proportions for proportional and continuous data with a 95% CI. The heterogeneity among studies was assessed and a random-effects model was used.

Publication bias

We did not evaluate publication bias using funnel plot or related tests, as the included studies fell short of the minimum of 10 required for such evaluation.[36]

Outcomes

The primary and secondary outcomes assessed were satisfaction (defined as the proportion of patients who indicate they are 'satisfied' or 'very satisfied') and knowledge acquisition (defined as the proportion of patients who indicated that they 'agree' or 'very much agree' with the assistance of a chatbot in education of perioperative information) after chatbots were used for perioperative communication. Untransformed proportional data on patients' satisfaction and knowledge acquisition in the four relevant studies were subjected to a meta-analysis. A forest plot was generated using Open Meta-Analyst software. The forest plot displayed the effect sizes and CIs of each included study as well as the overall pooled effect estimates. Other outcome measures reported by studies included patient adherence, patients' chatbot usage, patient feedback, postoperative opiate usage, and technical details related to chatbot performance.

Quality assessment

The Methodological Index for Non-Randomised Studies (MINORS)[37] and a Cochrane risk-of-bias tool (RoB 2)[38] were used by three independent reviewers to evaluate the methodological quality of studies.

The included comparative and non-comparative studies were subjected to qualitative analysis by using the revised MINORS. Two included randomised controlled trials (RCTs) were additionally assessed using RoB 2. Disagreement in ratings were resolved through the involvement of a third party or mediator.

RESULTS

Study selection

Study selection was graphically illustrated using the PRISMA 2020 flow diagram (figure 1). In total, 274 articles were initially retrieved and screened based on the inclusion criteria. Of the 274 studies identified in the initial search, the abstracts of 183 studies were screened after duplicates and protocols were excluded. Eight studies were eligible for inclusion in the meta-analysis after the full text of identified articles were independently screened by three authors. Disagreements in selection were resolved through the involvement of a third author.

Two randomised control trials were identified.[12 28] A non-randomised comparative clinical study included 303 orthopaedic participants is included.[5] The remaining five studies[5 10 15 39–41] were prospective observational studies. The eight included studies included a total of 1073 patients who received perioperative care with the assistance of a chatbot. In terms of medical specialty, five of the eight studies were related to orthopaedics (n=5, 62.5%),[12 15 28] and two focused on preanaesthesia.[5 10] The other medical specialties were urology,[40] radiology[39] and vascular surgery.[41] Because of heterogeneous outcome and differences in some study designs, a narrative synthesis was conducted (online supplemental tables 1 and 2).

The interventions started before surgery in three studies and after surgery in the others. The knowledge of chatbots was derived from expert surgeons, anaesthetists or forums. Only one AI-driven chatbot was included[15] and analysed with other seven included rule-based chatbots (n=7, 87.5%). In terms of the place of interventions in the eight included studies, chatbot from one study can be

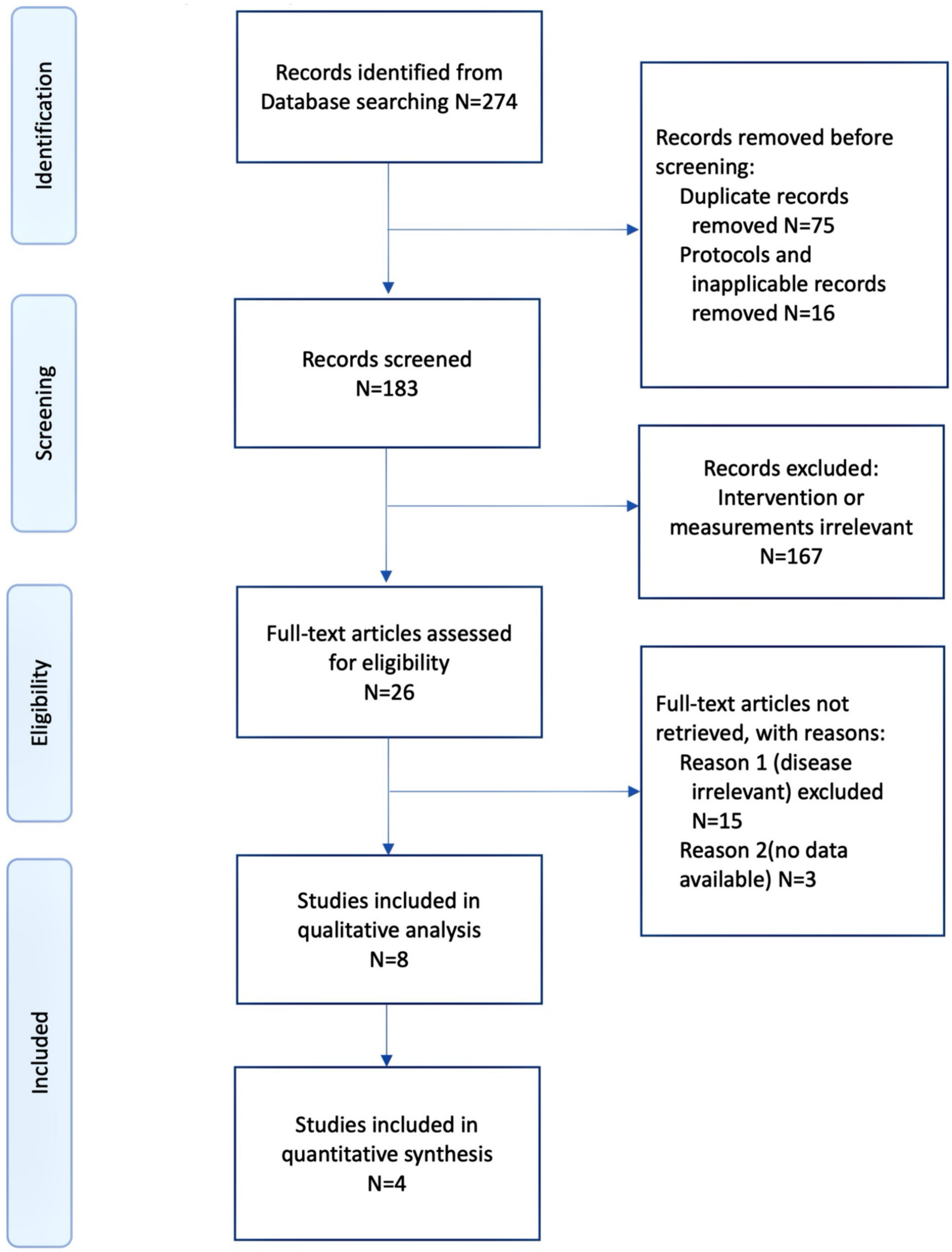

Figure 1 PRISMA (preferred reporting items for systematic reviews and meta-analyses) flowchart. From Page *et al*.[49]

applied in breast centre.[39] Chatbots from the other seven studies can be accessed through websites or applications in diverse locations.

Quality of included studies

MINORS was used to assess the quality of included studies. The quality levels of outcome measurement and assessment are shown in online supplemental table 3. Most of the included articles provided details on exclusion criteria and the rate of loss to follow-up; this was generally 0%–7%, except in one study, in which the engagement rate was 35%.[40] Overall, the studies included in the analysis had fair quality (MINORS score<50% poor, 51%–80% fair and >80% good). Two RCTs were additionally assessed using RoB 2. These two studies were determine to have some bias concerns (online supplemental table 4).

Quantitative analysis

Satisfaction

Primary outcome

The majority of participants were satisfied with the use of chatbots for perioperative communication (mean proportion=0.73; 95% CI: 0.62 to 0.85; figure 2, forest plot). The between-study heterogeneity variance was estimated at τ^2=0.010, with an I^2 value of 79.33%. The proportion of patients who stated that they were 'satisfied' or 'very satisfied' ranged from 60% to 82%. The chatbot with the highest satisfaction level had multiple sections such as team, support, technique, recovery room and frequently asked questions. Two studies with higher patient satisfaction levels investigated chatbot applications for orthopaedic patients. The other two studies with

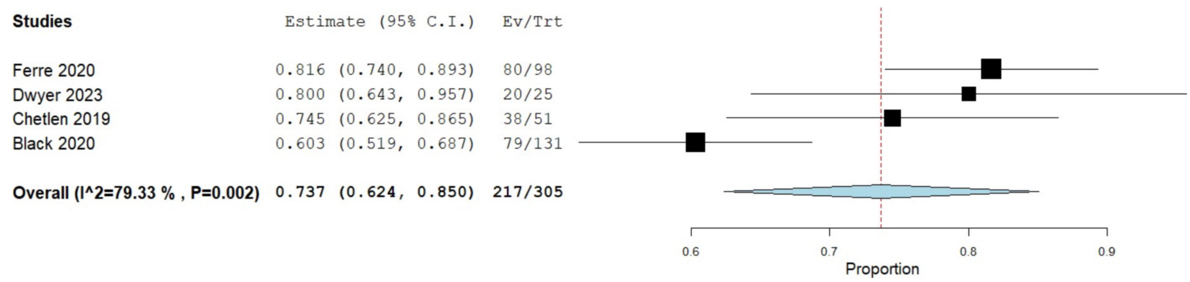

Figure 2 Meta-analysis of patient satisfaction.

lower satisfaction levels had an earlier publication time. The conversation capabilities of these two chatbots are limited; for example, patients ask questions by selecting predefined strings of text.

Knowledge

Secondary outcome

The majority of patients agreed that the use of chatbot was effective in improving their knowledge (mean proportion=0.80; 95% CI: 0.74 to 0.87) (figure 3, forest plot). The between-study heterogeneity variance was estimated at τ^2=0.001, with an I^2 value of 16.13%. The proportion of patients who had improved knowledge acquisition ranged from 75.5%;[5] 'self-reported anaesthesia knowledge test' score improvement compared with the baseline time point before the patients had used the chatbot) to 86% ('agree' or 'strongly agree' agreed that the chatbot aided their knowledge acquisition for Chetlen *et al*[39 39] and Dwyer *et al*[15 15]). The results consistently highlight the positive effect of the interventions on patient knowledge acquisition.

Other outcomes

Among the other three articles, one RCT indicated that a chatbot as an effective source of pain relief for patients with orthopaedic trauma. A significantly lower level of postoperative opioid use was noted in patients using chatbots compared with controls (p=0.03; online supplemental figure 1).[12] Another comparative study demonstrated a significant increase in knowledge test scores between the preintervention and postintervention period (p<0.00001, Z=8.42; online supplemental figure 2) and significantly higher scores in the chatbot group compared with the control group (p=0.00001, Z=4.94; online supplemental figure 3).[5] Another study emphasised the feasibility of chatbots for increasing adherence with in-home rehabilitation.[28]

DISCUSSION

In this systematic review, we revealed that patients' satisfaction and knowledge acquisition were improved by chatbot interventions in the preoperative or postoperative period. Effective communication and data feedback facilitated by chatbots contribute to improved decision-making. The integration of chatbots into perioperative care empowers patients by providing valuable information, enabling them to express their concerns, and by ensuring their actively involvement in treatment.

In a study, decision regret was associated with low satisfaction with preparatory information, depression, anxiety and stress.[42] Chatbot services provide patients with timely education or the flexibility to choose topics based on their needs, thus reducing anxiety.[43] Real-life data feedback on disease progression and treatment responses enhances physicians' understanding of patients' conditions.[44] The practicality and versatility of chatbots help bridge the gap between patients and healthcare providers in perioperative care, enhancing the cost effectiveness of medical care and patients' experience (online supplemental graphical abstract Abstract).

This review revealed that patients in perioperative care had high overall satisfaction with chatbots. Systematic reviews of the use of chatbots in healthcare have also reported a largely positive patient experience.[45] Patients with breast cancer have reported that chatbots can provide valuable support in helping them follow their treatment plans.[44] Similarly, a study focusing on patients with cancer demonstrated that engagement with a chatbot helped reduce patient anxiety.[46] However, chatbot applications for smoking cessation or promoting health-related behaviour changes may have limitations in terms of patient satisfaction.[47]

Chatbot applications are crucial tool for understanding diseases. One study in 2023 reported a significant

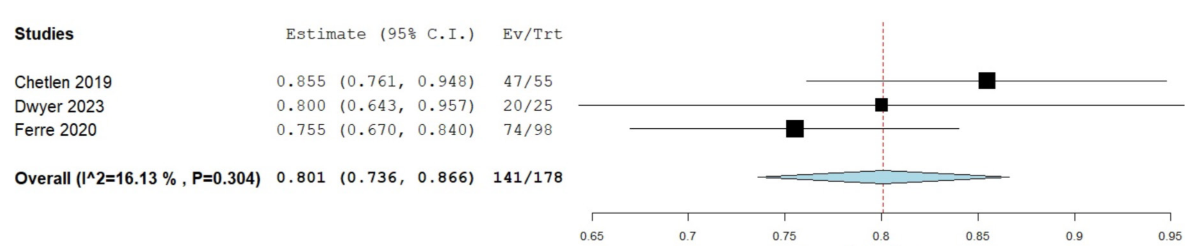

Figure 3 Meta-analysis of patients' knowledge acquisition.

increase in patients' asthma knowledge from 7.73 at baseline to 8.79 on a 10-point Likert-10 scale at the end of the study (p<0.01).[48] Furthermore, patients' scores in an anaesthesia knowledge test significant increased after a chatbot intervention (p<0.00001, Z=8.42), comparing with those before the intervention. Consistent with a significant increase in patient knowledge demonstrated in the included comparative study (p<0.00001, Z=4.94),[5] another study evaluating the impact of the chatbot platform Xploro DTx on the perceived procedural knowledge of children and their parents between indicated that the experimental group had significantly higher levels of procedural knowledge than did the control group (p<0.001, t value = −4.892 for children and p=0.01, t value = −2.621 for parents). However, the average Likert scale scores were lower than those of the Ferré *et al*[5 5] (all data have been converted to the 1–5 likert-5 scale system).[43]

Conducting multicentre trials with varied and diverse populations would help in establishing the applicability and effectiveness of chatbots across different demographics and clinical settings.

Limitations

Future research should aim to increase the number of studies and participants to enhance reliability and validity. Publication bias may be a concern due to the current available included studies. Since the risk-of-bias assessment of some included studies were found to be unclear, more RCTs in the future need to implement rigorous measures to reduce bias. Due to heterogeneity in outcome definitions across studies, the outcomes should be interpreted with caution.

Chatbot technology

In terms of chatbots' diversity in included papers, seven of eight chatbots communicate via automated text-message while one of eight additionally provided subtitled videos to optimise patients' comprehension, with which patients showed significant better odds of correction in anaesthesia tests comparing with the control group (p<0.00001, Z=4.94).[5] We expect continued development of chatbot and diversity of information delivering to ultimately improve patient experiences and education. Given the highly domain-specific characteristic of medical care, most interventions use rule-based chatbots (n=7, 87.5%). Most interventions (n=5, 62.5%) targeted perioperative care in orthopaedics. It may guide the healthcare providers and to evolve and integrate information retrieval system to promote general application on home rehabilitation and postoperative pain management.

To identify the most suitable chatbot models for various perioperative applications, there is a clear need for future head-to-head studies to optimise chatbot features and platforms. Moreover, the adoption rates and usage data of chatbots are expected to report in future studies to gauge the real-world uptake and effectiveness of these chatbots. Future multicentre trials with varied and diverse populations are also expected to help establish the applicability and effectiveness of chatbots across different demographics and clinical settings. Moreover, extended follow-up periods in future studies are essential to better understand the ongoing effects and sustainability of these technological interventions. Users should remember that chatbots have limitations and may not meet patients' need for human contact. The necessity of human expertise and supervision should be emphasised.

AI-based chatbots

In one study, patient interacted with an AI-powered chatbot incorporates proprietary natural language processing techniques. These techniques involve analysing context, keywords and patient intent to generate responses, with hundreds of thousands of combinations mapped to single responses. For AI-based chatbots growing more prevalent nowadays, future research should focus on improving the efficiency and dialogue quality of chatbots and incorporate standard evaluation metrics used in natural language processing. These metrics, such as Bilingual Evaluation Understudy (BLEU), Metric for Evaluation of Translation with Explicit Ordering (METEOR) and Translation Error Rate (TER), can measure the quality and accuracy of machine-generated translations and ensure the quality of chatbot-assisted care delivery.[16]

One notable limitation in the architecture of information retrieval chatbots nowadays is the absence of a flexible learnt AI model. Open-data set chatbots are widely used in various industries, including healthcare. However, open-access domain-specific linguistic data, which could aid model training, are lacking. Therefore, to further develop AI-based chatbots, clinicians require smaller, easily implemented, accurate and department-independent models that can be applied across various institutions for perioperative care.[16]

Interestingly, in this review, most studies focused predominantly on rule-based chatbots, indicating a notable gap in understanding the potential and impact of AI-driven chatbots. Given the advanced features and capabilities AI-driven models may offer, future research can prioritise investigating their effectiveness and practicality in perioperative care settings.

CONCLUSION

Chatbots enhance postoperative care by aiding patients in informed decision-making, providing personalised education, optimising medication management, supporting communication and facilitating data analysis. Consequently, they reduce postoperative complications and enhance patient satisfaction. However, while the existing research provides valuable initial insights into the use of chatbots in perioperative care, it also underscores the need for more comprehensive, standardised and diverse research to fully understand their potential benefits and limitations. We expect continued research, evaluation and integration between professionals across various institutions for efficient patient-centred chatbot systems to improve perioperative care.

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Acknowledgements This manuscript was edited by Wallace Academic Editing.

Contributors Study concept and design; data collection; analysis and interpretation of data; project administration: S-JL; C-YS and CC. Drafting of the manuscript: S-JL and CC. Review and editing of the manuscript: C-YS; D-NC; Y-NK; NML and K-HC. CC serves as the guarantor of the paper.

Funding None of the authors has a financial interest in any of the products, devices or drugs mentioned in this manuscript. This study was partially supported by National Taipei University of Technology and Wan Fang Hospital, Taipei Medical University Joint Research Program, NTUT-WFTMU-112-01.

Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement All data relevant to the study are included in the article or uploaded as supplementary information.

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