Effect of the Diameter of the Endoscope and of Surgeon Training on the Duration and Quality of Laparoscopic Surgery in a Rabbit Model

Carlos Roger Molinas, M.D., César Ramón Cabral, M.D., and Philippe Robert Koninckx, M.D., Ph.D.

Abstract

Study Objective. *To evaluate the effect of diameter of the endoscope on the duration and quality of laparoscopic surgery.*
Design. *Prospective, randomized trial (Canadian Task Force classification I).*
Setting. *Centre for Surgical Technologies.*
Subjects. *Sixty adult, female, New Zealand, white rabbits.*
Intervention. *Two series of laparoscopic nephrectomies, one each performed by an experienced and an inexperienced surgeon comparing 10-, 5-, 4-, and 2-mm endoscopes.*
Measurements and Main Results. *Besides duration of surgery and occurrence of bleeding, the quality of dissection was scored by adding scores of dissection of renal vessels, ureters, and kidneys. During consecutive nephrectomies, the duration of surgery ($p = 0.001$) and occurrence of bleeding ($p = 0.02$) decreased, whereas the quality of dissection increased ($p = 0.002$), demonstrating the learning curve, mainly for the less experienced surgeon. Duration of surgery ($p = 0.04$) decreased and quality of dissection increased ($p = 0.05$) when the larger endoscope was used. This was the case only for the less experienced surgeon, whereas for the experienced surgeon it had only a slight effect on learning curve.*
Conclusion. *These results confirm a learning curve of nephrectomy consisting of some 20 animals. In addition, the endoscope diameter and thus quality of image affect both duration and quality of surgery, especially for less experienced surgeons.*

(J Am Assoc Gynecol Laparosc 6(4):447–452, 1999)

Learning curves are frequently studied to evaluate the effect of training on duration and quality of endoscopic surgery both in vitro and in vivo. Training in endotrainers increases laparoscopic skills, both duration and quality of performance. This was shown for intracorporeal and extracorporeal knot tying,[1–6] suturing,[1,5] cutting,[2] clipping,[1,2] and transferring objects with both hands.[1,2,4,5] In animal models, such as the rabbit, operating time decreased and quality of surgery increased with training.[7] In humans the duration of laparoscopic Pomeroy tubal ligation decreased after only five procedures.[8] Similar results were reported in

From the Centre for Surgical Technologies (all authors), and Department of Obstetrics and Gynaecology, University Hospital Gasthuisberg (Dr. Koninckx), Leuven, Belgium.

Address reprint requests to Carlos Roger Molinas, M.D., University Hospital Gasthuisberg, K.U. Leuven Centre for Surgical Technologies and Department of Obstetrics and Gynaecology, Minderbroederstraat 17, B-3000 Leuven, Belgium; fax 321 6 337 821.

Supported in part by Karl Storz Endoscopy Belgium and Ethicon Endo-surgery, Belgium, and by a grant from Nationaal Fonds voor Wetesnchappelijk Onderzoek.

Presented as a poster at the annual meeting of the European Society for Gynecological Endoscopy, Stockholm, Sweden, September 15–18, 1999.

Accepted for publication August 19, 1999.

laparoscopic surgery performed for ovarian masses[9] and ectopic pregnancies.[10] Experienced surgeons achieve shorter operating times and better quality than inexperienced surgeons, and these differences decrease with training.[6,10]

It is widely assumed that the quality of videoendoscopic image affects the quality of surgery. Performance increased when the image was displayed in front of the surgeon at hand level,[11] but the direction of view of the endoscope had no effect on intracorporeal knot tying.[12] Much effort has been expended to improve the quality of the image of endoscopes and of video systems. Three-chip cameras, electronic image-enhancement systems such as digi-video, 3D cameras, and fiberoptic and electronic endoscopes have been developed. Although the increased quality of the image is obvious, it remains to be proved that it results in better quality of surgery.[13–15]

Miniendoscopy was developed to decrease surgical trauma and to permit outpatient procedures. Since image quality is less, it was suggested that the skills required for these procedures are higher than for traditional laparoscopy.[16] Several studies failed, however, to show differences in accuracy of diagnosis with a 2- or 10-mm endoscope.[17–21] No agreement exists as to the optimal endoscope diameter for diagnostic procedures, and the influence of diameter and of the associated quality of the image on the quality of surgery has not been assessed properly.

Therefore we performed a prospective, randomized trial to evaluate the effect of endoscope diameter on the duration and quality of surgery in a rabbit nephrectomy model. Effects of the surgeon's training and experience were confounding variables.

Materials and Methods

Animals and Surgical Procedures

Laparoscopic nephrectomies were performed in adult, female, New Zealand white rabbits weighing 2.5 to 3 kg. Anesthesia was induced with intramuscular ketamine 50 mg/kg and xylazin 0.3 mg/kg and maintained with inhalational halothane 2% and oxygen 1.5 L/m. The rabbit was placed in supine position, and the abdomen was shaved and disinfected with povidone iodine.

The first 10-mm cannula (all cannulas Endopath; Ethicon Endo-Surgery, Cincinnati, OH) was introduced by open laparoscopy through a 1-cm incision caudal to the sternum. After CO_2 pneumoperitoneum was established with a thermoflator (Karl Storz, Tuttlingen, Germany) with a flow rate of 5 L/m and pressure 6 mm Hg, the endoscope, connected to a single-chip videocamera and light source (Karl Storz, Germany), was introduced. A second 10-mm cannula was placed under direct vision at the level of the umbilicus. To perform right nephrectomy, the rabbit was placed in right lateral position and, after visualization of the left kidney, a 5-mm cannula was introduced into the abdomen at the level of the kidney hilus. To perform right nephrectomy a second 5-mm cannula was introduced in the same way but with the animal in left lateral position.

Nephrectomies were carried out as follows for both kidneys. The kidney was denuded from surrounding fatty tissue at the level of the hilus using sharp and blunt dissection. Both renal vessels, artery and vein, were dissected up to the aorta, skeletonized individually, and ligated with three medium clips (Horizon; Weck Closure Systems, Research Triangle Park, NC), one for the artery, one for the vein proximally, and one for the artery and vein together distally, and transected. The ureter was dissected from the hilus up to its intersection with the circumflex vein and artery, since this is an obvious anatomic landmark. The kidney was removed by isolating it without surrounding fat from the renal fossa.

Experimental Design

The experiments were carried out in series of 30 animals (60 nephrectomies) since pilot experiments showed a learning curve of some 25 animals. To assess the effect of experience, one series was performed by an experienced and another by an inexperienced surgeon. Both were gynecologists with 3 years of experience in open surgery but with different exposure to laparoscopic surgery. The experienced surgeon had had more than 6 months of in vitro training, and had performed more than 60 nephrectomies in rabbits and a significant number of diagnostic and operative laparoscopies in humans. The inexperienced surgeon had had 2 months of in vitro training and had performed only 10 nephrectomies in rabbits, his only exposure to laparoscopic surgery. His training was intentionally kept to the strict minimum for two reasons. First, interim analysis of the experienced surgeon's results showed that differences between small and larger endoscopes were so small that a very large series would be required to reach statistical significance. Second, since operating times are longer and quality

of surgery is reduced in the hands of inexperienced surgeons, the hypothesis was that an inexperienced surgeon would be a better model to demonstrate differences.

To evaluate the effect of the quality of the video image, nephrectomies were performed randomly with zero-degree endoscopes (Karl Storz) of different diameters. In the first series the experienced surgeon performed 20 nephrectomies with 10- and 5-mm endoscopes (series 1A). Since interim analysis did not show a difference in results, the next 40 nephrectomies were performed with 10-, 5-, 4-, and 2-mm endoscopes (series 1B). In the second series the inexperienced surgeon performed 60 nephrectomies with 10-, 4-, and 2-mm endoscopes (series 2). Rabbits were randomized daily in blocks of two (series 1A), four (series 1B), and three (series 2). Since right nephrectomy seemed slightly more difficult, the left side was performed first and the right side was done using the same endoscope. To avoid the potential effect of different relative positions of instruments for left and right nephrectomies, randomization was performed in animals, including two nephrectomies.

All procedures were continuously video recorded and evaluated for duration and quality of surgery. Scoring was done by the surgeon immediately after surgery and by a blinded independent observer. Since differences between observers were small, a manifest surgeon bias could be excluded and the mean of the two scores was used. The duration of surgery was scored in minutes from introduction of cannulas and instruments to end of dissection. If for any reason dissection could not be completed (e.g., life-threatening bleeding), the score was arbitrarily established as 18 minutes, as this was the longest duration of a procedure in this experiment. The quality of surgery was scored from zero to 3 (no–perfect) for dissection of renal vessels, ureter, and kidney, and for bleeding (none–fatal). Dissection quality score was defined as the sum of scores of dissection of renal vessels, ureter, and kidney.

Statistics

Statistical analysis was performed with the SAS system[22] using Spearman and Pearson correlation and regression analysis (Proc LOGISTIC, Proc REG). Effects of experience, learning curve (assessed by number of nephrectomies), and quality of videoimage (assessed by the diameter of the endoscope) on the duration and quality of surgery were determined.

Results

Dissections of renal vessels, ureter, and kidney were strongly intercorrelated for quality (Spearman $p < 0.0001$ for vessels-kidney, vessels-ureter, and kidney-ureter). Therefore they were grouped into dissection quality for further analysis.

For the inexperienced surgeon, duration of surgery decreased (logistic regression) with progressive gain in experience during consecutive nephrectomies ($p = 0.006$) and with a larger-diameter endoscope ($p = 0.015$). The decrease in duration of surgery correlated (Spearman) with the increase in quality of vessel dissection ($p = 0.001$), kidney dissection ($p = 0.003$), and ureter dissection ($p = 0.012$), and with decrease in bleeding ($p = 0.0002$). By stepwise forward selection using regression analysis (Proc LOGISTIC) the duration of surgery was predicted simultaneously by experience ($p = 0.007$), endoscope diameter ($p = 0.02$), quality of ureter dissection ($p = 0.03$), and quality of vessel dissection ($p = 0.003$).

For the experienced surgeon, duration of surgery only slightly decreased with experience. To become statistically significant, logistic regression (Proc LOGISTIC) was necessary, assessing simultaneously the effects of experience ($p = 0.05$) and endoscope diameter ($p = 0.06$) on duration of surgery.

The effect of endoscope diameter was investigated in more detail by regression analysis. For the experienced surgeon, no significant effect on duration of surgery, bleeding, or quality of dissection was found. For the inexperienced surgeon, endoscope diameter affected simultaneously duration of surgery ($p = 0.05$), quality of dissection ($p = 0.04$) and, occurrence of bleeding ($p = 0.08$). To correct for progressive gain in experience during the experiment, in one model endoscope diameter and experience simultaneously affected duration of surgery ($p = 0.04$ and $p = 0.001$, respectively), bleeding (NS and $p = 0.02$, respectively) and quality of dissection ($p = 0.05$ and $p = 0.002$, respectively).

The same model was used to evaluate differences between 10- and 4-mm endoscopes and between 4- and 2-mm endoscopes. For the former, endoscope diameter and experience simultaneously affected duration of surgery (NS and $p = 0.0001$, respectively), bleeding ($p = 0.02$ and NS), and quality of dissection ($p = 0.02$ and NS). For the latter, the two variables simultaneously affected duration of surgery (NS and $p = 0.0001$, respectively), bleeding (NS and $p = 0.03$),

and quality of dissection (NS and p = 0.005). Taking all data together in one regression model, endoscope diameter clearly affected duration of surgery (p = 0.04), bleeding (p = 0.02), and quality of dissection (p = 0.02). Results are summarized in Figures 1 and 2.

Discussion

To the best of our knowledge this is the first report that endoscope diameter affects duration and quality of surgery. This was shown for the inexperienced surgeon and for the total experiment. For the experienced surgeon the effect was statistically nonsignificant, but the number of animals required to pick up small differences would probably be much larger. Endoscope diameter also affected the frequency of bleeding, which could be considered a complication of surgery. Only two fatalities occurred, both with a 2-mm endoscope and by the inexperienced surgeon. That surgeon also had six cases of heavy bleeding, one with a 10-mm, two with a 4-mm, and three with a 2-mm endoscope. Since heavy bleeding occurred only once in the experienced surgeon's series, with a 2-mm endoscope, statistical significance could not be achieved. It is remarkable, however, that most complications occurred with the smallest endoscope. We realize that this experiment was performed by two surgeons only. Considering the difficulty recruiting well-motivated gynecologists with great experience in open surgery but with none in endoscopic surgery, additional experiments that could have made bleeding and fatalities significant were not performed.

The importance of these results for human surgery should not be underestimated. A decrease in the frequency of complications is obviously important. However, to demonstrate a decrease of a phenomenon that occurs rarely is difficult since the sample size required to reach statistical significance is probably too large; that is, to show a difference between 2% and 1% with a power of 80% and with significance of 0.05 requires a prospective, randomized trial of 5000 subjects, 2500 in both groups. Our results therefore suggest that a higher-quality image will decrease the frequency of complications, something that could be anticipated by common sense.

Our data confirm the well-known effect of training on the learning curve.[1–10] The inexperienced

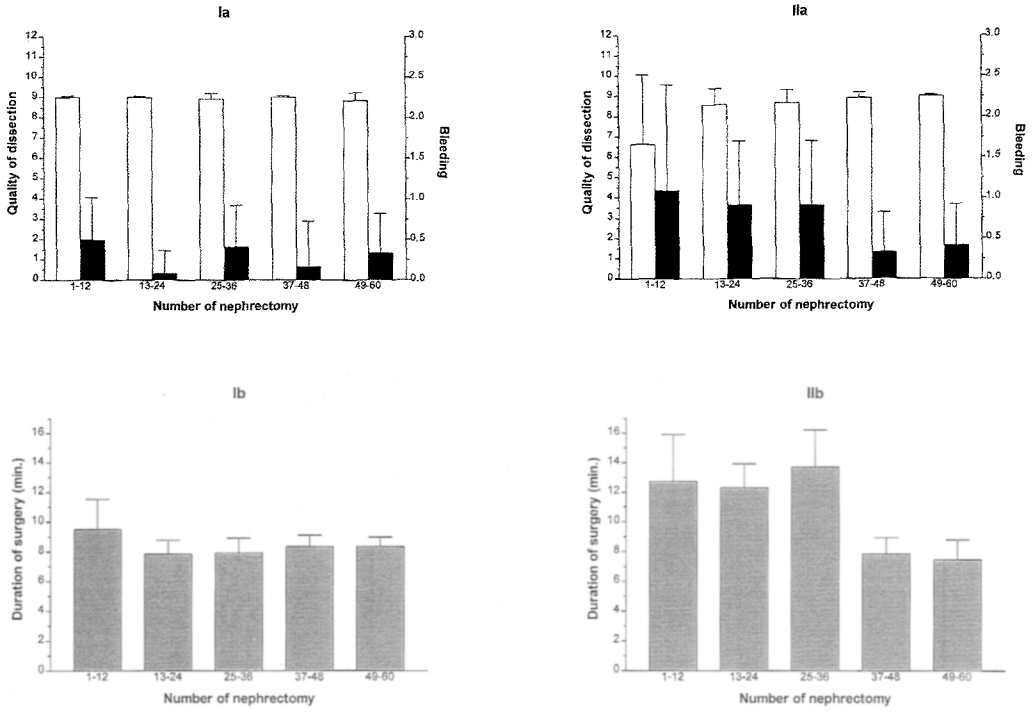

FIGURE 1. Effect of training on quality of □ dissection and bleeding ■ (a) and on duration of surgery ▩ (b) during consecutive nephrectomies performed by an experienced (I) and an inexperienced surgeon (II). Mean ± SD are indicated.

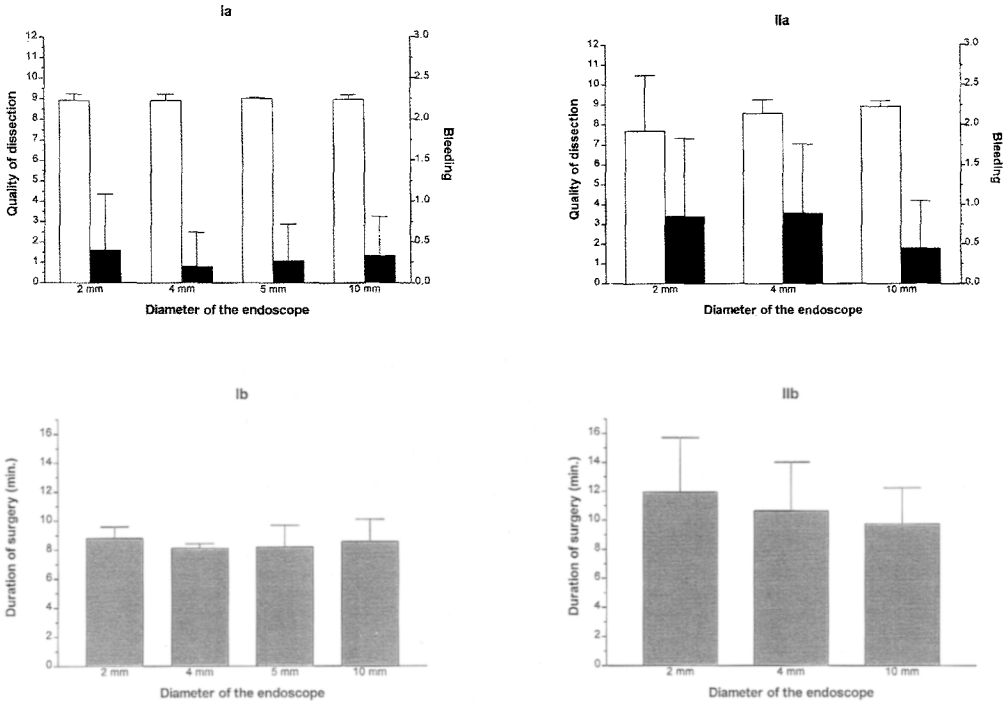

FIGURE 2. Effect of the diameter of the endoscope on quality of dissection □ and bleeding ■ (a) and on duration of surgery ▩ (b) during consecutive nephrectomies performed by an experienced (I) and an inexperienced surgeon (II). Mean ± SD are indicated.

surgeon had a considerable decrease in duration of surgery and occurrence of bleeding and an increase in quality of dissection after 20 rabbits. For the experienced surgeon, effects of training on the same variables were less important and did not reach statistical significance.

The rabbit nephrectomy model seems to be good for evaluating duration and quality of surgery because of dissection of majors vessels. The surgeon has to adapt to the opposite requirements of going fast to reduce time but without complications such as heavy bleeding.

These data are important for interpreting mini-endoscopy results. Failing to show a difference between 10- and 2-mm endoscopes in diagnostic procedures does not allow the conclusion that they are comparable. Reported series consisted of fewer than 100 cases with consequently a low power for these experiments.[17–21] Moreover, the surgeons were highly experienced and skilled. Our data suggest that for less experienced surgeons the difference between 10 and 2 mm could be much more important.

References

1. Chung JY, Sackier JM: A method of objectively evaluating improvements in laparoscopic skills. Surg Endosc 12(9):1111–1116, 1998

2. Derossis AM, Bothwell J, Sigman HH, et al: The effect of practice on performance in laparoscopic simulator. Surg Endosc 12(9):1117–1120, 1998

3. Vossen C, Van Ballaer P, Shaw RW, et al: Effect of training on endoscopic intracorporeal knot tying. Hum Reprod 12(12):2658–2663, 1997

4. Rosser JC, Rosser LE, Savalgi RS: Skill acquisition and assessment for laparoscopic surgery. Arch Surg 132(2):200–204, 1997

5. Shapiro SJ, Paz-Partlow M, Daykhovsky L, et al: The use of a modular skills center for the maintenance of laparoscopic skills. Surg Endosc 10(8):816–819, 1996

6. Mori T, Hatano N, Maruyama S, et al: Significance of "hands-on-training" in laparoscopic surgery. Surg Endosc 12(3):256–260, 1998

7. Ordoñez JL, Domínguez J, Evrard V, et al: The effect of training and duration of surgery on adhesion formation in the rabbit model. Hum Reprod 12(12):2654–2657, 1997

8. Fox MD, Long CA, Meeks GR, et al: Laparoscopic Pomeroy tubal ligation as a teaching model for residents. J Reprod Med 39(11):862–864, 1994

9. Yuen PM, Rogers MS: Laparoscopic management of ovarian masses: The initial experience and learning curve. Aust NZ J Obstet Gynaecol 34(2):191–194, 1994

10. Yeko TR, Villa A, Parsons AK, et al: Laparoscopic treatment of ectopic pregnancy. Residents' learning experience. J Reprod Med 39(11):854–856, 1994

11. Hanna GB, Shimi SM, Cuschieri A: Task perfomance in endoscopic surgery is influenced by location of the image display. Ann Surg 227(4):481–484, 1998

12. Hanna GB, Shimi S, Cuschieri A: Influence of direction of view, target-to-endoscope distance and manipulation angle on endoscopic knot tying. Br J Surg 84:1460–1464, 1997

13. Vakil N, Bourgeois K: A prospective controlled trial of eight-bit, 16-bit and 24-bit digital color images in electronic endoscopy. Endoscopy 27:589–592, 1995

14. Hanna GB, Shimi SM, Cuschieri A: Randomized study of influence of two-dimensional versus three-dimensional imaging on performance of laparoscopic cholecystectomy. Lancet 24;351(9098):248–251, 1998

15. Berci G, Wren SM, Stain SC, et al: Individual assessment of visual perception by surgeons observing the same laparoscopic organs with various imaging systems. Surg Endosc 9(9):967–973, 1995

16. Rosser JC, Olive DL, Zreik T, et al: Decreased performance of skilled laparoscopic surgeons at microlaparoscopy versus traditional laparoscopy. J Am Assoc Gynecol Laparosc 3(4, suppl):S44, 1996

17. Haeusler G, Lehner R, Hanzal E, et al: Diagnostic accuracy of 2 mm microlaparoscopy. Acta Obstet Gynecol Scand 75(7):672–675, 1996

18. Molloy D: The diagnostic accuracy of a microlaparoscope. J Am Assoc Gynecol Laparosc 2(2):203–206, 1995

19. Evans SF, Petrucco OM: Microlaparoscopy for suspected pelvic pathology. A comparison of 2 mm versus 10mm laparoscope. Aust NZ J Obstet Gynaecol 38(2):215–216, 1998

20. Faber BM, Coddington CC III: Microlaparoscopy: A comparative study of diagnosis accuracy. Fertil Steril 67(5):952–954, 1997

21. Karabacak O, Tiras MB, Taner MZ, et al: Small diameter versus conventional laparoscopy: A prospective, self–controlled study. Hum Reprod 12(11):2399–2401, 1997

22. SAS Institute. SAS/STAT user's guide, release 6.12.998. Cary, NC, Author, 1998.