The future of gynaecological surgery - telesugery with haptic sensation

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Abstract

The 19th century will be remembered as the era of open surgery. The history of gynaecological surgery started in 1807 in Kentucky, Missoury, when Ephraim McDowell performed the first successful cystectomy using a longitudinal abdominal incision. Throughout the 19th century, longitudinal incisions were routinely used in all gynaecological operations. In 1897, however, Johannes Pfannenstiel introduced the transverse incision, which showed to have benefits over the longitudinal one, such as less wound dehiscence(1). At the beginning of the 20th century, experimental endoscopy was introduced by Georg Kelling in Germany(2). Due to the development of light sources, insufflators, and endotracheal intubation, more and more gynaecological operations, such as the laparoscopy-assisted vaginal hysterectomy, were done endoscopically(3). At the beginning of the 21st century, telesurgical systems are emerging for gynaecological procedures, both for benign and malignant indications. It seems that in the course of this century this new technology will replace many of the conventional endoscopic techniques.

Keywords: *telesurgery, haptic sensation, cystectomy, endotracheal intubation*

Nowadays, most gynaecological operations already have endoscopic alternatives, just to mention procedures for extra-uterine pregnancies(4), cystectomies(5) and hysterectomies(6) for benign and malignant indications.

At the end of the 20th century, it seemed that the surgical know-how had reached its peak. Two new developments, however, opened a new surgical horizon: natural orifice surgery and telesurgery. Experimental tubal ligation(7) as well as oophorectomy(8) and partial hysterectomy(9) were already performed transgastrically. The claimed advantage of this method is the lack of scars. However, the operative disadvantages such as the limited diameter of the instruments and the pharmacological and bacteriological aspects as well as the necessity to design complicated surgical instruments make the use of this pathway complicated, and it does not seem that it will become routine. The transdouglas approach for gynaecological surgery seems promising, provided that the optimal surgical instruments will be developed(10).

The other development at the turn of the 21st century is the introduction of telesurgery. Many gynaecologists are using the term "robots" for the existing systems. This term is misleading. At the beginning of the 21st century, these systems are not yet equipped with artificial intelligence. Such systems have been in use since 1988, when the PUMA system was used for a brain biopsy guided by computer tomography(11). Other systems which were developed and were or are still in use are the PROBOT, ROBODOC, ZEUS and Da Vinci.

The benefits of these systems are improved ergonomy, filtration of tremor, 3D stereo vision and the potential of remote operating. The main disadvantages are long docking time, the lack of haptic feedback and the restriction to specific indications.

Recently, some studies have stressed the high costs of the equipment and its maintenance when compared to open surgery or endoscopy(12). Open surgery proved to be the most cost-effective.

Any new surgical method should add value to surgery. Endoscopy brought added value to gynaecological operations due to the lack of big abdominal scars, less need of analgesics and shorter hospital stay. However, general anaesthesia became mandatory with all its potential risks and disadvantages. Despite these disadvantages, endoscopy has come to be widely used.

As long as laparotomy was the state-of-the-art method in gynaecology, the surgeon was used to palpate the tissues, thus he could distinguish between physiological and pathological structures, look for and palpate hidden findings and estimate the force needed when suturing. Today's telesurgical systems lack haptic feedback and rely on visual feedback(13). Tactile feedback is a basic property which is used in many areas in order to achieve precision and sensitivity. Violinists use their fingertips to feel the vibrations of the strings, and so do musicians playing other string instruments as well as pianists and flutists. Operating without tactile feedback seems to be a step backwards. Indeed, in a review of six studies concerning hysterectomy it was concluded that operation times were longer and the costs significantly higher when telesurgical systems were used(14).

Gynaecologists constantly have to consider the needs of the patient. These are - next to accurate

Received: *October 12, 2011*
Revised: *December 17, 2011*
Accepted: *January 05, 2012*

Figure 1. The system with its extendable arms

Figure 1. Immediate exchange of instruments, which are attached to the arms with magnets

diagnosis, correct indication and surgical competence - also the use of optimal surgical instruments and systems. Should a telesurgical system be introduced due to its expected benefits like improved ergonomy, it should provide accuracy, safety, short intervention time as well as optimal outcome.

It seems that tactile sensation is a crucial aspect for achieving these goals. The New European Surgical Academy (NESA), which was founded in order to improve and optimise surgical methods, took the academic responsibility for a novel telesurgical system which provides all the benefits of telesurgery and, additionally, haptic sensation.

This system integrates up-to-date technical knowledge concerning transmission of delicate movements in combination with haptic sensation which enables the surgeon to estimate the consistency of anatomical structures as well as tensile strength of the suturing material, the so-called Telelap Alf-x. The characteristics of the system are as follows:

1. The system is modular, consisting of one or two consoles and three or four manipulating arms according to the specific surgical needs. The arms of the unit are extendable, thus enabling the surgeon immediate access to the patient in case of an emergency (Figure 1). The arms are constructed in a way enabling access to the abdomen or to the pouch of Douglas. This allows hybrid transdouglas-abdominal surgery.

2. The surgical instruments are attached to the arms by magnets (Figure 2). This ensures an immediate connection as well as detachment. All instruments are reusable, although very low-cost disposable instruments are available.

3. Once an instrument is inserted into the abdomen, the system calculates the location of the pivot

Figure 3. Console with 3D open sight and eye-tracking system

Table 1 First preclinical results. Cholecystectomy

Number of procedures	Number of arms used Telelap Alf-x	Average operation time (min) Telelap Alf-x	Median operation time (min) Conventional telesurgical system
4	3	31.75 (30-35)	91

Table 2 First preclinical results: Partial nephrectomy

Number of procedures	Number of arms used Telelap Alf-x	Average operation time (min) Telelap	Median operation time (min) Conventional telesurgical system
2	3	115 (110-120)	140

Table 3 First preclinical results. Total nephrectomy

Number of procedures	Number of arms used Telelap Alf-x	Average operation time (min) Telelap Alf-x	Average estimated blood loss (ml) Telelap Alf-x	Average operation time (min) Endoscopy
4	3	53.75 (45-70)	< 20	75.7

point located at the level of the fascia. This point will throughout the operation serve as an axis to all the instrument's movements, whatever its location in the abdomen should be. As a result, the opening in the fascia as created by the trocar will not extend.

4. The tremor of the surgeon's hands is filtered. The movements of the instruments are therefore precise and smooth.

5. 1:1 haptic sensation transmits the tissue's feedback to the surgical instruments into the surgeon's fingertips, enabling him/her to feel the consistency of observed and hidden structures as well as securely tie sutures, as the tension of the pulled suturing material is felt.

6. The console provides open sight (Figure 3) with 3D vision. An eye-tracking system has been included in the system. It detects the surgeon's line of vision and enlarges or reduces the image on the screen when the head is moved forward or retracted. Surgical instruments are activated when their respective icon on the screen is looked at, and any point looked at will move to the centre of the screen. This is very important in case of bleeding and contributes to the safety of the surgery. The system will stop moving when the surgeon is not looking at the screen.

7. The system is universal and can be used for any site where lumen exists or can be created.

As there is no point in introducing any new system unless it brings added value to existing ones, preclinical studies have been carried out. Despite the lack of accumulated surgical experience with the system, and although still being at the beginning of the learning curve, the operation time of experimental cholecystectomy using the Telelap Alf-x was much shorter than the median operation time using a conventional telesurgical system (15, Table 1). The same applied to partial nephrectomy (16, Table 2).

The first preclinical studies concerning total nephrectomy were compared to conventional endoscopy (17, Table 3), and also in this operation the average operation time was shorter.

Haptic sensation probably contributed to the self-confidence of the surgeon who was not dependent on visual force feedback only. Clinical studies will be needed to evaluate the quality, early and late complications as well as blood loss. However, it seems that this telesurgical system combining haptic sensation with optimal ergonomics and an eye-tracking system will combine all the advantages of open laparotomy, such as the ability to palpate structures and estimate the tension on the suturing material, and the advantages of endoscopy, i. e. small incision, short hospital stay, and reduced need of analgesics. Gynaecologists were pioneers by introducing endoscopy into surgery. It is therefore expected that this endoscopic telesurgical system with haptic sensation will bring about a renaissance of gynaecological and also other abdominal procedures. ■

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