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Integrated operation systems and voice recognition in minimally invasive surgery: comparison of two systems

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Abstract

Background Integrated operation systems were developed for centralization and easy control of all components within the operating room (OR). These systems represent central units that use communication technology to connect and control various components of the OR. Voice control that is independent of the speaker has been a pioneering innovation in the central control of different OR components. The aim of the present study was to evaluate the utility of two voice-activated control systems, the Siemens Integrated OR System (SIOS, Siemens Medical Solutions, Siemens AG) and the OR1 (Karl Storz GmbH & Co. KG), for delivery of commands to specific OR equipment.

Methods To compare the two systems, actions such as adjusting the operating table, increasing gas pressure, switching on the video recorder, and controlling the endolight source were defined according to a study protocol. These actions were to be executed by test persons through speech and manual control after a suitable training period. The parameters evaluated were training time, time to execute each action, number of repeated commands, and number of functional errors.

Results Seventy-four test persons from five nations were selected to participate. The numbers of repeated commands and functional errors differed significantly between systems in all user groups in favor of the SIOS (mean repeated commands for surgeons: SIOS, 2.4; OR1, 14.7, $p < 0.0001$).

Conclusion The SIOS voice control was more effective and more reliable than that of the OR1. Importantly, unlike the OR1, the SIOS produced no functional errors. The appropriate conditions for greater acceptance of these systems must be considered, together with additional technical improvements and possible combinations of advantages of the available systems.

Keywords Minimal invasive surgery · Voice recognition · Integrated operation systems · SIOS · OR1

The introduction of minimally invasive surgery represents a breakthrough within the scope of general surgery. Its rapid development has altered routine surgical practice, and videoendoscopic operation technology provides significant advantages for patients [1–18]. Within the scope of these revolutionary operation methods, numerous components have been developed to optimize surgical conditions and performance (e.g., insufflators, endolight source, video recorders, high-quality and high-resolution video cameras [1, 2, 4, 11, 14]). On the other hand, however, several different types of components with various control options are available and may interfere with the efficient use of the operating room (OR) and the concentration of the surgeon [1]. Thus, it is important to standardize and simplify the control of all electric and electronic components within the OR [13, 14]. Integrated operation systems have been developed to address this need. These systems represent central units in which communication technology, the so-called CAN-open BUS technology, is used to connect and control the various components of an OR (http://www.can-cia.org/can/). The introduction of voice control that is independent of the speaker was a pioneering innovation in the central control of different operation room components

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[11, 12, 14, 16]. Using these systems, the surgeon is able to concentrate on the operation while at the same time controlling all operation components using voice commands. The most important point is that the surgeon's hands are always unencumbered.

There are currently two primarily voice-controlled integrated operation systems: the Siemens Integrated OR System (SIOS, Siemens Medical Solutions, Siemens AG) and the Operating Room 1 (OR1, SESAM, Karl Storz GmbH & Co. KG) available in Germany. The important differences between the two systems are the introduction of monolingual orders, substitution of the design of the operation components with their company names, and illustrations of the control surface of every connected component on the main screen.

The aim of the present study was to evaluate and compare the utility of these two voice-activated control systems for the delivery of commands to specific OR equipment and the control options of both systems. Two generations of the voice control option were compared.

Materials and methods

Both SIOS and OR1 were installed in two operating rooms in our department and were routinely used during minimally invasive surgical procedures. Our study was performed in our operating rooms under normal conditions but not on patients during live surgery. All possible external noises such as conversations between staff and monitor alarms have been considered and have not been filtered out with any noise filters.

To compare the systems, a process of actions was defined according to a study protocol. These actions were to be executed by test people through voice and manual controls (touch-screen or remote control) after a suitable training period. For the vocal control we used a microphone for both systems. The actions tested were those most frequently used in minimally invasive operations, i.e., adjusting the operating table, increasing the gas pressure, switching on the video recorder, and controlling the endolight source. We selected 74 test people. The group comprised the same number of men and women and came from five nations (China, Greece, Turkey, Luxemburg, and Germany). The German subjects came from 12 states (Table 1). The parameters evaluated included training time, time to execute each action, number of repeated commands, and number of functional errors. We also prospectively tested whether the accent of the subjects, both between countries and between German states, influenced the use of the speech-control systems. Moreover, we compared the time required to use both control options (speech control and manual control). Finally, to produce a more objective representation of our results, the test people were divided into three subgroups: (1) surgeons with experience, (2) test people without experience, and (3) technical staff with experience. Both integrated operation systems, the SIOS and OR1, were used for comparison.

Table 1 Test persons ($n = 74$) from five nations and 12 German states

Country	n
China	1
Germany (state)	60
Baden-Wuerttemberg	6
Bavaria	37
Berlin	2
Bremen	1
Hesse	2
Lower Saxony	2
Mecklenburg-West Pomerania	1
North Rhine-Westphalia	2
Rhineland-Palatinate	2
Saxony	2
Saxony-Anhalt	2
Schleswig Holstein	1
Greece	5
Luxemburg	2
Turkey	6

SIOS (Siemens integrated operation system)

The SIOS integrates essential functions in the OR using a universal interface (CAN-open BUS system). The integrated operation system of the SIOS allows the user to use different devices belonging to both the sterile and unsterile areas of the OR. The following devices or OR components can be controlled: (a) operating table, (b) OR lights and space lights, (c) endolight and endocamera, (d) high-frequency devices, (e) X-ray, ultrasound, and C arm, (f) video recorder and video mixer, and (g) telephone and pager. All components are integrated as a unit and can be installed into a carriage device. The components are controlled using either a sterilizable remote control or voice control. Using a central and adaptable monitor system comprising three TFT LCD monitors, the surgeon can check the status of the connected devices at any time. In addition, the surgeon can receive information from all linked systems and databases (X-ray, ultrasound, and endoscope). Thus, all important information (live pictures, patient data, laboratory values, X-ray, and CT/MRT diagnostics) can be retrieved on the TFT monitors. Furthermore, the video mixer can be used to show two pictures from different databases on a single TFT monitor at the same time using the picture-in-picture function. The SIOS is based on the CAN-open BUS system technology, which functions as a transmitter of the information from the central unit of SIOS to the different OR components and devices. The advantage of this technology is that numerous devices can be connected to the SIOS without interfering with the reliability and the stability of the data transfer. The "brain" of this system is the computer unit that is responsible for interlinking the different OR components and devices to ensure stable data transfer.

Operating room 1 (OR1) with Storz communication BUS (SCB) from Karl Storz

The basic element of this integrated OR system is the central SCB, which is based on a serial communication interface. SCB is a BUS system by which all of the OR components and devices (e.g., OR lights, endolight source, video recorder) connected to the system communicate with the central unit. The components of the OR1 are (1) monitors; information is displayed on least two picture monitors and a menu monitor. Flat screen technology provides a jitter-free sharp picture. The menu monitor utilizes touch-screen technology. The monitor mount permits the monitor to be positioned in any direction to allow for optimum positioning of the screen; (2) serial communication for the connected OR components; up to 31 devices can be connected to the OR1; and (3) ethernet interface for the local area network connection with the advanced image and data archiving system documentation system. The OR1 can be controlled using (a) touch-screen control, (b) voice control SESAME (SCO), and (c) remote control.

Controlled area network (CAN) BUS system

The CAN BUS system is a serial BUS system that was developed in the early 1980s, originally for use in automobiles. An adaptation module makes it suitable for network-intelligent devices that have input/output functions and also for sensors and triggers (i.e., network-intelligent devices and actuators). The final standardization of the CAN BUS system occurred in 1993 when it was made ISO 11888-1 compliant (http://www.can-cia.org/can/). To provide a better understanding of these systems, we first describe the principles of a network: The central unit stands on the side at which the operator gives the orders. The central unit receives the orders, encodes them, and passes the encoded information to the various components being controlled. The connected components are placed on the other side of the OR table. The components are connected to nodes and have a unique identity in the network. They must receive the required information so that the given functions can be performed. The CAN BUS system is situated between the central unit and the controlled components connecting the two parts. CAN receives the information encoded by the central unit and broadcasts it to all of the nodes. The CAN has multimaster capabilities and functions as the coordinator of the components that are connected to the network. Thus, the CAN BUS system supervises, corrects mistakes and possible malfunctions of the transmission, and sends the orders to direct the functions of the components by broadcasting the appropriate signals.

Statistical analysis was performed using statistical software (SPSS for Windows v17.0, SPSS Inc., Chicago IL; and Excel 2007, Microsoft, Redmond, WA). Due to the multivariability of our study, all data were checked for significance using the "sign test" [19]. A p value of <0.05 was considered statistically significant. Continuous variables are reported as the mean ± standard deviation.

Results

The numbers of repeated commands and functional errors differed significantly between the two systems in all user groups ($p < 0.0001$; Table 2). The SIOS needed significantly fewer repeated commands and had no functional errors. The OR1 produced some functional errors (Table 3).

Regarding the influence of the speaker's accent on OR system accuracy, the numbers of repeated commands and functional errors by both systems were approximately the same for non-native and native German speakers (mean repeated commands: native, $n = 18.4$ vs. non-native, $n = 19.5$, $p = 0.872$; mean functional errors: native, $n = 8$ vs. non-native, $n = 9$, $p = 0.905$). In addition, the actions

Table 2 Comparison between SIOS and OR1 (time to complete and repeated commands)

	SIOS ($n = 74$)	OR1 ($n = 74$)	p
Time to complete (s)			
Steering of OR table	43.6 (10–310)	87.4 (17–298)	<0.0001
Steering of insufflator	12.8 (5–45)	83.9 (10–180)	<0.000
Steering of video recorder	11 (6–22)	18 (2–48)	0.003
Steering of endolight	21 (15–86)	35 (8–98)	0.043
Repeated commands			
Steering of OR table	4.1 (0–45)	21.3 (0–110)	<0.0001
Steering of insufflator	2.9 (0–39)	25.1 (0–114)	<0.0001
Steering of video recorder	2.8 (0–20)	19 (0–34)	<0.0001
Steering of endolight	8.1 (0–60)	18.1 (0–78)	< 0.0001

Table 3 Comparison of OR1 and SIOS

Test persons	Repeated commands		Functional errors	
	SIOS	OR1	SIOS	OR1
No experience	7.8 (0–60)	22.3 (0–114)	0	9
Surgeons	2.4 (0–18)	14.7 (0–63)	0	6
Technical staff	2.3 (0–12)	18.3 (0–74)	0	2

Values are mean (range)

were performed faster using manual control [mean of OR1 manual control (touch-screen) = 14.8 s vs. mean of OR1 voice recognition = 56.2 s, $p < 0.0001$; mean of SIOS manual control (remote control) = 14.9 s vs. mean of SIOS voice recognition = 22.1 s, $p = 0.04$]. In retrospect, it was observed that women had an increased rate of repeated commands when using the speech control of both systems and an increased rate of functional errors with OR1 (mean repeated commands: women = 18.6 vs. men = 11.7, $p = 0.002$; mean functional errors: women = 11 vs. men = 6, $p < 0.0001$). Experience using the systems also played an important role. For the group of inexperienced subjects, the mean number of repeated commands was 7.8 for the SIOS and 22.3 for the OR1 ($p < 0.001$, range = 0–114). In contrast, for the groups of experienced users (experienced surgeons and experienced technical staff), the mean numbers of repeated commands were 2.4 and 2.3, respectively, in the SIOS group and 14.7 and 18.3, respectively, in the OR1 group ($p = 0.887$ between surgeons and technical staff; $p = 0.03$ between SIOS and OR1). Importantly, the mean number of repeated commands in the group of experienced users (surgeons and technical staff) was significantly lower with the SIOS than with the OR1. Furthermore, functional errors were produced by the OR1 system in the same group, which may have clinically relevant ramifications.

Discussion

The 7-year experience with voice control in our department indicates that voice control has an important role in minimally invasive surgery. The surgeon is able to take control of the entire OR without interrupting the operation to steer the surgical components. This cannot be achieved using remote control and touch-screen options. There are several advantages to using voice activation of the surgical components, such as the ability to achieve "single surgeon surgery." The surgeon can perform the operation without assistance or a paramedical staff, which reduces the overall cost of an operation as well as the level of functional errors resulting from the "man (surgeon)–man (paramedical staff)–machine (OR components) interface." Functional errors at this level often result from a misunderstanding of the surgeon's orders and the lack of experience of the paramedical staff. By converting the "man–man–machine" interface to a "man–machine" interface [13] with integrated voice-activation systems, these systems can be further improved to eliminate functional errors in the OR, saving both time and financial resources. These aspects should be analyzed in a randomized clinical trial.

This study aimed to evaluate the functionality of voice activation for minimally invasive surgery in a modern OR, in both an objective (time, false actions, repeated commands) and a qualitative (native/non-native German speakers) manner. Other groups have examined the role of voice activation in steering an endoscope [16] or the general utility of voice activation in the OR [18]. Punt et al. [16] examined objective (time, functional errors) and subjective (preference and experience of the surgeon) criteria. Salama et al. [18] tested the efficiency of voice control in the OR using the voice-activated HERMES Operating Room Control Center control system (Computer Motion, Santa Barbara, CA). Adjustments of OR equipment were evaluated in three standard minimally invasive operations (laparoscopic fundoplication, laparoscopic hernia repair, and laparoscopic cholecystectomy), and the results indicated no functional errors or repeated commands. The study by Salama et al. [18] included only surgeons with experience, whereas the present study was randomized using subjects with and without experience in using integrated OR systems and voice activation. Our results revealed that the SIOS speech control is more effective and more reliable than the OR1. Importantly, the SIOS demonstrated no functional errors in testing, indicating that the system is safe. The voice control option of the SIOS, however, was not flawless. The device should be designed to avoid the user repeating commands and should comprise an easy and user-friendly speech-controlled system (e.g., commands can be one word, input rate can be adjusted, and media interface contains a representation of the operating surface of every connected component). On the other hand, using both the touch-screen control (OR1) and the remote control (SIOS) led to more rapid execution of the actions. Punt et al. [16] reported the same finding. The actual situation, however, seems to be different: The surgeon is using both hands to perform surgery, so the operation must be interrupted for the surgeon to operate a hand-controlled device, resulting in loss of time and concentration. Integrated OR systems are the first step in the right direction, but must be further developed. The aim should be to optimize the integrated voice-steered OR systems to obtain the necessary general acceptance, so that these systems can then be introduced into everyday clinical life as a standard. Unfortunately, the introduction of the new generation of the voice-controlled systems has not been successful. Although the first-generation SIOS was qualitatively and quantitatively better than the OR1, it was not flawless. The disadvantages of the SIOS were the outdated media interface, the complicated construction of the voice controls with many submenus, and the complicated voice commands.

These integrated OR systems have high technical potential and represent the future of minimally invasive surgery. The appropriate conditions for greater acceptance of these systems must be considered together with technical improvements and possible combinations of the advantages of the available systems. The developers of these systems and the surgeons who will use them must cooperate closely for further development of integrated voice-activated OR systems. The cost-effectiveness of these systems in everyday clinical life should also be examined in randomized clinical trials.

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