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Remote, automatic, digital preanesthetic evaluation – are we there yet?

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Abstract
Recent years have witnessed multiple advancements in the field of information technology in medicine. The need to ensure patient and doctor safety during COVID-19 resulted in improved telemedicine adaptation across various fields, including anaesthesiology. In this review, the authors examine the current state of the elements of preanesthetic evaluation and their remote execution using current and future telemedical facilities and technologies, as well as the potential of future advancements in this field.

Key words: telemedicine, e-health, artificial intelligence, anaesthesia, remote, preanaesthetic evaluation, preanaesthetic visit, automatic preanaesthetic evaluation, remote preanaesthetic evaluation, preanaesthesia questionnaire.

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In recent years there have been multiple advancements in information technology, specifically e-health and telemedicine. Many of these advancements stemmed from the need to ensure patient and doctor safety during the coronavirus disease 2019 (COVID-19) pandemic. Patient evaluation without face-to-face contact to minimise the risk of viral transmission has become a new safety standard for doctors in many specialties.

In this review, we examine the current state of the preanaesthetic evaluation and analyse its components and their potential for remote execution using current and potential future telemedical facilities and technologies. We review the literature regarding the beneficiaries of remote preanaesthetic evaluation. Finally, we discuss which aspects of the preanaesthetic assessment can be performed automatically.

RATIONALE FOR REMOTE PREANESTHETIC EVALUATION

Social distancing during the COVID-19 pandemic

Zhang *et al.* [1] reviewed the effectiveness of virtual perioperative assessment for surgical patients during the time of increased virtual care adoption as a result of the COVID-19 pandemic. The authors concluded that "virtual preanaesthesia evaluation had similar surgery cancellation rates, high patient satisfaction, and reduced costs compared to in-person evaluation". Out of the 15 analysed studies, videoconferencing was used most often (9 studies), followed by telephone (3 studies). Only 2 studies used electronic questionnaires, while one used electronic consultations through a shared electronic health record portal.

Remote areas, trip time, and cost savings

The time required and distance to be covered to travel to the hospital could play key roles for patients from remote rural areas when considering preanaesthetic evaluations. In their analysis of telemedicine evaluation at H. Moffitt Cancer Center in Tampa, Florida, Aldawoodi *et al.* [2] found that telemedicine helped save a median round-trip distance of 80 miles (128 km), with the range being 4–1180 miles (6.5–1900 km), which resulted in a median cost saving of USD 46 (range: USD 2.3–678). The authors also found that telemedicine preanaesthesia evaluations had similar surgery cancelation rates.

Their publication included a simple decision tool for referring patients to an in-person visit.

Morau *et al.* [3] reported similar results. In their study, the median round-trip travel distance for a patient was 60 km (range: 20–97.8 km). The total round-trip distance saved by all preanaesthesia teleconsultations was 6438 km. This study also noted that before the pandemic, preanaesthesia consultations by telephone were proposed on an experimental basis for prisons to limit the cost of extraction and transportation of prisoners.

Green anaesthesia and climate change mitigation

In recent years, the idea of sustainability in the operating room and the need for climate change mitigation in the context of anaesthesiology have gained prominence. A study by Gordon [4] on sustainability in the operating room clearly compares desflurane use with car emissions: "(…) greenhouse gas emissions generated by a 2-hour anaesthetic with desflurane (…) are equivalent to driving a car 608 km (…)". Unfortunately, the author did not suggest the possibility of remote preanaesthetic evaluation, despite the obvious benefits it offers for climate change mitigation.

Similar cancelation rates, anxiety, and satisfaction

Many publications on telemedicine for preoperative consultations have reported similar rates for day-of-surgery case cancelation [1, 2, 5]. These studies also found similar (high) satisfaction scores. Some publications have noted a high patient preference for telemedicine consultations [6], but this result does not appear unequivocal, because it probably depends on the examined population [7]. Gibas *et al.* [8] performed a randomised clinical trial comparing the level of patient anxiety after face-to-face (FTF) consultations and after telephone consultations. No differences were noted in anxiety levels.

Special case: optimisation of day surgery

In an ongoing trial conducted by Shi *et al.* [9], the authors created a study protocol for a new day surgery management mode based on the WeChat platform. In this protocol, the WeChat app sends personalised information based on the patient's medical history at different time points, both preoperatively and postoperatively. The authors noted that despite numerous advancements in day surgery, other medical services remain conventional. In their study, patients receive important information through WeChat (both before and after the procedure), and health practitioners from multiple departments, including anaesthesiology, internal medicine, nursing, and psychology, participate in this new mode of treatment. The results of this trial are of interest because it utilises telemedicine effectively for multiple departments and keeps the remote approach as its core, supplementing day surgery and minimising the time spent by patients at the hospital.

Prehabilitation monitoring

In 2016, Rumer and Melcher [10] suggested that wearable devices could be used to monitor and change health behaviour to reduce frailty. In 2021, Finely *et al.* [11] examined 18 patients scheduled for lung cancer surgery, who received exercise prescriptions along with a commercially available wearable device from their surgeons. They found that activity tracking may promote clinically significant improvements in the aerobic capacity of patients with lung cancer. Although further studies are required in this area, it is our opinion that it is feasible to perform remote consultations with exercise prescriptions, which could then be objectively and remotely tracked using commercially available wearable devices. These wearable trackers with sufficient validation could then be used as an objective measure of actions taken by patients during prehabilitation (e.g. steps walked each day, calories burned, etc.).

CURRENT STATE OF PREANAESTHETIC EVALUATION GUIDELINES

The current guidelines do not include any indicators for remote preanesthetic evaluation. Perioperative evaluation of a noncardiac surgery patient is described in the guidelines of the European Society of Anaesthesiologists (ESA) and the American Society of Anesthesiologists (ASA) [12, 13]. ESA guidelines published in 2011 contain a step-by-step guide on how to evaluate a patient, and each intervention is backed by a specific level of evidence. ASA guidelines published in 2012 follow a similar structure. Both guidelines have comparable evaluation structures consisting of collecting the patient's medical history, performing physical examinations, and ordering a selection of perioperative tests. Neither of the documents directly imposes any specific form of communication with patients. This is also true for the newer ESAIC/ESC guidelines published in 2022 [14]. The United Kingdom's National Institute for Health and Care Excellence (NICE) guidelines [15] on perioperative care of adults, published in 2020, do not provide any particular suggestions on specific forms of communication with the patient and refer only to the generalised patient experience guideline [16] created in 2012. In Poland, the guidelines of the Ministry of Health [17] do not impose any specific forms of communication during preanesthetic evaluation, and the guidelines only set the minimum time span for preanesthetic evaluation to occur before planned surgery as 24 hours.

TOOLS FOR REMOTE PREANAESTHETIC EVALUATION

Remote consultation

Remote consultations can be performed via telephone or video calls using a computer. The first study on telemedicine in preanesthetic evaluation published in 2004 used computers equipped with cameras connected through network [18]. The University of California, Los Angeles (UCLA) Health telemedicine preoperative anaesthesia evaluation, initiated in 2017, used phone screening and phone evaluation if the patient met specific criteria [5]. For many cases of remote consultation, the telephone should be sufficient. In several cases, communication with patients can be performed using a smartphone app, such as WeChat [9], which usually allows communication via text, voice, and video and facilitates document sharing.

Even with the implementation of remote consultations, there will still be a group of patients who would benefit from FTF visits. Khera *et al.* [19] identified patient-related factors that determine whether an FTF consultation was indicated. In their study, these factors included patient age above 65 years, presence of type I or II diabetes mellitus, and the use of 7 or more of the listed medications.

Automatic analysis of the patient's history

An automatic analysis of a patient's medical history does not appear to be feasible at the moment. To the best of our knowledge, no common data interchange format exists for free-text medical notes, and no attempts have been made to make free-text medical notes easier to analyse using a computer algorithm. There are statistical codes for procedures and diagnoses (for example, ICD-9 and ICD-10), and their presence in a patient's electronic health record could possibly be used to determine the patient's ASA status. There is some potential to use them to decide whether the patient needs an FTF visit. However, at the time of writing, we are not aware of any studies conducted in this area.

Artificial intelligence (AI) and techniques such as natural language processing (NLP) appear to be promising for the automatic analysis of medical history data. Suh *et al.* [20] published a proof-of-concept study in which they analysed the efficiency of an NLP toolkit in processing free-text medical notes to identify the presence or absence of a specific condition. In 16% of the cases in which the computer program identified a condition, an anaesthesiologist did not. The opposite was true for only 2% of the cases.

Legal status and reimbursement

It is important to consider the legal status of remote consultations before implementing them. Azizad and Joshi [21] indicated that the "potential barrier for telemedicine is compliance with federal and state regulations." They noted that during the pandemic, the Centers for Medicare and Medicaid Services (CMS) paid the same rates for telehealth visits and in-person visits. They also expressed uncertainty about whether this would be a new standard after the pandemic ends.

Automated chatbots or other turnkey solutions

To the best of our knowledge, fully automated systems for preanesthetic screening and/or evaluation have not yet been developed. We are also not aware of any AI chatbots that would make remote automatic preanesthetic screening possible. We hope such tools are close to becoming a reality and within our reach, especially considering that AI models such as ChatGPT have successfully answered board examination practice questions [22]. Therefore, they can potentially be taught to process free-text medical notes [20]. Perhaps an AI chatbot asking questions modelled after some kind of web form would be more approachable for some patients. We consider that this kind of software should not be modelled after a general purpose chatbot; rather, it should be a special AI model that collects medical history.

Web forms: remote questionnaires

Forms are a structured way to collect a patient's medical history. Although they may not cover all cases, depending on their structure, they can be sufficient for an anaesthesiologist to automate the preanaesthetic evaluation.

O'Shea *et al.* [23] used a web application comprising a patient survey with 22 questions and then applied an algorithm to stratify the risk of anaesthesia and identify nonroutine preoperative investigation and intervention. An online assessment was found to be acceptable in 92% of the patients. The tool accurately predicted perioperative risk and the need for intervention.

Goodhart *et al.* [24] recruited 330 patients to complete a computerised electronic personal assessment questionnaire. They found that the ASA grades assigned by the software matched consultant-assigned grades more frequently than nurse-assigned grades and that 98% of patients would be happy to use the questionnaire again.

Zhang *et al.* [1] mentioned that even if "patients were assessed by anaesthesiologists, residents, nurses, and nurse practitioners (…), there is a possible role for virtual preoperative evaluation by other healthcare workers, including family practitioners". We conclude that implementing a web-based preanesthetic form system can potentially lessen the burden on anaesthesiology workers, even if it is not fully automatised.

Almeshari *et al.* [25] used electronic preanaesthesia forms and found that electronic forms had better data quality and met the expectations of anaesthetists. A few publications also indicate a lower chance of missing documentation in the case of telemedical consultations [1, 26], because patients who are interviewed at home usually have the full medical history available to them.

In our opinion, remote preanaesthesia questionnaires are safe and effective for performing a remote semi-automatic or automatic (depending on the patient) preanaesthetic evaluation.

Remote physical examination

Airway assessment

Hrishi *et al.* [27] decided to perform a "virtual airway assessment" (VAA) during the COVID-19 pandemic, primarily to reduce viral exposure. VAA included mouth opening, Mallampati classification, thyromental distance, upper lip bite test (ULBT), neck movements, and the Look-Evaluate-Mallampati-Obstruction-Neck Mobility (LEMON) scoring system. The tool used for VAA was a smartphone. The authors concluded that VAA could be reliably used as an alternative to direct medical consultations. The pictures in this study were manually analysed without the help of AI algorithms.

A pilot study on the automatic analysis of mouth opening was conducted by Jeon *et al.* [28]. The study was performed on patients with temporomandibular joint disorders. The study protocol required placing a special sticker on the patient's mouth before performing the test for device calibration. To our knowledge, no studies have yet been conducted on automatically assessing mouth opening for preanesthetic evaluation. To the best of our knowledge, no publications at the time of writing have examined a model for automatic ULBT image classification.

Zhang *et al.* [29] created a deep convolutional neural network (DCNN) model, which automatically performed Mallampati score classification in an accurate and objective manner. Hayasaka *et al.* [30] developed an AI model that assesses intubation difficulty. The model required taking 16 photos of the patient in sitting and supine positions, with the mouth open and closed, and with the neck in base and in an extended position. The best predictive value for the AI model in this study was noted for images taken in the supine-side-closed mouth-base neck position.

We conclude that automatic airway assessment in preanaesthetic telemedicine is not only possible and convenient, but some tests can also be automatically analysed using tools such as the neural network model described by Zhang *et al.* [29]. We also note the problems with current implementations, which would require the patient to be trained in how to obtain optimal images. If the patient is not properly trained, the pictures could be of suboptimal quality. We also hypothesise that sending a picture of their face could raise privacy concerns for some patients.

Auscultation

Leng *et al.* [31] analysed electronic stethoscopes in their comprehensive review. They provided a presentation of electronic stethoscopes and described the medical and technological bases for the development and commercialisation of a real-time integrated heart sound detection, acquisition, and quantification system.

Recently, a small, portable device for auscultation called the Stemoscope (Hulu Devices, California, USA) was developed. Fan *et al.* [32] evaluated this and concluded that in-person auscultation and tele-auscultation by the Stemoscope were in agreement with manual acoustic auscultation and that the Stemoscope can be used in telemedicine.

Grzywalski *et al.* [33] analysed pulmonary auscultation in children using a neural network model. Machine-learning-based approaches have been found to be more effective in detecting all 4 types of pulmonary phenomena (wheezes, rhonchi, and coarse and fine crackles) than doctors. Ghanayim *et al.* [34] described similar results when analysing AI detection of aortic stenosis. In an article titled "Lung and Heart Sound Analysis: State-of-the-Art and Future Trends", Padilla-Ortiz [35] discussed the potential for intelligent diagnosis of heart and lung diseases.

Based on these works, we conclude that auscultation as part of a physical examination can not only be performed remotely, but the results can also be automatically analysed using an AI algorithm. The auscultation device can be sent to the patient (or used on site when performing a remote preanaesthetic evaluation, for example, at a family doctor's practice), together with instructions for performing the recording of auscultation. The recording can then be transferred over the internet via the patient's smartphone. There is a commercial system called StethoMe that implements a similar approach for children with asthma. Kevat *et al.* [36] studied a part of it – an algorithm for sound analysis called StethoMe AI.

Laboratory tests

Nowadays, laboratory tests are readily available in electronic form. Therefore, their manual analysis performed by an anaesthesiologist in a remote manner should be feasible.

In our opinion, automatic analysis of lab results using a computer should be easy to implement for simple, one-time preoperative tests. The problem lies in the actual data interchange between various external systems used by different laboratories, which is not as easy as it should be. Laboratory results obtained in any digital format, including Portable Document Format (PDF) files, would probably have to be preprocessed by connector software (created specifically for that digital format) and then imported to the preanaesthetic platform for automatic analysis. We recognise the efforts of the Clinical Data Interchange Standards Consortium (CDISC), but there are still significant barriers to the implementation of their standards, as noted in a Delphi survey performed by Facile *et al.* [37].

Cadamuro *et al.* [22] analysed laboratory reports using ChatGPT, which failed. However, the authors concluded that future generations of similar AI tools, when trained specifically for medical data, might revolutionise healthcare.

Electrocardiography (ECG)

Single-lead ECG can be easily performed using an Apple Watch Model 4 (introduced by Apple in 2018) and newer versions. The algorithm for atrial fibrillation detection on Apple Watch has received United States Food and Drug Administration (FDA) clearance. Iskadze and Martin [38] examined the possible uses and challenges of this feature. Single-lead ECG from an Apple Watch can be easily shared remotely as a PDF file using built-in functions in the software.

Numerous publications have studied automated ECG analysis using special algorithms, such as neural networks or other forms of AI. Kennedy *et al.* [39] developed and validated a DCNN model that analysed ECG data in a device-agnostic manner and achieved performance similar to that of a cardiologist. ECGs can also be analysed remotely without AI using the help of cloud telemedicine services, such as the one created by Hsieh *et al.* [40].

Performing a 12-lead ECG recording using a smartwatch is a challenge for the patient. Although it is technically possible to perform this using an Apple Watch, as described by Li *et al.* [41], the procedure will require extra equipment, such as a piece of wire for augmented leads (aVR, aVL, and aVF). The authors also mention that the accuracy of the ECG data obtained in this way has not yet been reviewed.

Therefore, we conclude that a single-lead ECG can be easily obtained using the patient's wearable device and then shared via electronic means of communication. Nowadays, ECGs can be analysed using external services that automatically employ either AI or a cardiologist. We suggest that recording a 12-lead ECG by a patient in a professional manner is still a challenge that needs to be addressed. We believe that the current best way to obtain a 12-lead ECG must involve the patient's visit to a family doctor's practice (or a home visit performed by a doctor or a nurse). Therefore, 12-lead ECG recording is not yet telemedicine ready.

Chest X-ray

Just like laboratory test results, radiology results nowadays are digital and can thus be easily sent over a network to remote locations. Teleradiology became the norm for many hospitals long before the pandemic.

Efforts have been made to create AI models for X-ray pathology identification, such as the one by Albahli and Yar [42], with variable results. In most cases, a patient's chest X-ray will already be described by a radiologist during a preanaesthesia interview. While clinically useful, such a description will be another hurdle to analyse automatically because there is no common standard for the structure of radiological reports. Several studies, such as López-Ubeda *et al.* [43], have analysed natural language processing in radiology.

Data safety concerns

The medical sector is a huge database at risk of leakage of critical patient data. This is where full homomorphic encryption (FHE) can help. FHE is a type of encryption that allows data analysis to be performed on encrypted data without having to decrypt it first. The use of encrypted data without decryption is a response to patients' concerns about their privacy and the potential threat from hackers. Data encryption is covered by the SHA256 algorithm, which increases data security and verifies data integrity. The implementation of such systems, which is possible in the current technological reality, was presented and proven in 2009 by Gentry [44] in his doctoral thesis.

Predictive analysis of encrypted patient data

Machine learning (ML) models can be used to analyse large amounts of data in the medical sector. AI/ML can be used to perform predictive analyses and draw conclusions based on encrypted data, which also translates into the security of healthcare systems because ML models will significantly accelerate treatment processes and be able to diagnose and predict patient test results [45]. Through the synergy of ML with FHE, patient data can be safely shared between trusted entities.

TABLE 1. Current problems with remote automatic preanaesthetic evaluation

Unclear legal status, which will become additionally complicated when multiple parties participate in the process, when using common external software tools, such as readily available communication applications
Reimbursement concerns
Patient privacy concerns
Unclear guideline status
Problems with digital medical history and laboratory data: – lack of common, easily readable data interchange formats – lack of a commonly accepted structure for digital medical history – lack of NLP AI models
Lack of specialised AI models for medical history collection
Lack of feasible telemedical airway assessment tools and models
Lack of NLP AI models for radiological data

TABLE 2. Remote preanaesthetic evaluation benefits

Epidemiological safety
Cost savings
CO_2 emission reduction
Objective assessment of prehabilitation measures taken by patients
Research potential: data for additional AI model training
Less burden on anaesthesia providers
Potential to perform various parts of preanesthetic evaluation by less skilled personnel with the aid of computerised tools

FUTURE PERSPECTIVES AND CHALLENGES

In this review, we have shown which elements of preanaesthetic consultation can be performed remotely. We show which ones have been currently performed automatically or hypothesised to be able to do so and which ones could be performed automatically in the future. We also pointed out potential pitfalls in the implementation of remote or automatic preanaesthesia services (Table 1).

Telemedicine preanaesthetic consultations seem promising not only because of their value in reducing travel time, absence from work, cost reduction, and CO_2 emissions, but also because of their potential to lessen the burden on anaesthesia providers (Table 2). They also facilitate improved research potential not only in providing data for AI model training but also for taking objective measures instead of subjective ones. Remote preanaesthetic evaluation results in similar cancelation rates and similar or higher patient satisfaction, especially for ASA I–II patients. A few authors have attempted to develop tools to decide which patients should be referred to FTF visits, with various degrees of success. Day surgery is a special use case for telemedicine in anaesthesia and surgery because they are likely to benefit from a more comprehensive approach using a software platform.

Tools available for remote preanaesthetic evaluation range from simple web forms to special perioperative portals. They can be automated to various degrees. Even if there are no special chatbots collecting preanaesthetic history yet, web forms seem to be a sufficient tool for now, especially because they can be filled in by the patients themselves or by medical personnel other than anaesthetists, thus lessening the burden on anaesthesia providers. It is also important to analyse the legal status of remote consultations before implementing them, because it is often not clear. Most of the typical physical examination steps (airway assessment, auscultation, laboratory test analysis, ECG, and X-ray screening) can already be performed remotely. However, further improvements in the software we use today are required to be able to perform them fully automatically.

There is also a lack of guidelines on telemedicine from anaesthesiology associations. The question arises as to whether the guidelines should include such information at all. Nowadays, we live in a world of vast, ever-improving information technology. Is it even sensible to expect that any medical guidelines will ever be able to catch up with the latest trends? And would it be reasonable for us, medical practitioners, to expect that from guideline authors?

As a general rule for the implementation of future systems – automated or not – we suggest that the implementors do everything possible to ensure that the created system brings no less value – both to patients and practitioners – compared to the standard, face-to-face, nonautomated, nonremote, and nondigitised approaches.

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