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VoiceCheck: An Intelligent Assistant for Enhancing Surgical Safety Through Guided Checklist Use

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Abstract. Challenges such as time constraints, distractions and multi-tasking can compromise patient safety in the demanding environment of surgery. To mitigate these risks, checklists have emerged as simple yet effective tools for ensuring critical aspects of patient care, such as verifying patient identity and planned interventions. However, their consistent and accurate implementation in daily practice remains a challenge. This paper presents an intelligent assistant, VoiceCheck, designed to enhance patient safety during surgical procedures by guiding the use of checklists. Seamlessly integrated into the surgical workflow, VoiceCheck uses advanced speech recognition technology to ensure compliance with safety protocols. Combining speech-to-text and text-to-speech capabilities, the assistant facilitates interactive communication with users and accurately captures approved information. Future work will study user acceptance and usability. An open issue is linking the system to a hospital information for retrieving relevant patient data.

Keywords. Patient safety, Checklist, Voice assistant, Surgery

1. Introduction

In the demanding environment of surgery, factors such as time pressure, inattention and multi-tasking can compromise patient safety. To mitigate these risks, checklists have proven to be simple yet effective tools for ensuring critical aspects of patient care, such as verifying patient identity and planned interventions [1]. By minimising errors and preventing confusion of patients or information, checklists improve patient safety.

In Switzerland, the "Surgical Safety Checklist," originally developed by the World Health Organization (WHO), was adapted as part of the pilot program "progress! Safe Surgery" by the Swiss Patient Safety Foundation. This checklist is structured into three phases: "Sign In" (before anesthesia induction), "Team Time Out" (prior to incision), and "Sign Out" (at the end of the surgery). The checklist items for the sign-in phase include key safety checks, including confirmation of the patient's identity, the type and location of the planned procedure, the intended anaesthesia and verification of informed consent. In addition, the surgical site is verified. Patient-specific risks, such as known

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allergies or the presence of a difficult airway, are also carefully assessed and confirmed [2]. However, practical studies reveal that the first and third phases are often inconsistently or incorrectly implemented. A study of 200 surgical interventions [3] showed that the Sign In phase was implemented in 93% of all assessed cases, the Team Time Out phase in 94% of all cases and the Sign Out phase in 86% of all cases, either partially or fully. Reasons are competing tasks and workload that prevents staff in staying for the Team Time Out or arriving in time for the Sign In phase. Looking at the differences between partial and full implementation, the study showed that the Sign In phase was fully implemented in 87% of cases and only partially implemented in 6% of cases, the Team Time Out phase was fully implemented in 85% of cases and only partially implemented in 9%, and the Sign Out phase was fully implemented in 71% of cases and only partially implemented in 15%.

To support the complete and correct implementation and use of checklists in the surgical workflow and to increase efficiency, this paper explores the integration of an intelligent digital assistant named VoiceCheck. The assistant aims to seamlessly integrate into surgical workflows, and facilitate comprehensive, consistent, and secure implementation of surgical checklists, eliminating errors in surgical treatment.

2. Methods

Requirements were collected through observations, interviews, and document analysis at the Universitätsspital Zürich. One surgeon provided insights into the practical needs and challenges faced in surgical settings. This phase identified critical points where VoiceCheck could enhance safety and efficiency. After collecting the requirements, the user interface was designed using Figma. The system should ideally be integratable in the clinical information system, address data privacy and security issues and should consider hygiene requirements in the operating room.

The system was designed to integrate a voice assistant capable of interacting with surgical staff through natural language processing. Various technical solutions were evaluated, including hardware, but also speech recognition and voice assistant technologies. An intelligent assistant could in principle be realized in three ways: using a smart speaker, a robot or a tablet. We collected benefits and limitations of each of these three options. While a smart speaker could be used hands-free without any physical interaction, it would be necessary to place several speaker in the different rooms and quality of recognition could be impacted by noise in the room. A robot could move from one room to another room autonomously and would carry speaker and microphone. However, it would be challenging in terms of hygiene requirements in the surgical context. There are no limits to the positioning of a tablet. Voice recording and voice output is possible. Hygiene requirements can be met more easily, at least during the Team Time Out and Sign Out phases. Verification of user input could be done on the screen. For these reasons, we chose a tablet as the hardware for running VoiceCheck.

As we wanted to rely only upon open source software, we collected voice assistant technologies to process voice commands that are available open source and are able to process German language. We identified Mycroft (https://mycroft-ai.gitbook.io), Rhasspy (https://rhasspy.readthedocs.io), Leon (https://getleon.ai), Jasper (https://jasperproject.github.io) and Aimybox (https://github.com/just-ai/aimybox-android-sdk) as possible options. We compared them along several criteria important for our use case: security, accuracy, applied speech-to-text / text-to-speech and natural language processing technologies. We selected Rhasspy for our implementation because it can be used offline (which was one requirement from the collaborating hospital, see below) and it follows high security standards.

Further, we identified speech recognition technologies available open source and compared them by their accuracy to process medical terminology, their benefits and limitations. We compared Whisper (https://openai.com/index/whisper/), Vosk (https://alphacephei.com/vosk/), Kaldi (https://github.com/kaldi-asr/kaldi) and Coqui STT (https://github.com/coqui-ai/STT). Whisper had the highest accuracy in our initial tests and is easy to implement. The other tools recognize medical terminology with medium or high quality but are rather difficult to implement or require additional training. The technologies Rhasspy as voice assistant and Whisper for speech recognition were selected for their accuracy and compatibility with the project's requirements.

3. Results

3.1. Requirements

The intelligent assistant for safe surgery must guide users through the checklist. Besides, it has to support documenting content at defined sections of the checklist. The checklist questions should minimize redundancy, ensuring clarity and efficiency. Existing and familiar terminology should remain unchanged, and no reductions to the current checklists are permitted. The application must operate offline and avoid cloud storage or WLAN connectivity. The checklist for the "Sign Out" process is required to take place within the operating room rather than outside. VoiceCheck must include a time-tracking feature to display the duration of checklist phases. It should also allow generating and saving a PDF of the checklist along with the recorded content. The solution is to be used by healthcare professionals, including anaesthesia staff, surgical specialists, and operating room technicians, also known as technical surgical assistants). Table 1 shows the phases along with the relevant user group for VoiceCheck, characteristics of the process and location where the checklist procedure takes place.

Table 1. Characteristics of the three phases to be supported by VoiceCheck

	Sign In	**Team Time Out**	**Sign Out**
User group	- Anaesthesia nurses - Anaesthetist	- Surgical technology specialists - Anaesthesia nurses - Anaesthetist - Surgeon - Specialist	- Surgical technology Specialists - Anaesthetist Surgeon
Location	Anteroom (before operating room)	Operating room	Operating room
Process characteristics	Aspects can come to light during checklist process that can lead to the cancellation of the surgery.	Confirm procedure, expected challenges (e.g., bleeding). Needed devices in the room and functional, ensuring patients positioning. Full team presence and focus required. Critical: No incision before team time out.	Further procedure will be communicated (prescription of antibiotics; strain on the musculoskeletal system, positioning, bed rest, splint; anticoagulation, leads). Takes usually place before the suture and before counting materials, swabs and instruments.

3.2. Process

Figure 1 shows the overall interaction process between the user and VoiceCheck. Once initiated by a wake up call by the user, VoiceCheck guides through the checklist. It asks for confirming single data items and transcribes the voice input from the user. The user confirms states or data as requested by VoiceCheck using voice input. The data to be confirmed by the user (e.g. patient name, type of surgery) originate from a database (Source 2 in Figure 1).

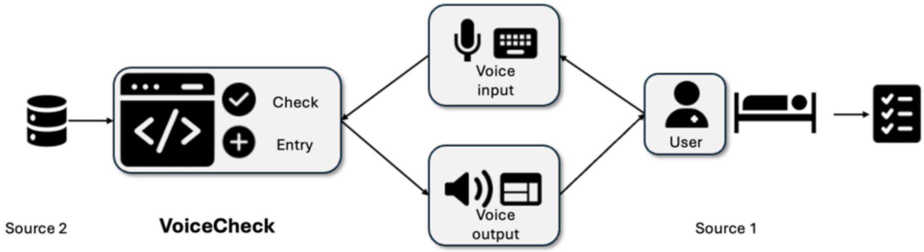

Figure 1. Process overview. The user interacts with VoiceCheck via voice input and output. Information provided by the user (source 1) is validated by a second source (e.g. hospital information system)

As an example, we outline the user scenario for the Sign In phase. During this phase, the anaesthetist or anaesthetist nurse accompanies the patient to the anteroom. The voice assistant is activated with a command such as "Begin Sign-In", to which VoiceCheck responds: "Sign-in started. Please answer the following questions”. The process begins with VoiceCheck verifying the patient's identity by asking: "Please confirm the patient's name and date of birth [...]", providing specific details. The anaesthetist repeats this question to the patient and confirms the name and date of birth. The assistant checks this information against the database and confirms: "Patient identity correct".

VoiceCheck then asks for confirmation of the planned procedure and location by saying: "Please confirm procedure type and location". The anaesthetist checks this information against the operating room schedule and verbally confirms it to the voice assistant. The assistant validates the data and responds: "Procedure type and location correct".

Other relevant checklist items are addressed in a similar manner. If information is missing, VoiceCheck supports data entry. For example, regarding allergies, VoiceCheck asks: "Are there any known allergies?". The user can then reply accordingly with VoiceCheck recording the answer and confirming the recording of the information. Any incomplete checklist items are highlighted visually in the user interface on the tablet and flagged through voice prompts. Finally, VoiceCheck asks for confirmation of the assigned operating room. After confirmation, the Sign In process is completed, with VoiceCheck confirming its completion.

3.3. Technical realisation

The system consists of backend and frontend components, as well as interfaces that connect the backend to a voice assistant (Rhasspy) and a database. User interaction is primarily realized through the frontend (see Figure 2), which provides a visualisation of the checklist and displays a list of patient names retrieved from the database. A WebSocket server realizes the interface between the frontend and the voice assistant Rhasspy. In addition, Whisper acts as a speech-to-text component, allowing data to be entered into free-text form fields via voice commands. VoiceCheck was developed using TypeScript and Angular. When a user interacts with VoiceCheck, voice input is captured by Rhasspy. The recorded voice data is then transmitted to other system components via WebSocket. The transcription of the voice data is handled by Whisper, enabling seamless text input. Once the interaction is complete, the checklist data is stored in MongoDB and a PDF of the completed checklist is generated for documentation purposes. In future, the data could also be stored as HL7 FHIR QuestionnaireResponse resource to ensure interoperability. The prototype has a user-friendly interface with functionality for managing patient lists and checklists. To ensure data security and compliance with privacy regulations, the system operates entirely offline.

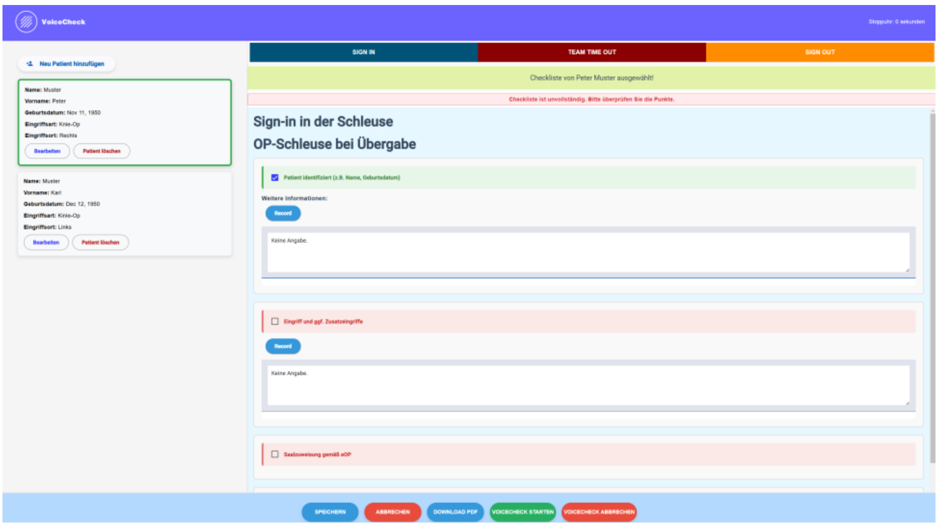

Figure 2. User interface of VoiceCheck

4. Discussion

In this paper, we introduced concept and implementation of VoiceCheck, a digital assistant supporting the verification of information using checklists as part of the surgical workflow. There is one digital system, OP-Check, available that implements the checklist for the three phases of a surgery (https://www.op-check.eu/funktionen) which is already integrated with the electronic health record. Our voice assistant could be well integrated into that system to facilitate the interaction in the critical phases of sign in and sign out. The hands-free operation would be particularly beneficial in maintaining sterility and efficiency [4].

Kiefel et al. found in their literature review that a tablet-based client-server system with integration in the electronic health record is the most promising approach to realize surgical safety checklists in a digital manner [5]. Their suggestion of a user interface does not consider voice interaction. However, they point to several benefits that the tablet device can provide such as the possibility to scan the patient's wristband for identity check. We decided for a voice interface to be more intuitive and to not disturb the interaction with the patient by forced interaction with a computer or touch-based interface. By leveraging voice recognition technology, the system addresses common challenges in checklist compliance and workflow integration. Results from a prototype testing are still pending and needed to verify our hypothesis that the voice interaction is more accepted than interaction with a paper-based checklist. Pati et al. found that the implementation of surgical safety checklists through technology has potential to increase completeness of the checklists [6]. Voice assistants in the surgical environment demonstrated already that they can improve the workflow in the operating room [4].

Our work comes along with some limitations: Although we implemented VoiceCheck with specifically selected tools (Whisper, Rhasspy), the overall concept can be implemented with any other technology. As the quality of our chosen technology still needs to be systematically assessed regarding quality and performance for the given use case, it might be necessary to exchange technology at some later stage of this work. The technology was selected based on initial tests by the authors and was not yet systematically studied. The requirements were collected from only one surgeon. Additional input from other future users such as anaesthetists or anaesthesia nurses may help improving the user interaction and integration into the workflow.

5. Conclusions

This study demonstrates the feasibility of integrating an intelligent voice assistant into the surgical workflow to implement the Surgical Safety Checklist. Our findings confirm that such an assistant can be effectively developed using open-source technology. Future work will focus on evaluating user acceptance, usability and the impact of the system on workflow efficiency. Specifically, the prototype will be tested in a simulated surgical environment to assess its performance and usability. Feedback from surgical staff will be collected to refine the system and address any challenges identified during testing. Following these refinements, a field trial will be conducted to further investigate the impact of the system on workflow efficiency and its potential to improve surgical safety practices.

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