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Impact of 2D and 3D Vision on Performance of Novice Subjects Using da Vinci Robotic System

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Key words. Minimal invasive surgery ; robotic laparoscopy ; training.

Abstract. *Purpose of the study :* The aim of this study was to evaluate the impact of 3D and 2D vision on performance of novice subjects using da Vinci robotic system.
Methods : 224 nurses without any surgical experience were divided into two groups and executed a motor task with the robotic system in 2D for one group and with the robotic system in 3D for the other group. Time to perform the task was recorded.
Results : Our data showed significant better time performance in 3D view (24.67 ± 11.2) than in 2D view (40.26 ± 17.49, $P < 0.001$).
Conclusions : Our findings emphasized the advantage of 3D vision over 2D view in performing surgical task, encouraging the development of efficient and less expensive 3D systems in order to improve the accuracy of surgical gesture, the resident training and the operating time.

Introduction

The objective of this article was to answer an important question present in the literature : do the 2D-3D vision have an influence on motor performance in minimal invasive surgery ? Depth perception is an important factor determining the utility of many computer- and video-based environment (1), it is thus useful in a safety and economical point of view to know if depth perception also plays a predominant role in minimal invasive surgery.

The cognitive literature has shown that image in 2D and image in 3D do not contain the same information (2, 3). Although 2D vision compensates somewhat for the lack of depth perception using a lot of monocular cues, image in 3D contains more information especially in order to accurately and efficiently guide the action. If monocular cues are useful and provide performances comparable with binocular cues for some tasks (e.g., distance estimation (4, 5)), 2D vision has been shown to affect kinematics and pattern human motion. Indeed, motion appears to rely on binocular depth cues particularly in reaching and grasping movements, main component of the surgical gesture.

According to this literature, surgical tasks should be performed better in 3D view than in 2D view. However, the surgical literature shows contradictory results about the benefits of the 3D vision in laparoscopic surgery : some studies showing best motor performances with 3D vision (6-10) while others failed to obtain difference of performance between 2D and 3D (11-13). Divergence in all these results is partially because first-generation 3D systems, with their lower resolution, were compared with standard 2D systems (4). Our objective was to answer this debate and to evaluate the benefits of 3D vision in minimal access surgery using the da Vinci robotic system that allows quasi natural three-dimensional visualization of the operative field. To avoid any bias from earlier laparoscopic experience, we selected a large sample of participants without any experience in open, minimally invasive or robotically assisted surgery.

Material and methods

The Da Vinci system consists of two primary components : the surgeon's viewing and control console and, a moveable cart with three articulated robot arms. 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

Table I

Time (in seconds) to perform the task in the two conditions

	2D	3D
All subjects	40.26 ± 17.49	24.67 ± 11.2
Men	40.36 ± 15.24	25 ± 11.18
Women	42.25 ± 17.86	24.64 ± 11.26

Table II

Subjects self-confidence and satisfaction in performing task in 2D or 3D condition

	2D	3D
All subjects	42.78 ± 19.11	29.26 ± 13.14
Men	38.29 ± 6.28	31.6 ± 7.43
Women	43.5 ± 2.5	29 ± 2.56

2:1). It can eliminate physiologic tremor, and can adjust grip strength applied to the tools. The computer generated electrical impulses are transmitted by a 10-meter long cable and command the three articulated "robot" arms. Disposable laparoscopic articulated instruments are attached to the distal part of two of these arms. The third arm carries an endoscope with dual optical channels, one for each of the surgeon's eyes. The 3D visualization can be changed to 2D if desired. In this study, we used 3D and 2D options in order to investigate the influence of 3D vision in performing surgical tasks. The only difference between the two conditions was the depth-vision type : 2D or 3D vision.

Participants

224 nurses (198 women and 26 men) without any experience in conventional, laparoscopic or robotic surgery were randomly divided into two conditions : one group performing with the robotic system in 2D and the other group performing with the robotic system in 3D. Except the dimension view (2D versus 3D), all task characteristics were identical in the two conditions.

Task

The task consisted in displacing a plastic bead of five millimetres from a closed isolating tube to another one. The tubes were parallel and horizontally disposed at different depths (interval of 5 cm). This mainly involved visuo-motor processes (eye-hand coordination without any other feedback than visual). Task did not require camera displacement, only manipulating instruments (microforceps) using the two hands.

Measures

We measured the time (in seconds) to perform the task. Immediately after performing the task, participants were asked their self-confidence and satisfaction about their performance on a 4-point likert scale.

Statistical analysis

We conducted t student analysis in order to compare the performance in the two viewing conditions (2D-3D view).

Results

Our results showed better time performance in 3D than in 2D. Participants were significantly faster to perform the task in 3D than in 2D ($t(222) = 7.93$, $p < 0.001$). Concerning the actual time, men and women showed similar performance (Table I).

Concerning self-confidence and satisfaction about their performance, no difference appeared either between the 2D and 3D conditions or between gender (Table II).

Discussion

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. Our study emphasizes the important role of depth perception and the advantage of the 3D view when using da Vinci robotic system. Indeed, 3D view allows novice participants to execute faster a basic motor task. Our results thus confirm conclusion from other studies (6-10) concerning the advantage brought by 3D in performing surgical tasks. Birkett *et al.* (10) suggested that the advantage of the 3D view was only observed in complex surgical tasks, our results show that 3D view also leads to better performance in basic motor task with novice subjects. Moreover, recent studies have shown that 2D vision requires longer and slower information processing than 3D vision (14, 15). 3D vision appears to be essential and more intuitive, requiring less cognitive elaboration and mental load. The cognitive resources usually involved in the 2D image processing may be involved in other processes when 3D vision is used, allowing to increase gesture precision and safety. However, the robotic system is a technique ahead of its time, expensive and not very accessible. Our results that showed obvious advantage of 3D vision for novice subject performance are encouraging the development of efficient and less expensive 3D systems for conventional laparoscopic surgery in general. Indeed, 3D vision may have an impact on the operating time and on the resident training, the loss of depth perception being the main drawback for the novice to overcome when facing the televi-

sion monitor (16). The use of 3D view could reduce the long learning curve that constitutes the only existing path to overcome the difficulties met with minimal invasive surgery. Nevertheless, as our study was conducted on only one task performed by novice participants without any surgical experience, we may observe different results with experienced surgeons that are used to operating with 2D vision in conventional laparoscopy.

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