Transcontinental anaesthesia: a pilot study

T. M. Hemmerling1*, E. Arbeid1, M. Wehbe1, S. Cyr1, F. Giunta2 and C. Zaouter2

1 Department of Anaesthesia, McGill University, Montreal, QC, Canada H2W 1T8
2 Department of Anaesthesia and Intensive Care, University of Pisa, Pisa, Italy
* Corresponding author. E-mail: thomas.hemmerling@mcgill.ca

Editor’s key points

- This is among the first few studies that have explored the feasibility and efficacy of teleanaesthesia.
- Master and slave computer set-ups were established in Montreal and Pisa, respectively.
- Twenty patients underwent elective thyroidectomy in Pisa, and their total i.v. anaesthesia (TIVA) was controlled by Montreal.
- Overall control of TIVA was feasible with good performance indices.

Background. Although telemedicine is one of the key initiatives of the World Health Organization, no study has explored the feasibility and efficacy of teleanaesthesia. This bi-centre pilot study investigates the feasibility of transcontinental anaesthesia.

Methods. Twenty patients aged ≥18 yr undergoing elective thyroid surgery for ≥30 min were enrolled in this study. The remote and local set-up was composed of a master-computer (Montreal) and a slave-computer (Pisa). Standard Internet connection, remote desktop control, and video conference software were used. All patients received total i.v. anaesthesia controlled remotely (Montreal). The main outcomes were feasibility, clinical performance, and controller performance of transcontinental anaesthesia. The clinical performance of hypnosis control was the efficacy to maintain bispectral index (BIS) at 45: ‘excellent’, ‘good’, ‘poor’, and ‘inadequate’ control represented BIS values within 10, from 11 to 20, from 21 to 30, or >30% from target. The clinical performance of analgesia was the efficacy to maintain Analgoscore values at 0 (−9 to 9); −3 to +3 representing ‘excellent’ pain control, −3 to −6 and +3 to +6 representing ‘good’ pain control, and −6 to −9 and +6 to +9 representing ‘insufficient’ pain control. The controller performance was evaluated using Varvel parameters.

Results. Transcontinental anaesthesia was successful in all 20 consecutive patients. The clinical performance of hypnosis showed an ‘excellent and good’ control for 69% of maintenance time, and the controller performance showed an average global performance index of 57. The clinical performance of analgesia was ‘excellent and good’ for 92% of maintenance time, and the controller performance showed a global performance index of 1118.

Conclusions. Transcontinental anaesthesia is feasible; control of anaesthesia shows good performance indexes.

Clinical registration number. NCT01331096.

Keywords: BIS; teleanaesthesia; telemedicine; TIVA

Accepted for publication: 1 October 2012

Telemedicine has been developed to overcome the shortage of qualified specialists in remote areas.1–5 Both the European Union and the World Health Organization (WHO) have identified telemedicine as a major initiative.6–7 Although telemedicine has been developed rapidly in recent years, few studies have looked at the application of telemedicine in anaesthesia.8–10 Closed-loop systems are systems that control the administration of anaesthetic drugs by monitoring appropriate control variables (e.g. bispectral index (BIS)) to enable feedback control of the infusion of propofol. Such systems have been developed for research purposes and have been successfully tested in clinical trials, showing higher precision to maintain defined clinical targets compared with manual control.11–15 The advantage of automated closed-loop anaesthesia delivery systems is that anaesthesia is provided independently of subjective or real differences of quality of anaesthetic care, similar to an automatic car which drives independently of who the driver is. With the help of automated closed-loop systems, the workload of anaesthesiologists might be decreased and their vigilance for other aspects of perioperative care can be increased, for example, fluid management or control of surgically induced complications. Automated anaesthesia delivery systems can be controlled remotely and have the potential to provide anaesthesia at distance (‘teleanaesthesia’).

Teleanaesthesia must consist of the following components: continuous audio–video communication with the local healthcare providers, continuous video feed of important monitoring systems, including the surgery site, and remote control of a locally installed anaesthesia system.
It is also important to be able to perform a preoperative interview with the patient using audio-visual communication. Tele-anaesthesia can benefit from using closed-loop systems which can be installed in a local centre but can be controlled remotely, with possible distant (and local) manual override.

In the current study, we investigated the hypothesis that transcontinental anaesthesia is feasible via a standard Internet connection from one continent to another: the success of such transcontinental anaesthesia was determined and also the controller performance of the anaesthesia delivery system.

**Methods**

After ethics approval in the remote (Montreal General Hospital, Canada) and local centre (Hospital of University of Pisa, Italy) and written informed consent, 20 patients undergoing thyroid surgery in Pisa were enrolled in this prospective pilot study. All patients received anaesthesia treatment from anaesthesiologists in Montreal. The remote set-up (‘anaesthesia cockpit’) and local set-up were composed of a master-computer (Montreal), an audio–video-purpose computer (both sites), and a slave-computer (Pisa), respectively (Fig. 1A).

![Fig 1](A) The remote set-up and local set-up were composed of a master-computer (Montreal), an audio–video-purpose computer (both sites), and a slave-computer (Pisa), respectively. The master-computer in Montreal controlled the slave-computer in Pisa via TeamViewer. The audio–video communication was done via Skype. (i) The live feeds of four webcams were displayed on a second computer in the remote control station, showing: ventilator parameter (upper left image), vital sign monitor (upper right image), view of the surgical field (lower right image), and videolaryngoscope (lower left image) with anaesthesia automated system interface (inset, lower left image).
The local centre (Pisa) computer set-up was composed of two computers (both ASUS G51J, ASUS Tek Computer Inc.). The automated anaesthesia delivery program (an expert-based self-adaptive closed-loop system) was installed on one computer to control delivery of the anaesthetic drugs (‘Slave’-system) automatically via standard syringe infusion pumps (Graseby 3400). On a second computer, live feeds of four webcams were displayed for different monitoring purposes: automated anaesthesia delivery system interface, view of the surgical field, imaging of the glide scope during intubation, and vital sign monitor (Fig. 1a). One headset microphone was used by the local anaesthesiologist for communication.

The remote centre (Montreal) computer set-up consisted of two computers: the Sony VAIO (PCG-61411L, Sony Corp.) and the ASUS K42J (ASUS Tek Computer Inc.). The automated delivery system control program was installed on one computer (‘Master-system’); communication of the ‘slave-system’ was achieved using remote desktop control software TeamViewer (TeamViewer Version 6, Göppingen, Germany). The second computer was connected with the video-feed local computer in Pisa via video-conference software Skype (version 5.1, Skype Technologies, Luxembourg). Both local computer systems and remote computer systems were connected via a standard Internet connection with a high bandwidth of up to 8 Mb s\(^{-1}\).

In the case of computer crash or power failure, manual override was possible at any time by using the syringe infusion pumps in the manual mode.

The anaesthetic monitor outputs are fed back to Montreal, through the Pisa computer. All the monitor outputs are analysed in Montreal, and the Montreal cockpit changes the drug infusion rates according to the target values. The Pisa computer system serves as a ‘slave’ to the ‘Master’ system in Montreal. The infusion rate changes are sent back to the Pisa computer which relays this information to the pumps. However, if broadband communication broke down, or the Montreal system went offline, the Pisa computer continues the infusion of drugs using the Montreal cockpit information which are stored in its—Pisa—database and will continue to adjust the infusion rates; in this situation, the Pisa ‘slave’ becomes the ‘Master’.

Standard preoperative anaesthesia assessment for thyroid surgery (ASA classification, incidence of allergies, medical history, airway assessment, e.g. mouth opening, Mallampati classification, thyromental distance, neck mobility, larynx mobility) was performed in a preoperative assessment area both face to face by the local anaesthesiologist and remotely by anaesthesiologists in Montreal. The set-up incorporated a webcam, headset microphone, a laptop computer ASUS G51J (ASUS Tek Computer Inc.), and a small metering system: skin marker ruler labels (Medline Industries, Inc., USA). The remote anaesthesiologist recorded a medical history from the patient as in a conventional consultation. This was done in a cross-over fashion, with either the remote or the local preoperative assessment being performed first. By placing the webcam (Logitech Webcam Pro 9000, Logitech, Fremont, CA, USA) right in front of the patient’s head and instructing the patient to widely open his or her mouth, mouth opening and Mallampati classification were assessed. Using a side-view visual assessment of the airway profile, thyromental distance, and neck and larynx mobility measurements were obtained. After patients’ arriving at the operating theatre, the local computers in Pisa were set up, and the Internet connection with the computers to the remote centre in Montreal was established. Standard monitoring (non-invasive arterial pressure monitoring, ECG, pulse oximetry) and BIS monitoring and neuromuscular block monitoring were started before anaesthesia induction and maintained until extubation. Anaesthesia was induced and maintained in all patients using remifentanil, propofol, and rocuronium delivered using the automated delivery system controlled at distance from Montreal. Tracheal intubation was performed using the Glidescope (Glidescope, Verathon Company, USA), guided by the Montreal team, facilitated using rocuronium 0.3 mg kg\(^{-1}\) and neuromuscular block was maintained automatically for a TOF ratio of <4 twitches at the adductor pollicis muscle using boluses of rocuronium 0.1 mg kg\(^{-1}\).

The pilot study determined the success rate of transcontinental anaesthesia: a successful transcontinental anaesthesia was defined as induction, maintenance, and emergence from anaesthesia without necessitating intervention of the local anaesthetic team. Further outcomes were clinical and controller anaesthesia performance. The clinical performance of hypnosis is the efficacy to maintain BIS as close to the target of 45 as possible, which was defined using four categories: excellent, good, poor, and inadequate control, when the real BIS values are within 10, from 11 to 20, from 21 to 30, or >30% from the target BIS. The clinical performance of analgesia is the efficacy to maintain target of 0 of a pain score Analgesocore, which is derived from heart rate (HR) and mean arterial pressure (MAP), within the range of −3 to +3, which represents excellent pain control, −3 to −6 and +3 to +6 which represent good pain control, and −6 to −9 and +6 to +9 which represent insufficient pain control.\(^{16}\) The controller performance is evaluated by the Varvel and colleagues\(^{17}\) parameters. Further outcomes included the agreement between remote and local preoperative assessment.

Sample size was chosen as recommended for pilot studies within the range of 12–30. We chose 20 patients expecting 10% fallout of patients due to technical problems. Drug consumption, frequency of drug modifications, and time to extubation were also measured. Data are presented as mean (SD) or value; comparison of the preoperative assessment was done by Cohen’s \(\kappa\) test, SPSS.

**Results**

A total of 20 patients were enrolled in the study: four men and 16 women aged [mean (SD)] 44 (13) yr and weighing 66 (14) kg underwent anaesthesia for 54 (24) min. The ASA classification score was I for 10 patients and II for the other 10. Transcontinental anaesthesia was successfully
performed in all patients. There was good to excellent agreement of the local and remotely performed preoperative assessment (Table 1).

The propofol dose was automatically modified 37 (20) times h⁻¹, and the mean administered dose was 118 (32) μg kg⁻¹ min⁻¹. The remifentanil dose modifications were 16 (9) times h⁻¹, with a mean administered dose of 0.28 (0.07) μg kg⁻¹ min⁻¹. The total rocuronium dose was 0.63 (0.11) mg kg⁻¹, and the extubation time was 9.8 (4.0) min. The control performance values of the closed-loop system are shown in Table 2. The BIS values showed excellent, good, poor, and inadequate control of hypnosis in 36.6 (15.1)%, 32.8 (6.4)%, 13.3 (5.6)%, and 8.1 (4.3)% of maintenance time, respectively; artifacts (due to electrocautery) were detected 4.6 (3.6)% of the time. The AnalgoScore values showed excellent, good, or insufficient control of pain during anaesthesia in 68.0 (21.9)%, 24.2 (18.4)%, and 5.9 (10.5)% of maintenance time; artifacts were detected 1.8 (3.2)% of the time.

### Discussion

The current study demonstrates that transcontinental preoperative assessment and control of an automated anaesthesia delivery system are possible via a standard Internet connection from the North American continent to Europe. Transcontinental preoperative assessment of patients was as accurate as local assessment. The remotely controlled closed-loop system maintained anaesthesia for all patients throughout surgery without any interruption of the Internet connection, thus providing 100% control of the teleanesthetic drug infusion with good to excellent performance, similar to previous studies performed by local teams.

There are very few studies of applying telemedicine in the field of anaesthesia. In one study, Fiadjo and colleagues reported real-time monitoring and anaesthetic consultation provided by a Philadelphia-based anaesthesia team to a team in Bangalore, India. Their study pointed out that the ideal system for teleanaesthesia should consist of a recording system that would display patients’ data at both locations and would enable both teams to fully access the ongoing patient records. In the present study, the automatic closed-loop anaesthesia delivery system requires patients’ characteristics for set up; it displays the infusion drug dose, the actual rate, the average dose, and standard clinical monitoring variables in real time on the screen. With the remote desktop control software, anaesthesiologists in both, the remote centre and local centre, have full access to all the patients’ data simultaneously. Data of all recorded parameters can be extracted automatically in a form of an Excel file which allows documentation of the anaesthetic record.

Although telemedicine has been developed rapidly in recent years, few studies have looked at the application of telemedicine in anaesthesia. In one study, Ihmsen and colleagues investigated the feasibility of a EEG-controlled closed-loop administration of propofol distantly; anaesthesiologists in Erlangen performed distant control of propofol administration for hypnosis of patients undergoing general surgery in Munich, Germany. In one patient, the teletherapeutic drug administration was stopped and continued manually because of network interruption. Comparing with the 65% of the time achievement of teletherapeutic drug control in their study, 100% control of the time teleanaesthetic drug infusion was achieved in this present study without any interruption. According to Varvel and
colleagues’ parameters, the median absolute performance error (MDAPE) indicates the size of errors. Our system had an average MDAPE for hypnosis of 14.3, comparing with 18.8 of MDAPE in Ihmsen and colleagues’ study, indicating that our automatic closed-loop system had smaller size of errors than the one in Ihmsen and colleagues’ study.

In a pilot study, Wong and colleagues\(^6\) evaluated the technical aspects and implementation of telemedicine anaeesthesia consultation in 10 patients outside the Greater Toronto Area. Patients received anaesthesia consultation remotely from attending anaesthesiologists from Toronto Western Hospital. Their study reported the technical aspects and implementation of teleanaesthesia consultation could be successfully performed. However, they did not compare the telemedical consultation with the conventional consultation. In our present study, remote preoperative assessment was achieved in all patients. Out of the eight parameters of comparison of preoperative assessment, four showed perfect agreement, two showed good agreement, and two showed moderate agreement, indicating that remote preoperative assessment can easily be performed without elaborate set-up.

Liu and colleagues\(^3\) compared closed-loop administration of propofol and remifentanil guided by BIS. The controller performance of BIS in the closed-loop group with MDPE, MDAPE, and Wobble at $-6.9$ (6.4), $11.4$ (4.3), and $8.7$ (3.3), respectively, performed slightly better compared with the present study with MDPE, MDAPE, and Wobble of $-9.2$ (7.5), $14.3$ (4.8), and $10.4$ (3.6). As Liu and colleagues\(^11\) have demonstrated, taking MDPE, MDAPE, and Wobble along may mislead the interpretation of the system evaluation. We therefore calculated the GPI (global performance score) which is inversely proportional to the MDAPE, Wobble, and the percentage of time of inadequate control. Thus, to indicate good performance, the GPI should be high. With an average GPI of 57 in the present study, it indicates that the system performs well even when used remotely.

The transcontinental approach was performed in order to deliver a proof of concept in a setting without specific Internet set-up other than standard Internet communication. Globally, there is a severe lack of specialists and specialist treatment in medicine, especially in anaesthesia, for example, only nine anaesthesiologists are available in Rwanda for a population of more than 10 million.\(^{19}\) But even in highly industrialized countries such as Canada, a significant population lives in remote regions away from tertiary healthcare centres. Teleanaesthesia could help to overcome the shortage of specialists in remote areas, and it can potentially reduce travel costs and improve patients’ accessibility to professional consultations and treatments.

In conclusion, distant preoperative assessment and distant control of anaesthesia are feasible via standard means of Internet communication.

**Declaration of interest**

None declared.

**Funding**

This trial was funded by a Canadian governmental grant, ‘Ministère du Développement économique, de l’Innovation et de l’Exportation - Programme de soutien à la recherche: Soutien à des initiatives internationales de recherche et d’innovation’ (MDEIE PSR-SIIRI number 449).

**References**


Handling editor: R. P. Mahajan