Impact of robotic surgery on surgical performance: Implications for learning

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Abstract
The objective of this paper is to study the impact of depth perception and movement freedom on learning surgical tasks by novice subjects using new laparoscopic technology.

Keywords: new technology - depth perception – movement freedom – learning - surgery

1- Introduction: new technology in surgery
Surgery is considerably and constantly evolving, new technologies are more and more present and transform the surgeon’s activity and practice. In traditional open surgery, surgeon has a direct 3D view of the surgical site, a great freedom to approach the organ in a versatile manner for optimal perception, and can use tactile and strength feedback. However, open surgery presents some disadvantages that minimal access surgery removes. Laparoscopic surgery is a new surgical method that has been introduced in 1980. This surgical technique is characterized by the introduction of a camera and instruments into the body through very small incisions in the skin. Laparoscopic surgery brings a lot of advantages, particularly for the patient: very small incisions, smaller risks of infections, higher accuracy due to the magnification by the camera and fast recovery. For all these reasons, minimally invasive techniques are now ubiquitous and indispensable in the management of surgical disease [1]. However, despite these benefits, significant challenges have been noted: the view of the surgical site is now indirect and restricted, the surgeon has to observe and manipulate tissues and organs through very small incisions with long and rigid instruments, the tactile observation is lost, the feedback of the action is principally visual with a 2D image and finally, the degree of freedom for the instruments movements is restricted at 4. Laparoscopic surgery comprises many precise movements in a confined space. The surgeon often has to maintain his precision through an operation in an ergonomically uncomfortable position hampered by tremor and fatigue [2, 3].

A new robotic system (da Vinci robotic system) allows to restore three-dimensional visualization of the operative field and the degrees of freedom lost in classical laparoscopy. This system consists of two primary components: the surgeon’s viewing and control console and, a moveable cart with three articulated robot arms: two arms contain instruments and the third carries an endoscope with dual optical channels. The surgeon is seated in front of the console, looking at an enlarged three-dimensional binocular display on the operative field while manipulating handles that are similar to “joy-sticks”. Manipulation of the handles transmits the electronic signals to the computer that transfers the exact same motions to the robotic arms. The computer interface has the capacity to control and modify the movements of the instrument tips by downscaling deflections at the handles by a factor between (5:1 to 2:1). It can eliminate physiologic tremor, and can adjust grip strength applied to the tools.

As the tactile and force feedbacks are lost in minimal-access surgery, the video image plays the most crucial role in giving the surgeon information about the performance of the operation. Depth perception is an important factor determining the utility of many computer- and video-based environment [4], it has also to play a predominant role in minimal invasive surgery.

Compensation for the lack of depth perception in a 2D environment invokes the use of monocular depth cues such as light and shade, relative size of objects, object interposition, texture gradient, aerial perspective and motion parallax. Using these cues, all laparoscopic operations can be accomplished; however, time and accuracy may be lost as these techniques do not completely compensate for stereoscopic depth perception. Indeed, monocular cues compensate somewhat for the lack of depth.
perception of 2D vision, but not make up completely for the accuracy of the 3D view [5,6]. Moreover, representation of depth perception in 2D vision is difficult and resource intensive [4]. However, the literature shows contradictory results about the benefits brought by the 3D vision: some studies showing best motor performances with 3D vision [6,7,8,9,10] while others failed to obtain difference of performance between 2D and 3D [11,12,13]. In some studies [6], only the complex tasks were performed more easily and more quickly with 3D view than with 2D view while no difference between 2D and 3D appeared in the easiest tasks. Divergence in all these results is partially because first-generation 3D systems, with their lower resolution, were compared with standard 2D systems [14]. A purpose of our study is to answer this debate using the new 3D generation from da Vinci robotic system that provides quasi natural bi-dimensional view and suppresses the bias met in anterior studies. Indeed, effective development and application of such systems relies, at least in part, on understanding the manner in which depth cues are employed by users [4].

2- Implications for learning
The development of technical skill is fundamental to the process of becoming a surgeon. The fundamental change, produced by new technology, in how surgeons perform operations has educational implications related to learning curves and patient safety [15]. Moreover, educational issues have proved to be a significant hurdle to the widespread dispersion of minimal access surgery techniques [15]. Traditionally, surgeons have honed their skills in the operating room through hands-on experience with veteran mentors [16]. This manner of teaching effectively trains surgeons in traditional open surgical techniques, but is costly in terms of time, resources and patient morbidity [17]. Over the past decade, minimally access surgery has revolutionized general surgery, posing new obstacles for experienced surgeons attempting to acquire laparoscopic skills [18]. Indeed, laparoscopic surgery requires specialized training and practice in order to acquire new skills to operate, to manipulate tissues with long instruments and a new knowledge of anatomy and spatial orientation [19,20]. Classical laparoscopic surgery is generally a two-dimensional surgery. The loss of depth perception and spatial orientation are the main drawbacks for the novice to overcome when facing the television monitor [21]. Advanced complicated laparoscopic surgery requires precise manipulation of the instruments. The success of surgery, the operating time, and the morbidity rate are directly related to the manipulation skills. These factors are responsible for the well-described “learning curve” [15,22]. Mastery of technical skill is thus crucial to surgical training. However, a survey in 2003 revealed that 82% of Canadian surgical residents considered their training in minimally invasive surgery inadequate [23] and 65% of American residents surveyed would pursue extra training in laparoscopy if it were available [24]. With the growing complexity encountered in performing minimally invasive surgery, training in the operating room alone may be inefficient and impractical [16]. Practice using inanimate models increases psychomotor skills and translates into improved performance in the operating room [25]. In our studies, we used standard and ecological surgical tasks developed and validated in several studies (bench models, [25,26,27] in order to precisely analyse the nature of the benefits brought by the new surgical technologies. A three-dimensional camera system may improve the efficiency, shorten the learning curve and reduce the operating time [21]. We studied the perceptual and instrumental impacts of new technology on learning surgical performance by novice subjects.

3- References