scientific reports

OPEN

International expert consensus on the current status and future prospects of artificial intelligence in metabolic and bariatric surgery

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Artificial intelligence (AI) is transforming the landscape of medicine, including surgical science and practice. The evolution of AI from rule-based systems to advanced machine learning and deep learning algorithms has opened new avenues for its application in metabolic and bariatric surgery (MBS). AI has the potential to enhance various aspects of MBS, including education and training, decision-making, procedure planning, cost and time efficiency, optimization of surgical techniques, outcome and complication prediction, patient education, and access to care. However, concerns persist regarding the reliability of AI-generated decisions and associated ethical considerations. This study aims to establish a consensus on the role of AI in MBS using a modified Delphi method. A panel of 68 leading metabolic and bariatric surgeons from 35 countries participated in this consensus-building process, providing expert insights into the integration of AI in MBS. Of the 28 statements evaluated, a consensus of at least 70% was achieved for all, with 25 statements reaching consensus in the first round and the remaining three in the second round. Experts agreed that AI has the potential to enhance the evaluation of surgical skills in MBS by providing objective, detailed assessments, enabling personalized feedback, and accelerating the learning curve. Most experts also recognized AI's role in identifying qualified candidates for MBS referrals, helping patient and procedure selection, and addressing specific clinical questions. However, concerns were raised about the potential overreliance on AI-generated recommendations. The consensus emphasized the need for ethical guidelines governing AI use and the inclusion of AI's role in decision-making within the patient consent process. Furthermore, the results suggest that AI education should become an essential component of future surgical training. Advancements in AI-driven robotics and AI-integrated genomic applications were also identified as promising developments that could significantly shape the future of MBS.

Keywords Artificial intelligence, Simulation training, Virtual reality, Machine learning, Bariatric surgery, Metabolic surgery

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Advancements in artificial intelligence (AI) are shaping the field of medicine, including surgical science and practice. Currently, AI is evolving rapidly, transitioning from rule-based systems to modern machine learning and deep learning algorithms[1]. In the field of metabolic and bariatric surgery (MBS), AI may have the potential to significantly impact education and training, decision-making and planning, cost and time reduction, procedure optimization, outcome and complication prediction, patient education, and access to care.

Virtual reality (VR) and augmented reality (AR) aid in surgical skill development while reducing surgical risks[2] Meanwhile, machine learning (ML) models can predict patient responses to MBS, including weight loss outcomes, remission of obesity-associated medical problems, recurrent weight gain, and post-surgical complications[3–5].

Large language models (LLMs) like ChatGPT can enhance physician and patient education before and after surgery by providing accurate and reliable answers to frequently asked questions about MBS[6]. However, they may occasionally include incorrect information or outdated data. Their integration with healthcare applications or robotic systems could serve as a dependable resource for both patients and clinicians[7,8].

Despite these advancements, any AI-generated decision should be made with patient informed consent, following the General Data Protection Regulation (GDPR), ensuring transparency and a patient's right to understand how AI-based decisions are made as best possible[9].

There are still some concerns about the reliability of AI-generated decisions and related ethical issues. This study aims to make a consensus on different aspects of AI in the field of MBS using a modified Delphi method.

Methods

The scientific core team, consisting of 13 members, was tasked with drafting statements addressing various aspects of the current status and future perspectives of AI in metabolic and bariatric surgery (MBS). Each statement was supported by references derived from a preliminary literature review and refined based on feedback from all core team members. The compiled statements were then reviewed by moderators and presented to the group for further discussion. This process resulted in the creation of 28 draft statements, each offering two response options (agree/disagree) alongside a comment box for additional feedback.

An international consensus group was invited to participate in a modified Delphi process to build consensus. This group included prominent academic and private surgeons, key opinion leaders in MBS, current and former presidents of the ASMBS and IFSO, as well as notable representatives from all IFSO chapters and national societies and well-known investigators in the field of AI in MBS. A total of 68 renowned metabolic and bariatric surgeons from 35 countries participated in the exercise, forming the Delphi consensus committee. The consensus-building process was conducted via an online platform (@SurveyMonkey). Along with the survey link, supporting evidence for each statement was provided to participants via email.

The first round of voting began on December 16, 2024, and concluded on December 29, 2024. Participants voted on all 28 statements, selecting either "agree" or "disagree." A consensus was defined as ≥ 70% agreement or disagreement, in line with previous consensus methodologies in MBS[10–12]. Following the first round, consensus was achieved on 25 out of the 28 statements. The scientific core team then reviewed feedback and revised the remaining three non-consensus statements based on the majority opinion of the voting experts. These revised statements were prepared for a second round of voting.

The outcomes of the first round were shared with all committee members, who were invited to participate in the second round to finalize the remaining statements. This second round began on January 11, 2025, and concluded on January 25, 2025. Through this iterative process, consensus was successfully achieved on all statements.

Ethical approval

All procedures performed in the study involving human participants followed the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. This consensus exercise was approved by the ethical committee of the Iran University of Medical Sciences (Approval ID: IR.IUMS.REC.1403.968).

Informed consent

Informed consent was obtained from the participants included in the consensus study.

Results

Sixty-eight MBS experts from 35 countries participated in two rounds of voting to assess the statements. The detailed results of both voting rounds for each statement are summarized in Table 1. Out of the 28 statements, a consensus of at least 70% was achieved for all, with 25 statements reaching consensus in the first round and the remaining 3 in the second round.

Education and training

The experts achieved consensus that AI has the potential to provide a more objective and detailed evaluation of surgical skills in MBS, enabling personalized feedback and accelerating the learning curve for MBS procedures. It may enhance the quality of training, optimize faculty time, expand the educational capacity of institutions, and simplify bariatric surgical education while streamlining operative steps in MBS. Additionally, AI could play a significant role in improving patient education before MBS. However, patients should be thoroughly informed about how AI is utilized in their care and its impact on treatment modalities.

Decision making and planning

Most experts agreed that AI can assist in identifying qualified candidates for the referral process for MBS, as well as in both patient and surgical procedure selection, and can help answer certain clinical questions. However, there is a potential risk that healthcare providers may become overly reliant on AI recommendations.

Cost and supportive system

The experts reached a consensus on AI's role in supporting systems by integrating it with Electronic Health Records (EHR) to identify patterns in social determinants of health that impact MBS outcomes. This integration can help reduce healthcare costs related to MBS by optimizing surgical processes and enhancing patient outcomes.

Prediction and follow-ups

The experts' consensus indicated that AI can aid in predicting weight loss outcomes, post-MBS complications, readmission rates, and remission or relapse of obesity-related medical conditions following MBS. Additionally, AI-powered wearable devices can support postoperative monitoring.

Statement	First Round	Second Round	Final Result
1. Artificial Intelligence (AI) may enable a more objective and detailed assessment of surgical skills in bariatric surgery, facilitating personalized feedback and enhancing the learning curve of surgeons in training.	98.5% Agree	–	CONSENSUS (AGREE)
2. Implementing AI-based systems for evaluating bariatric procedures may improve the quality of training, optimize faculty time, and increase the educational capacity of institutions.	98.5% Agree	–	CONSENSUS (AGREE)
3. AI can simplify bariatric surgical education.	82.1% Agree	–	CONSENSUS (AGREE)
4. The use of AI may help streamline operative steps in both sleeve gastrectomy and gastric bypass.	83.8% Agree	–	CONSENSUS (AGREE)
5. AI has a substantial contribution to patients' education.	85.3% Agree	–	CONSENSUS (AGREE)
6. Patients may not fully understand the role of AI in their treatment plans. Ensuring that patients are adequately informed about how AI is used in their care and how it affects their treatment decisions is crucial for ethical practice.	92.6% Agree		CONSENSUS (AGREE)
7. AI can help identify patients who qualify for bariatric surgery in a primary care setting to streamline the referral process.	82.3% Agree	–	CONSENSUS (AGREE)
8. AI can help in standardizing surgical procedures.	80.9% Agree	–	CONSENSUS (AGREE)
9. AI can be used for patient selection.	83.8% Agree	–	CONSENSUS (AGREE)
10. Al may develop the capability to match the appropriate operation type for patients seeking bariatric surgery. Still, the surgeon should make the final decision, especially based on the intraoperative findings.	61.2% Agree	91.0% Agree	CONSENSUS (AGREE)
11. When AI systems make recommendations or decisions, it can be unclear who is accountable or responsible for those decisions, especially if outcomes are negative.	80.9% Agree	–	CONSENSUS (AGREE)
12. There is a potential risk that healthcare providers may over-rely on AI recommendations, which could lead to a decline in clinical skills and critical thinking.	92.5% Agree	–	CONSENSUS (AGREE)
13. AI and large language models (LLMS) can be used to answer clinical questions related to the field of MBS at the level of practicing surgeons.	77.9% Agree	–	CONSENSUS (AGREE)
14. The use of AI has the potential to identify which patients may need a diagnostic laparoscopy with negative imaging to rule out an internal hernia, but it can't make the final decision.	49.2% Agree	85.1% Agree	CONSENSUS (AGREE)
15. The integration of AI with Electronic Health Records (EHR) systems can identify patterns in social determinants of health that influence bariatric surgery outcomes, enabling more targeted pre- and post-operative support systems for underserved populations.	88.2% Agree	–	CONSENSUS (AGREE)
16. AI has the potential to reduce healthcare costs associated with metabolic and bariatric surgery (MBS) by optimizing surgical processes and improving patient outcomes.	88.2% Agree	–	CONSENSUS (AGREE)
17. AI simulation models can play an important role in evaluating diet adherence MBS.	88.1% Agree	–	CONSENSUS (AGREE)
18. AI can help to predict weight loss outcomes after MBS.	83.8% Agree	–	CONSENSUS (AGREE)
19. AI can help to predict post-MBS complications and readmission.	75.8% Agree	–	CONSENSUS (AGREE)
20. AI can help predict remission/relapse of obesity-associated medical problems after MBS.	85.3% Agree	–	CONSENSUS (AGREE)
21. Machine learning models can predict postoperative outcomes based on preoperative data, allowing for better risk stratification and tailored patient management.	88.2% Agree		CONSENSUS (AGREE)
22. AI-powered wearable devices to help postoperative monitoring to facilitate early discharge(day-case) of patients.	82.3% Agree	–	CONSENSUS (AGREE)
23. The use of AI should comply with ethical guidelines and the General Data Protection Regulation (GDPR).	97% Agree	–	CONSENSUS (AGREE)
24. The use of AI in decision-making should be part of the consent process with the patient.	88.2% Agree	–	CONSENSUS (AGREE)
25. The introduction of AI may alter the traditional dynamics of the doctor- patient relationship, potentially affecting trust and communication.	77.9% Agree	–	CONSENSUS (AGREE)
26. AI learning should be a mandatory part of the surgical curriculum in the future.	70.6% Agree	–	CONSENSUS (AGREE)
27. Advancements in AI-driven robotics are expected to lead to more sophisticated surgical systems capable of performing complex procedures under the expert guidance of skilled surgeons.	66.2% Agree	91.0% Agree	CONSENSUS (AGREE)
28. Future AI applications may include integration with genomic data to tailor interventions based on genetic predispositions to obesity and metabolic disorders.	89.7% Agree		CONSENSUS (AGREE)

Table 1. Consensus statements voting results.

Ethical issues

Most experts agree that AI use should adhere to ethical guidelines and that its role in decision-making should be included in the patient consent process.

AI perspectives

The consensus results suggest that AI education should become a mandatory component of the future surgical curriculum. Additionally, advancements in AI-driven robotics and AI-integrated genomic data applications have the potential to revolutionize future MBS.

Discussion

Education and training

AI can play a crucial role in evaluating the surgical skills of both surgeons and trainees while also enhancing the learning curve to refine their skills before performing real operations. Incorporating virtual reality (VR) and augmented reality (AR) into surgical training allows for surgical skill development and minimizes the risk of surgery[13,14]. Each metabolic and bariatric surgery (MBS) procedure has a learning curve based on its complexity, aiming to improve patient safety and reduce complications. Typically, proficiency requires approximately 25–50 operations for sleeve gastrectomy (SG), 75–100 operations for Roux-en-Y gastric bypass (RYGB), and 50–75 operations for one-anastomosis gastric bypass (OAGB)[15]. A study evaluating the RYGB training program using VR demonstrated improvements in laparoscopic surgical skills, resulting in reduced operative time and lower complication rates[16]. In addition, AI can provide objective, personalized feedback to surgical trainees by analyzing performance metrics from data gathered during simulations or real procedures, helping identify areas for improvement[17,18].

This evidence supports the agreement among experts regarding AI's role in evaluating surgical skills, accelerating the learning curve, and enhancing the quality of training.

AI, through large language models (LLMs), can simplify metabolic and bariatric surgical education, though concerns about its accuracy remain[19,20].

Experts reached a consensus that AI may help streamline operative steps in both sleeve gastrectomy and gastric bypass procedures. A study demonstrated that an AI-based computer vision model can enhance the surgical quality and efficacy of SG[21]. A study by Fer et al. found that AI can identify surgical landmarks in RYGB, outperforming surgeons in recognizing certain landmarks with greater accuracy[22].

While AI can greatly improve patient education on MBS procedures, it has limitations in managing complex clinical cases, ensuring up-to-date evidence and reliability, and preventing misinformation[20,23]. To enhance patient education in the context of AI, it is essential to address privacy concerns and the need for surgeons' expertise in complicated scenarios[1]. AI and traditional medicine share the same ethical responsibility regarding informed consent[9]. Ensuring that patients understand how AI is used in their care, to the extent possible, and its impact on treatment decisions remains crucial for ethical practice[24,25].

Decision making and planning

Experts agreed that AI can assist in identifying eligible MBS candidates in primary care, helping to streamline the referral process. A significant obstacle to patient referrals for metabolic and bariatric surgery is the insufficient knowledge among referring physicians and patients regarding the indications, safety, and efficacy of these surgical procedures[26]. AI has the capability to bridge this information gap and may significantly improve patient-centered primary care by facilitating better communication between patients and healthcare providers through the utilization of patient data.

A significant majority, around 81%, of experts concurred that AI can play a crucial role in the standardization of surgical procedures. The implementation of an AI-driven computer vision model has demonstrated its ability to assist in identifying surgical steps and anatomical landmarks, which may contribute to the standardization of MBS procedures[21,22].

Most experts agreed that AI can be used for both patient selection and matching the appropriate operation type for patients pursuing bariatric surgery, however, the bariatric surgeon should make the final decision, especially based on the intra-operative findings. A recent study found that ChatGPT matched their established surgical algorithm in only 34% of the patients, concluding that ChatGPT-4 should not replace expert consultation in selecting MBS techniques[27]. Similarly, another study comparing expert opinions with ChatGPT for selecting the appropriate MBS procedure found only a 30% match in recommended operation types[28]. Clinicians should be aware of significant variations among different LLMs and supervise to ensure the accuracy of AI-generated answers[6] Ultimately, the surgeon should decide on the appropriate procedure.

One of the most important questions that arises in discussing AI systems making decisions is the question of accountability. Indeed, 81% of the experts agreed with the statement that, when AI systems make recommendations or decisions, it can be unclear who is accountable or responsible for those decisions, especially if outcomes are negative", and the fact that responsibility and accountability are unclear when AI systems make recommendations or decisions. Habli et al. predominantly discussed the safety assurance and moral accountability, underling the question of how far it would be reasonable to hold human clinicians accountable for patient harm when artificial intelligence systems are involved in the decision-making process[29]. The team concluded that we need to update safety risks based on actual clinical practice by quantifying the morally relevant effects of reliance on AI systems and determining how clinical practice is influenced by the machine system itself[29].

Conversely, more than 90% of experts agreed that there is a potential risk of healthcare providers becoming overly dependent on AI recommendations. This over-reliance could ultimately diminish clinical skills and critical thinking abilities. AI has immense potential to reduce administrative and cognitive burdens. On the other side, the risk of potential job displacement, increased complexity of medical information and cases, and the danger of diminishing clinical skills is feared[30]. Therefore, Pavuluri et al. highlighted the importance of reinforcing the role of caregivers among healthcare workers[30]and Mohanasundari et al. reassumed the importance of human interaction in patient care and underlined that the role of AI should be complementary to emotional intelligence, empathy, and nuanced understanding of nursing care[31]. Automation bias affected by over-reliance on AI-driven systems should be actively diminished and a comprehensive review by Abdelwanis et al. showed the improved diagnostic accuracy on the one hand, and the risk of potential pitfalls of over-relying on automation, as it may lead to decreased performance, an increase in false positives, and a higher rate of false alarms on the other hand when using clinical decision support systems[32].

Another consensus statement supported the role of using AI and large language models (LLMs) to answer clinical questions related to the field of MBS at the level of practicing surgeons. Lee and the ASMBS Artificial Intelligence and Digital Surgery Task Force showed, using the three different chat models OpenAI ChatGPT-4, Microsoft Bing, and Google Bard, that AI chat models can effectively generate appropriate responses to clinical questions, though the performance of different models can vary greatly[6]. The same group entered multiple-choice questions found in "The ASMBS Textbook of Bariatric Surgery, Second Edition" into the 3 LLMs and found that ChatGPT-4 demonstrated the highest proportion of correct answers in questions related to treatment and surgical procedures (83.1%) and complications (91.7%)[19]. On the other hand, comparing expert opinions and ChatGPT-4 regarding the decision-making process regarding the recommendation of bariatric surgery, only in 30% of cases did AI match expert opinion[28].

One of the most difficult diagnoses in the long-term after gastric bypass is the correct and prompt diagnosis of internal hernia. Misdiagnosis of internal hernia can lead to bowel ischemia and bowel resection and might be associated with increased mortality. Except for the mesenteric swirl sign, CT signs show good specificity, but sensitivity is low[33]. Only 49% of the experts agreed in the first round that the use of AI has the potential to identify which patients may need a diagnostic laparoscopy with negative imaging to rule out an internal hernia. Finally, in the second round, underlying the sentence "but can't make the final decision," the statement had a consensus. AI might be helpful in the future using certain algorithms to help surgeons in giving the right diagnoses, since currently we might use a score where excess body weight loss > 95%, swirl sign, and free liquid are independent predictors of internal hernia and in a retrospective work with 228 patients operated for suspected internal hernia a score of > = 2 was associated with an internal hernia incidence of 60.7% (n = 34/56), and 5.3% (3/56) had a negative laparoscopy[34].

Cost/supportive system

The Experts agree in both of the statements, with 88% that AI can identify patterns in social determinants of health that influence bariatric surgery outcomes and that, finally, AI has the potential to reduce healthcare costs associated with MBS by optimizing surgical processes and improving patient outcomes. The worldwide health systems have an urgent need for cost reduction and support due to higher bureaucracy, personnel reduction, and burnout. A workgroup has used a machine learning approach to identify social risk factors associated with textbook outcomes after surgery[35]. Another group tried to analyze social determinants of health in adults diagnosed with type 2 diabetes mellitus. Predicting novel social determinants might help to improve work; nevertheless, there is still a lot of work to do for addressing data gaps, which may require government and payer mandates, standardized social determinants of health screening tools, and personnel training[36].

In MBS, we have just a spectrum of works in the current literature that show us that different AI models showed remarkable results in helping physicians in the decision-making process, thus improving the quality of care and contributing to precision medicine[37]. Furthermore, AI tools can leverage large datasets and identify patterns to surpass human performance in several healthcare aspects, offering increased accuracy, reduced costs, and time savings while minimizing human errors[1].

Prediction/follow-ups

In daily clinical practice, it is of most importance when recruiting patients to MBS to provide the patients with all important information regarding MBS and lifestyle change after surgery. The patient has not only to understand the risk of potential complications but also has to accept changing eating habits. Health care providers often cannot calculate lifestyle habits or control diet adherence after MBS. Since different simulation models exist in the current literature[38], the experts agreed that AI simulation models can play an important role in evaluating diet adherence after MBS.

Furthermore, different works have shown that AI can help to predict weight loss outcomes after MBS, and more than 80% of the experts agreed on this. It might be the most common question that our patients ask in daily clinical practice. Indeed, a pilot study by Nadal et al. showed that a machine model correctly classified 71.4% of subjects with TWL < 30%, although 36.4% with TWL ≥ 30% were incorrectly classified as "unsuccessful procedures"[39].

The group of Perretta et al. showed in a multicenter study that machine learning might not predict the success of endoscopic sleeve gastroplasty due to preoperative data, but the ability of machine learning models to adapt and evolve with the patients' changes could assist in providing effective and personalized postoperative care[40].

The group of Pattou et al., in a multinational retrospective observational study including 10.231 patients from 12 centers in ten countries, were able to develop a machine learning-based model, which is internationally validated, for predicting individual 5-year weight loss trajectories after three common bariatric interventions. As the best of all the machine learning systems, this model showed a mean difference between predicted and observed BMI of -0·3 kg/m^2 (SD 4·7)[41]. Up to date, we might all include this model in our daily clinical practice.

Nevertheless, 76% of experts agreed that AI can help to predict post-MBS complications and readmission. Different works have shown how AI can predict short-term thromboembolic risk following Roux-en-Y gastric bypass, achieving a sensitivity of 0.60 and a specificity of 0.91[42] and readmission, achieving a sensitivity and specificity of 73.81% and 70%, compared with 52.94% and 70% for logistic regression[43].

Using the analysis of the MBSAQIP database to predict gastrointestinal leak and venous thromboembolism after weight loss surgery including 436,807 patients, the group of Nudel et al. showed that two learning machine models outperformed traditional logistic regression in predicting leak[44].

The big question might be, which of the different machine models might be included in the hospital information systems in the future, and how might the different AI models be automatically included in daily clinical practice.

AI and machine learning (ML) have shown significant promise in predicting the remission or relapse of obesity-associated comorbidities, such as type 2 diabetes, hypertension, and sleep apnea, following MBS. By analyzing large datasets of patient outcomes, AI models can identify patterns and predictors of success or failure that may not be apparent through traditional statistical methods. For example, studies have demonstrated that preoperative factors such as age, BMI, duration of obesity, and specific biomarkers can be used to predict the likelihood of remission of type 2 diabetes after MBS[45–47]. AI algorithms can also incorporate postoperative data, such as weight loss trajectories and adherence to lifestyle changes, to refine predictions about relapse risks[48]. This capability allows clinicians to tailor postoperative care plans and interventions to individual patients, potentially improving long-term outcomes.

ML models excel at analyzing complex, multidimensional datasets to predict postoperative outcomes. By leveraging preoperative data such as patient demographics, comorbidities, laboratory results, and imaging studies, these models can stratify patients into risk categories and predict outcomes such as complications, length of hospital stay, and weight loss success[49]. For instance, ML algorithms have been used to predict the risk of postoperative complications like venous thromboembolism and infections, enabling clinicians to implement preventive measures for high-risk patients[50]. Additionally, ML models can help identify patients who are likely to benefit the most from MBS, optimizing resource allocation and improving patient selection[51]. This predictive capability supports personalized medicine, where treatment plans are tailored to the individual's risk profile and expected outcomes.

AI-powered wearable devices are revolutionizing postoperative care by enabling the continuous, real-time monitoring of patients outside the hospital setting. These devices can track vital signs, physical activity, and other biomarkers, providing early warning signs of complications such as infections or dehydration[24]. For example, wearable sensors that monitor heart rate, oxygen saturation, and mobility can alert healthcare providers to deviations from expected recovery trajectories, allowing for timely interventions[24]. This technology is particularly valuable for facilitating early discharge (day-case surgery) by ensuring that patients can be safely monitored at home. Studies have shown that AI-driven wearables can reduce hospital readmission rates and improve patient satisfaction by minimizing the need for prolonged hospital stays[37]. Furthermore, these devices can enhance patient engagement by providing feedback on recovery progress and encouraging adherence to postoperative guidelines.

Ethical issues

The General Data Protection Regulation (GDPR) is a cornerstone of data protection and privacy, and its implications for AI are significant. The GDPR emphasizes transparency, accountability, and fairness in data processing, which directly impacts how AI systems are developed and deployed. For instance, AI systems must ensure that personal data is processed lawfully, and individuals must be informed about how their data is used. This aligns with ethical guidelines that prioritize patient autonomy and privacy. In addition, GDPR imposes strict requirements on AI systems, particularly in healthcare. For example, AI algorithms must be explainable, and decisions made by AI must be subject to human oversight. This ensures that AI systems do not operate as "black boxes" and that patients retain control over their data. Compliance with GDPR also requires that AI systems are designed with privacy-by-design principles, minimizing data collection and ensuring data security. The Impact of the EU's New Data Protection Regulation on AI.

Furthermore, ethical guidelines emphasize the importance of fairness, non-discrimination, and accountability in AI systems. These principles are essential in healthcare, where biased or opaque AI systems could lead to inequitable treatment outcomes. Thus, compliance with GDPR and ethical guidelines is not just a legal obligation but a moral imperative to ensure that AI benefits all patients equitably[37,52].

Informed consent is a fundamental ethical principle in healthcare, and the integration of AI into clinical decision-making introduces new complexities. Patients must be informed about how AI is used in their care, including the potential risks, benefits, and limitations of AI-driven decisions. This is particularly important given the potential for AI to influence diagnoses, treatment plans, and prognoses[37].

In a study by Hryciw et al. they concluded the ethical challenges of AI in healthcare, emphasizing the need for transparency in AI decision-making processes. Patients have the right to understand whether and how AI is being used in their care, and they should be able to opt out if they are uncomfortable with its use. This aligns with GDPR's requirement for explicit consent when processing personal data[53].

Additionally, they highlighted the importance of patient autonomy in the context of AI. The consent process should include clear explanations of how AI algorithms work, the data they use, and the potential for errors or biases. This ensures that patients can make informed decisions about their care and maintain trust in the healthcare system[53].

The doctor-patient relationship is built on trust, communication, and mutual respect. The introduction of AI into healthcare has the potential to disrupt this dynamic, as patients may perceive AI as a replacement for human judgment or as a tool that depersonalizes care. This could lead to an erosion of trust if patients feel that their concerns are not being adequately addressed by human clinicians.

AI limitations

There are several limitations to the consistent integration of AI in MBS. One major limitation is the need for large volumes of high-quality, standardized data for AI systems to function effectively. However, variations in surgical techniques[54], patient demographics, and outcome reporting create variability that barricade the development of reliable and uniform AI models. Additionally, AI's involvement in decision-making could potentially undermine patient trust in the treatment team, as reliance on technology may be perceived as reducing the human element in care. Akingbola et al. explored how AI can shift the role of healthcare providers from decision-makers to interpreters of AI-generated insights. While this can enhance efficiency, it may also create a sense of detachment if patients feel that their care is being driven by algorithms rather than human empathy and understanding. Effective communication is essential to mitigate these concerns, ensuring that patients understand AI's role as a supportive tool rather than a replacement for human clinicians[55].

Moreover, the potential exists for AI to exacerbate health disparities if not implemented thoughtfully. For example, if AI systems are perceived as favoring certain populations or making errors, patients may lose trust in both the technology and their healthcare providers. Therefore, maintaining the human element in healthcare is crucial to preserving the doctor-patient relationship. A study by Huedel et al. on cancer patients concluded that for AI to be beneficial, its integration should be collaborative and patient-centered, ensuring that technological advancements support and enhance the quality of the doctor- patient relationship rather than undermine it. The article emphasizes the importance of transparent communication, patient education about AI, and the need for oncologists to effectively understand and convey AI-generated data[56].

Another limitation is that AI algorithms, especially deep learning models, often operate as “black boxes,”[57] generating predictions without clear explanations. This lack of transparency can make clinicians hesitant to trust and integrate AI-driven recommendations into surgical decision-making.

An important limitation is that the current AI models may struggle with complex visual tasks essential in surgery. For instance, studies have shown that AI tools like ChatGPT-4 and DALL-E 3 have significant limitations in accurately recognizing and generating illustrations of bariatric surgical procedures[58].

AI prospective

The integration of AI into surgical education is increasingly seen as essential due to the rapid advancements in AI-driven technologies in healthcare. AI is transforming surgical practices by enhancing decision-making, improving diagnostic accuracy, and enabling personalized treatment plans. As AI becomes more embedded in surgical workflows, surgeons must be equipped with the knowledge to interpret AI-generated insights and collaborate effectively with these systems[59]. Although AI should be implanted in the future MBS world, incorporating AI tools into existing clinical workflows presents challenges, including the need for additional training, potential disruptions to established practices, and ensuring that AI recommendations align with clinical judgment.

Ifthekhr et al., in their study, highlighted the growing role of AI in surgical training, emphasizing the need for curricula to include AI literacy, data interpretation, and ethical considerations[60].

Furthermore, Reddy et al. in 2023 discussed how AI can simulate complex surgical scenarios, providing trainees with realistic practice environments that improve their skills and confidence[61].

Incorporating AI into the surgical curriculum ensures that future surgeons are prepared to leverage these technologies to enhance patient outcomes, reduce errors, and optimize surgical workflows. Without such training, there is a risk of a knowledge gap, where surgeons may not fully utilize AI tools or understand their limitations.

The integration of AI with robotic surgical systems is revolutionizing the field of surgery. AI-driven robotics enhance precision, reduce human error, and enable minimally invasive procedures with faster recovery times. These systems are becoming increasingly sophisticated, with capabilities such as real-time image analysis, tissue differentiation, and adaptive learning to improve surgical outcomes.

Present AI-driven systems incorporate functionalities such as image recognition, motion control, and haptic feedback, allowing real-time analysis of surgical field images and optimizing instrument movements for surgeons. The advantages of AI integration include enhanced precision, reduced surgeon fatigue, and improved safety[60].

Nevertheless, obstacles such as high development expenses, dependence on data quality, and ethical issues surrounding autonomy and liability impede broader adoption. Regulatory challenges and difficulties in integrating AI into existing workflows also pose significant barriers. Looking ahead, the future of AI in robotic surgery involves advancing autonomy, tailoring surgical methods to individual patients, and improving surgical training through AI-driven simulations and virtual reality technologies.

The convergence of AI and genomics holds immense potential for personalized medicine, particularly in managing obesity and metabolic disorders. In a study by Trang and Grant, they discussed how AI can analyze vast genomic datasets to identify genetic markers associated with these conditions, enabling early intervention and tailored treatment plans. For instance, AI algorithms can predict an individual’s response to specific diets, medications, or surgical interventions based on their genetic profile. In addition to risk prediction, AI plays a crucial role in drug discovery and therapeutic optimization. By analyzing gene expression profiles and molecular pathways, AI can identify novel therapeutic targets for obesity and metabolic disorders, accelerating the development of precision drugs[62,63].

In another study by Suarez et al. Explored the role of AI in integrating multi-omics data (genomics, proteomics, and metabolomics) to provide a comprehensive understanding of metabolic health. This approach allows for the development of precision therapies that address the root causes of obesity and related disorders, rather than relying on generalized treatments[64,65]Additionally, AI has the potential to streamline the analysis of genomic data, making it more accessible for clinical use. By combining genomic insights with AI-driven predictive models, healthcare providers can offer personalized interventions that improve patient outcomes and reduce the burden of chronic diseases.

There is a need for rigorous clinical validation of AI tools to ensure their safety and efficacy. Additionally, regulatory bodies must establish clear guidelines for the approval and monitoring of AI applications in MBS.

Strengths and limitations

This study represents the first consensus-building exercise on the role of artificial intelligence in MBS, bringing together experts from 35 countries with significant experience in the field. The experts followed a modified Delphi methodology to reach their conclusions.

However, several limitations should be acknowledged. The selection of experts was restricted to MBS surgeons and AI specialists in MBS, whereas including patients, caregivers, or other healthcare professionals involved in MBS care could have provided a more comprehensive perspective. Additionally, some aspects of AI’s role were not explored, such as its potential usefulness in prioritizing surgical waiting lists.

The recommendations in this study were also constrained by the limited availability of high-quality evidence, which restricted the depth of discussion in some areas. Further research is essential to enhance the decision-making process and address existing knowledge gaps.

Finally, we believe that these statements require further validation through well-designed studies with higher levels of evidence.

Conclusion

This expert consensus underscores the numerous potential roles of AI in metabolic and bariatric surgery, including education and training, decision-making and planning, cost management and supportive systems, prediction of outcomes, and patient follow-ups. However, certain concerns and ethical considerations must be addressed. Nonetheless, AI is poised to play a crucial role in the field of MBS, making AI education a necessary component of future surgical curricula. Furthermore, advancements in AI-driven robotics and AI-integrated genomic data applications have the potential to revolutionize the future of MBS.

Data availability

Data are however available from the corresponding author (Mohammad Kermansaravi) upon reasonable request.

Received: 6 February 2025; Accepted: 13 March 2025
Published online: 18 March 2025

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Author contributions

All authors contributed equally and reviewed the manuscript.

Declarations

Competing interests

The authors declare no competing interests.

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