Design of a Box Trainer for Objective Assessment of Technical Skills in Single-port Surgery

Tim Horeman, PhD,[*,†] *Siyu Sun, MSc,*[*] *Gabrielle J.M. Tuijthof, PhD,*[*,†] *Frank William Jansen, PhD,*[*,‡] *Jeroen W.J.H.J. Meijerink, PhD,*[§] *and Jenny Dankelman, PhD*[*]

[*]Department of Biomechanical Engineering, Delft University of Technology, Delft, The Netherlands; [†]Department of Orthopaedics, Academic Medical Center, Amsterdam, The Netherlands; [‡]Department of Gynecology, Leiden Medical University, Leiden, The Netherlands; and [§]Department of Surgery, VU University Medical Center, Amsterdam, The Netherlands

OBJECTIVE: Laparoscopic single-port (SP) surgery uses only a single entry point for all instruments. The approach of SP has been applied in multiple laparoscopic disciplines owing to its improved cosmetic result. However, in SP surgery, instrument movements are further restricted, resulting in increased instrument collisions compared with standard multiport (MP) laparoscopy.

METHODS: Our goal was to develop a trainer that can quantitatively measure task time, force and motion data during both MP and SP training to investigate the influence of instrument configuration on performance. Custom-made abdominal force sensors and accelerometers were integrated into a new training box that can be used in an SP and an MP configuration. This new box trainer measures forces, acceleration, and tilt angles during training of SP and MP laparoscopy. With the new trainer, 13 novices performed a tissue manipulation task to test whether significant differences exist between MP and SP in maximum abdominal force, maximum tissue manipulation force, maximum acceleration, and tilt angles of the handles.

RESULTS: The results show that the task time (SP—145 s, standard deviation (SD) = 103 vs MP—61 s SD = 16), maximum abdominal force (SP—8.4 N, SD = 2.0 vs MP-left (L)—3.3 N, SD = 0.8 and MP-right (R)—5.8 N, SD = 2.1), tissue manipulation force (SP—10.4 N, SD = 3.6 and MP—5.6 N, SD = 1.3), maximum acceleration (MP-L—9 m/s^2, SD = 5 vs SP-L—14 m/s^2, SD = 7), and tilt angles of the left handle are significantly higher in SP.

CONCLUSIONS AND DISCUSSION: This study shows that the new trainer can be used to find the most important differences in instrument and tissue handling, which is an important step toward the assessment of surgical skills needed for safe SP surgery depending on force and motion-based parameters. (J Surg 72:606-617. © 2015 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: medical education, objective assessment, laparoscopy, single-port surgery, training

COMPETENCIES: Practice-Based Learning and Improvement, Medical Knowledge

INTRODUCTION

Background

Over the past decade, training for surgical skills has evolved from traditional apprenticeship model in the operating room (OR) to training programs with simulators outside the OR. Although many training simulators are now commercially available, new methods for tracking of instruments,[1] producing artificial tissues,[2] and simulating the haptic sensations[3] are still in development. The need for training and assessing in conventional laparoscopic multiport (MP) surgery was recognized from the presence of a higher complication rate and longer learning curves in initial trials.[4] In addition, the skills required in laparoscopy can hardly be transferred from training in open surgery.[5] Impaired hand-eye coordination, lack of depth perception, poor haptic feedback, difficulties with handling of long instruments, and the presence of a fulcrum effect are challenges that require technical skills that cannot be gained

Correspondence: Inquiries to Tim Horeman, MSc, Department of BioMechanical Engineering, Faculty of Mechanical, Maritime and Materials Engineering (3mE), Delft University of Technology, Mekelweg 2, 2628 CD Delft, The Netherlands; fax: (15) 278-5095; e-mail: T.Horeman@tudelft.nl

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effectively from observations alone but require hands-on practice and repetition.[6]

Metrics used for assessment of laparoscopic skills have been studied extensively with the introduction of sensory systems for box trainers and virtual reality simulators.[7] A division can be made between time-related, motion-related, and force-related metrics. Motion-related metrics such as path length and motion smoothness are widely used and validated for numerous training systems that use motion sensors to track the movements of both instruments.[8] Force-related metrics as maximum/mean force, force area, and force volume were developed and validated for suture and tissue manipulation tasks in laparoscopic box trainers.[9,10] The common factor in all these studies is that they indicate that metrics can be used for the assessment of the trainee's skills level and to provide formative feedback to trainees.

Laparoscopic single-port (SP) surgery has received much attention in the past 5 years. This advanced approach allows surgeons to perform surgical tasks through a single port of entry instead of multiple entry points. SP provides patients with improved cosmetic results compared with MP and has already been applied in multiple surgical procedures such as cholecystectomy, appendectomy, colorectal surgery, and gastric sleeve resection.[11,12] Yet questions arise about the risks related to the difference between SP and MP and whether SP-specific training is needed. Some researchers claim that no significant difference is found in performance between the 2 different approaches.[12] Other researchers concluded that SP requires a different mind and skill set from MP and that SP-specific training is needed.[13,14] According to the Laparoendoscopic Single-Port Surgery Consortium for Assessment and Research, techniques and training cannot be extrapolated from existing resources for laparoscopic surgery and must be addressed specifically for SP.[15] Possibly, differences can be found related to a reduced working volume inside the abdominal cavity. In most cases, a SP device has 3 or 4 channels to guide the laparoscope and instruments. Multichannel trocars do not allow the same range of motion for each instrument compared with MP surgery without stretching the portals or pushing the scope or other instruments aside. Our previous study indicated that the forces acting on the training tasks are higher if a SP configuration is used.[16] No studies were performed to investigate the forces acting on the abdominal wall (pivoting point) in SP and the relation to instrument motions.

Study Objectives

The goal of this study is to develop a box trainer that can quantitatively measure task time, force, and motion data during both MP as SP training to investigate the influence of instrument configuration on performance. To show the potential of the new box trainer, a study is conducted with unskilled medical students who perform a validated tissue manipulation task to find the difference in abdominal force, tissue interaction force, and instrument motion between MP and SP.

MATERIALS AND METHODS

Trainer Requirements

According to Cesanek and Horeman, the framework of a trainer should combine a physical training environment with real instruments and a computer system for objective evaluation of task performance while retaining the features of a simple box trainer.[10,17] Similar to MP, the surgeon who uses the SP approach is able to move the instrument in 4° of freedom (4-DOF), where every motion results in a reaction force in the model owing to surface contact between moving parts in the shaft (2nd DOF), valves in the trocar (1st DOF), or stiffness of the abdominal wall (3th and 4th DOF) (Fig. 1). The force exerted on the training task and the reaction force at the incision site in the abdominal wall depend on the instruments used and the instrument and tissue handling skills. The generated force during tissue manipulation in this study is assumed to be a contact force without torque and should provide important information about performance.[10,16] During operation, surgeons move the instrument on one end (handle) to obtain certain motion on the other end (instrument tip). Acceleration is one of the kinematic characteristics of this motion, indicating the rate of change of velocity with respect to time.

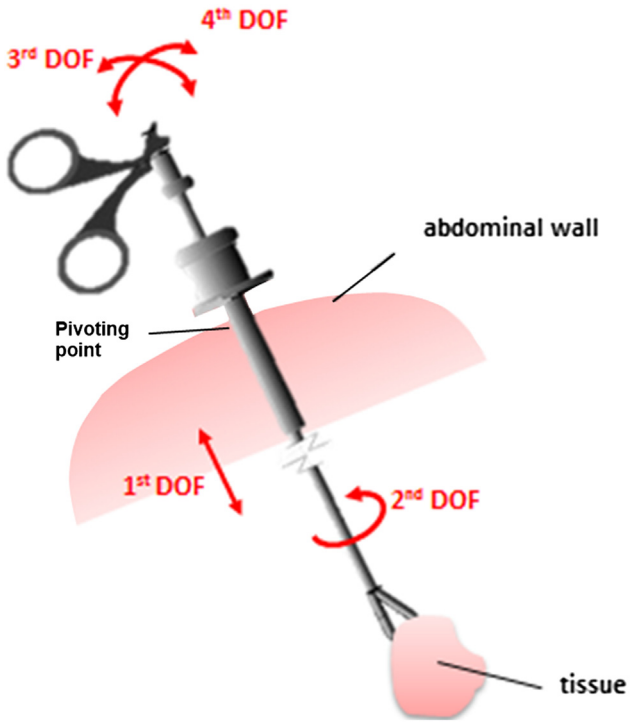

FIGURE 1. A 4-DOF theoretical model of instrument movements during tissue grasping. Rotation of the instrument around its pivoting point results in reaction force in the abdominal wall and grasped tissue.