Combining of ETHOS Operating Ergonomic Platform, Three-dimensional Laparoscopic Camera, and Radius Surgical System Manipulators Improves Ergonomy in Urologic Laparoscopy: Comparison with Conventional Laparoscopy and da Vinci in a Pelvi Trainer

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Abstract

Background: Posture, vision, and instrumentation limitations are the main predicaments of conventional laparoscopy.

Objective: To combine the ETHOS surgical chair, the three-dimensional laparoscope, and the Radius Surgical System manipulators, and compare the system with conventional laparoscopy and da Vinci in terms of task completion times and discomfort.

Design, setting, and participants: Fifteen trainees performed the three main laparoscopic suturing tasks of the Heilbronn training program (IV: simulation of dorsal venous complex suturing; V: circular suturing of tubular structure; and VI: urethrovessical anastomosis) in a pelvi trainer. The tasks were performed conventionally, utilizing the three devices, and robotically. Task completion times were recorded and the surgeon discomfort was evaluated using questionnaires.

Outcome measurements and statistical analysis: Task completion times were compared using nonparametric Wilcoxon signed rank test and ergonomic scores were compared using Pearson chi-square test.

Results and limitations: The use of the full laparoscopic set (ETHOS chair, three-dimensional laparoscopic camera, Radius Surgical System needle holders), resulted in a significant improvement of the completion time of the three tested tasks compared with conventional laparoscopy ($p < 0.001$) and similar to da Vinci surgery. After completing Tasks IV, V, and VI conventionally, 12 (80%), 13 (86.7%), and 13 (86.7%) of the 15 trainees, respectively, reported heavy total discomfort. The full laparoscopic system nullified heavy discomfort for Tasks IV and V and minimized it (6.7%) for the most demanding Task VI. Especially for Task VI, all trainees gained benefit, by using the system, in terms of task completion times and discomfort. The limited trainee robotic experience and the questionnaire subjectivity could be a potential limitation.

Conclusions: The ergonomic laparoscopic system offers significantly improved task completion times and ergonomy than conventional laparoscopy. Furthermore, it demonstrates comparable results to robotic surgery.

Patient summary: The study was conducted in a pelvi trainer and no patients were recruited.

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1. Introduction

Laparoscopic surgery offers less postoperative pain, shorter hospital stay, and better cosmetic results. Nevertheless, surgeons have to operate in a hostile environment, maintaining a suboptimal static posture for a long time [1]. The fulcrum effect, the two-dimensional (2D) visualization, and the mechanical inefficiency of laparoscopic instruments that have a range of motion limited to 4 degrees of freedom (DOF), become more evident during intracorporeal suturing [2]. Hence, laparoscopy can be harmful to the surgeons, and patients’ safety may also pose a risk [3]. These drawbacks limit its distribution [4]. The da Vinci surgical robot was developed to provide surgeons with an attractive, user-friendly interface while maintaining minimal invasiveness. It offers significantly improved ergonomics providing a console with 3D vision and instruments with 7 DOF [5].

Since the introduction of ergonomics, laparoscopy has become more competitive. Yet, to date, only minor ergonomic changes have been made [6]. This study tries to assess three main ergonomic parameters, namely, surgeon posture, vision, and instrumentation, and utilizes three devices to improve them. These tools are the ETHOS ergonomic platform, the 3D laparoscope, and the Radius Surgical System (RSS) manipulators. The ETHOS (Figs. 1A and 1B) is an operating chair that offers multiple ergonomic improvements, the 3D laparoscope (Fig. 1C) decreases mental stress, and the RSS (Fig. 1D) are two articulated needle holders offering 7 DOF. We aimed to combine these tools and compare this ergonomic system (Fig. 1E) in terms of task completion time and discomfort, with conventional laparoscopy and with the da Vinci (Fig. 1F), in an inanimate pelvi trainer radical prostatectomy setting.

2. Material and methods

2.1. Laparoscopic tasks

The study is based on our already described training model in laparoscopic radical prostatectomy [7,8]. Its tasks include the hand-eye coordination (two-row metal-pin model; Step I), the linear and curved suturing with changing needle angles (chicken leg and catheter model; Steps II–V; Figs. 1G and 1H), and the urethrovaginal anastomosis in a porcine bladder (Step VI; Fig. 1I). The assessment tool was developed by expert opinion from within our research team [7]. During the years, the model has been thoroughly assessed and demonstrated content, as well as construct and predictive validity [7,8].

2.2. Setting

All tasks were performed in a laparoscopic training box (Karl Storz GmbH & Co. KG, Tuttingen, Germany). A three-chip camera was connected to a 10-mm, 30°, 2D laparoscope (Karl Storz). Additionally, a 3D laparoscope (Karl Storz) was utilized. Images were displayed on a standard 14-in or a 32-in 3D monitor.

2.2.1. Conventional laparoscopic and robotic instruments

The instruments included a 5-mm endo-dissector (Karl Storz), two 3-mm microendoscopic needle holders (Karl Storz), and laparoscopic curved scissors (Karl Storz). All robotic steps were performed with the da Vinci-S model (Intuitive Surgical Inc., Sunnyvale, CA, USA) using two robotic needle holders.

2.3. The second-generation ETHOS ergonomic operating platform

The ETHOS (ETHOS-Surgical, Portland, OR, USA) is an operating chair with adjustable arms and footrests. It has been evaluated in a clinical [9] and in an experimental [10] setting demonstrating significant time and ergonomic improvements.

2.3.1. The 3D laparoscopic camera

The 3D cameras are already compared with the conventional 2D demonstrating improved vision quality and motor reaction to the visual stimulus [11]. An improved performance and accuracy in pelvi trainers has also been reported [12].

2.4. The RSS manipulators

RSS manipulators (Tübingen Scientific Medical GmbH, Tübingen, Germany) consist of two hand-guided surgical manipulators and provide a deflectable and rotatable tip allowing 7 DOF. They have been tested in a pelvi trainer as well as in a clinical setting [13].

2.5. Training

Fifteen trainees and two experienced laparoscopists participated. The ETHOS, the 3D camera, and the RSS were utilized, individually and in combination, and were finally compared with the robotic system. All participants had to perform the first three tasks with all instrument combinations and at adequate times in order to proceed to the next three steps, which constitute the main part of the study. Times of 3 min, 15 min, and 15 min for Steps I, II, and III, respectively, were defined as adequate [7,8]. The mentor evaluated the quality of the suturing and the timing stopped when the suture quality was judged as sufficient. The trainees received verbal feedback on their performance at the end of each task and gradually advanced to the more difficult steps. However, the order of performing the different combinations was random, in order to avoid any bias related with increasing laparoscopic confidence during training.

The Tasks IV, V, and VI were repeated five times as the trainees successfully accomplished the three first tasks after a mean number of five repetitions. The times needed to complete a task were documented and discomfort was estimated by questionnaires. Fourteen different types of discomfort were recorded, in a scale from 0 to 5, and the individual scores were added to form the total discomfort score for each trainee in each combination and task. A total discomfort score range from 0 to 70 points was possible.

2.6. Statistical analysis

Statistical analysis was performed with IBM SPSS Statistics 20 software (IBM Corp., Armonk, NY, USA). Task completion time was studied as continuous variable and the normality of the distribution was evaluated by Sapiro-Wilk test and Normal Q-Q plots. The differences of task completion time between ETHOS ergonomic combinations and conventional laparoscopy or da Vinci was analyzed by the nonparametric Wilcoxon signed rank test. The comparison of the ergonomic scores for each type of tested discomfort was evaluated using the four ordinal groups of no (Grade 0), low (Grade 1), moderate (Grades 2–3), and heavy (Grades 4–5) discomfort by Pearson chi-square test. Using the 33rd and 66th percentile as cut-off points, the continuous variable of total discomfort was categorized to No/Low (≤ 33rd percentile), Moderate (> 33rd and ≤ 66th percentile), and Heavy (> 66th percentile) total discomfort groups in each step. Thereafter, total discomfort was evaluated...
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