

# Effectiveness of grasping and duration of clamping using laparoscopic graspers

E. A. M. Heijnsdijk,<sup>1,2</sup> J. Dankelman,<sup>1</sup> D. J. Gouma<sup>2</sup>

<sup>1</sup> Man-Machine Systems Group, Faculty of Design, Engineering, and Production, Delft University of Technology, Mekelweg 2, 2628 CD Delft, The Netherlands

<sup>2</sup> Department of Surgery, Academic Medical Center, University of Amsterdam, Post Office Box 22700, 1100 DE Amsterdam, The Netherlands

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## Abstract

**Background:** Manipulating tissue with laparoscopic forceps is more difficult than using the hands. This study investigates the effectiveness of grasping and the duration of tissue-clamping using laparoscopic forceps.

**Methods:** Video recordings of 10 laparoscopic colectomies and 15 cholecystectomies were analyzed using time-action analysis.

**Results:** The results indicated that 62% of the grasping actions were successful: the tissue was clamped sufficiently to perform an action. Of all the clamping actions on the colon, 10% were repeated actions. On the gallbladder 7% were repeated actions. The bowel slipped out of the grasper in 7% of the clamping actions, whereas the gallbladder slipped in 17%. In 89%, the colon was clamped less than 1 min. The maximum clamping time was 7 min for the colon, and 55 min for the gallbladder.

**Conclusion:** The low percentage of successful grasping actions indicates that the design of laparoscopic graspers is not optimal.

**Key words:** Laparoscopic instruments — Tissue damage

During laparoscopic surgery, long rigid graspers with limited force feedback are used [2]. Therefore, it is difficult to position the jaws on the tissue in the desired way, and the surgeon may apply an inappropriate amount of force on the tissue. Because the tips of laparoscopic graspers are small, high pressures can be generated locally on the tissue [3], resulting in damage or even perforation. Too little force results in the tissue slipping out of the forceps, leading to procedure delay. In a study analyzing surgical errors during

laparoscopic cholecystectomy, most of the errors in using graspers involved dropping and tearing the gallbladder [6].

To design new, safer graspers, the problems with currently used graspers should be evaluated in more detail. Evaluation of phenomena such as tissue damage with these new graspers will require insight into the usage of graspers and the duration for which tissue is clamped during laparoscopic procedures.

The purpose of this study was to evaluate the general use of laparoscopic graspers by determining the frequency and duration of clamping and the outcome of grasping actions. Two different procedures, laparoscopic colectomy and cholecystectomy, were analyzed using time-action analysis. Colectomies were chosen because in this type of procedure a large part of the colon needs to be dissected, and therefore, the colon frequently is manipulated. Cholecystectomies were analyzed because with this procedure, the gallbladder is held aside for a long time and often perforated [6, 7].

## Materials and methods

To evaluate the use of grasping forceps, video recordings of laparoscopic procedures in 25 surgeries were analyzed. Recordings were made of 10 colectomies and 10 cholecystectomies performed by experienced surgeons in various hospitals. In addition, we recorded five cholecystectomies performed by residents with less than 1 year of experience.

The procedures were recorded with two small CCD cameras, giving an overview image of the operation theater and a close-up of the surgeon's hands, as previously described [4]. With a mixing device, the images of the cameras and the laparoscopic image were recorded simultaneously. After the operations, the procedures were analyzed. The duration of clamping, the clamped tissue, the type of grasper, and the outcome of grasping action were analyzed for each clamping action of the laparoscopic graspers. The following definitions for the outcome of grasping actions were used:

- **Successful clamping:** The tissue is clamped and manipulated in such a way that the action the surgeon wants to perform (e.g., dissecting or

**Table 1.** Duration of the surgical procedures and the number and frequency of clampings

	Colectomies (n = 10)	Cholecystectomies by experienced surgeons (n = 10)	Cholecystectomies by residents (n = 5)
Duration (min)	66 ± 30	30 ± 14 <sup>a</sup>	51 ± 6 <sup>a</sup>
Number of clampings (n)	117 ± 48	26 ± 14	42 ± 16
Frequency (n/min)	1.9 ± 0.7	0.9 ± 0.2	0.8 ± 0.3

<sup>a</sup> Significant difference between experienced surgeons and residents ( $p < 0.05$ )

coagulating) is possible. After the action, the jaws are opened by the surgeon to replace the grasper and to perform the next action.

- **Repeated clamping:** The tissue is clamped for a short time. However, before the tissue is stretched, the grasper is repositioned to make it possible to pull with a higher force or in another direction.
- **Slip:** The tissue slips out of the grasper because too little clamping force is applied in relation to the pulling force.
- **Damage from clamping:** The tissue is damaged by pulling or pinching with too much force.
- **Undefined:** No definition can be given because the tissue is released from the grasper outside the image.

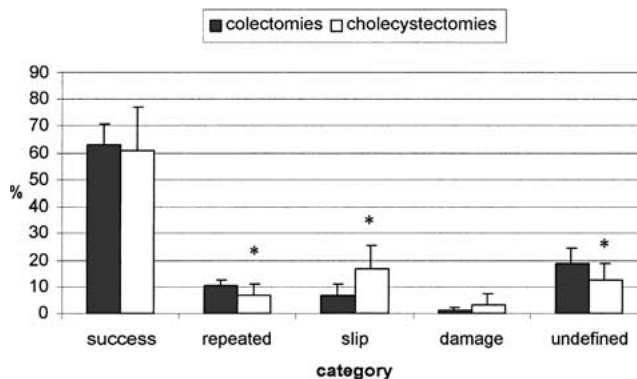
The frequency of the grasping actions was calculated by dividing the total number of grasping actions per procedure by the time between the insertion of the first grasper and the release of the last grasper. Differences between colectomies and cholecystectomies and differences between experienced surgeons and residents were tested for significance using a two-sided Student's *t*-test ( $\alpha = 0.05$ ).

## Results

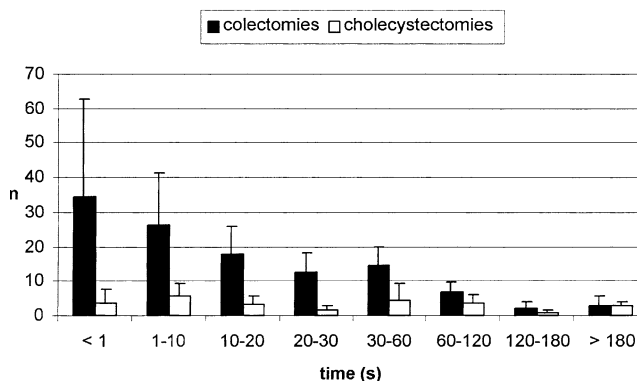
The duration of the laparoscopic part of the colectomies varied between 24 and 119 min and the duration of the cholecystectomies varied between 14 and 62 min. The colon was clamped an average of 117 times per procedure, with a mean frequency of 1.9 per minute. The gallbladder was clamped an average of 26 times per procedure, with a mean frequency of 0.9 per minute (Table 1).

The outcome of grasping actions for the colectomies and cholecystectomies is presented in Fig. 1. The percentage of successful grasping was 63% and 61%, respectively. The colon was repeatedly clamped more often (10% vs 7%;  $p = 0.03$ ), and the gallbladder slipped out of the forceps more often (17% vs 7%;  $p = 0.008$ ). Damage occurred in 1% to 3% of all actions (for both procedures on average once per operation), and 12% to 19% of the actions were performed outside the image and therefore undefined. In five procedures, the gallbladder was perforated.

The duration of clamping is presented in Fig. 2. During the colectomies, 34 (28%) of the clamping periods were less than 1 s, and 105 (89%) were less than 60 s. An average of three times per operation, the colon was clamped longer than 3 min, up to a maximum of 7 min. Although there were fewer clamping actions on the gallbladder than on the colon, the gallbladder was clamped longer. Of all the clamping actions, 13% were shorter than 1 s, 69% shorter than 60 s, and 12% (an average of three times per operation) longer than 3 min. The maximal clamping time was 55 min.



**Fig. 1.** Outcome of grasping actions during colectomies and cholecystectomies. The average percentages and standard deviations are shown. \*Significant difference between colectomies and cholecystectomies ( $p < 0.05$ ).



**Fig. 2.** Distribution of clamping time during colectomies and cholecystectomies. The average values and standard deviations are shown.

The duration of the cholecystectomies performed by the residents was significantly longer than the procedures performed by experienced surgeons (51 vs 30 min;  $p = 0.007$ ). The residents did not use significantly more actions (42 vs 26;  $p = 0.065$ ). However, relatively fewer actions were successful (45% vs 61%;  $p = 0.020$ ). Significantly more actions with clamping times of more than 3 min were used (2.7 vs 4.8;  $p = 0.010$ ).

## Discussion

Surgical performance generally is evaluated by studying subsequent complications of the procedure and mortality. Such evaluation does not tell how well instru-

ments have functioned. In the current study, analysis of grasper use during laparoscopic surgery has shown that, in total, 62% of the grasping actions could be defined as successful. However, actions inside the image were sometimes difficult to interpret because the intention of the surgeon was not always known.

Forceps limitations can be found by analyzing the less successful actions. Repeated clamping indicates the difficulties with positioning the long, stiff forceps on the desired location, and in the desired direction. Visible tissue damage indicates that inappropriate forces have been used, possibly caused by the forceps limited force feedback. Slip indicates too little applied force or a low friction between forceps and tissue. Because forceps were used to pull tissue out of the camera image, 17% of all grasping actions could not be defined. However, it can be expected that it is difficult to apply the appropriate force when visual feedback is not provided because the force feedback of the forceps is low.

We found differences between the grasping actions during colectomies and those during cholecystectomies. During the colectomies, the colon was frequently repeatedly clamped for short periods of time using atraumatic babcocks because the surgeon wanted to grasp the colon very carefully to prevent perforation. Damage leading to a delayed perforation after 5 to 7 days must be prevented also, because it leads to high morbidity and mortality rates [10]. Even perforation of a colon segment that will be removed may lead to contamination of the abdomen.

During the cholecystectomies, the gallbladder often slipped out of the grasper. This occurred even though the gallbladder generally was grasped with a sharp profile grasper or one that even had teeth. Possibly, the small opening of the grasper's short jaws makes it difficult successfully to grasp the large volume of the distended gallbladder. In addition, greater force is necessary to pull the gallbladder. An adequate forceps for grasping the gallbladder has yet to be designed [9]. The gallbladder was clamped for longer periods than the colon. More traumatic forceps were used on the gallbladder. Surgeons are less concerned with injuring the gallbladder because it will be removed and because perforation of the gallbladder generally does not increase postoperative complications [7].

Because experienced surgeons have adapted to the limitations of forceps, the consequences of the limitations are more obvious when residents perform the actions. Residents performed fewer successful actions and used longer clamping times. The results indicate that residents have more difficulty applying the appropriate amount of force, resulting in less successful actions. After training, their use of graspers will become more effective.

This study was performed to get insight to the use and limitations of graspers. Therefore, the outcome of grasping actions and the duration of tissue clamping were determined. An ideal forceps provides enough grip

on the tissue and yet prevents damage. To determine the optimal design of forceps' jaws, both the manipulation forces surgeons use and the maximum forces allowable should be obtained in an experimental setting. In addition, experiments should be performed to determine the histologic damage after clamping. Although visible damage hardly occurred, it can be expected that tissue is microscopically damaged after clamping. Histologic damage was found after clamping of the gallbladder [8] and bowel [1, 5]. However, in the studies concerning bowel graspers, clamping periods of 20 min to 1 h were used, whereas the duration of clamping during the colectomies exceeded 3 min in only 2.7% of all actions. Hence, studies into histologic damage caused by laparoscopic bowel graspers must concentrate on short clamping periods.

In conclusion, to improve laparoscopic forceps, the design of the jaws should be improved to achieve more grip and less damage to the tissue. Furthermore, force feedback should be provided to achieve less slipping and tearing of tissue. The results of this study will be used in experimental settings to obtain design criteria for laparoscopic graspers.

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