

## Original article

# Assessment of resident training in laparoscopic surgery based on a digestive system anastomosis model in the laboratory

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## ARTICLE INFORMATION

## Article history:

Received June 11, 2009

Accepted August 13, 2009

Online October 31, 2009

## Keywords:

Laparoscopic training

Endotrainer

Intestinal anastomosis

## A B S T R A C T

**Background:** The complexity of laparoscopic surgery makes specific training out of the operating rooms necessary to shorten learning curves and to minimise morbidity rates. Our aim was to analyse the increase in laparoscopic skills after completion of a laboratory training program.

**Material and methods:** Prospective study of surgical resident training based on anastomosis performance on an "endotrainer." The program consisted of 4 weeks per year (20 h per week) between 2004 and 2007. The outcome measures were the time and number of anastomosis necessary to perform a proper anastomosis. Upon completion, the anastomosis was checked by both trainee and evaluator and quality was assessed. Time and technical failures (loose suture, edge eversion, leakage) were recorded.

**Results:** Twelve surgical residents were trained. They performed 189 jejuno-jejunal anastomoses (JJA), mean 15.8 per resident and 197 gastro-jejunal anastomoses (GJA), mean 16.4 per resident. The performance mean time was 72.7 min for JJA and 87.2 for GJA. There was a marked reduction in time from the beginning to completion of training. The percentage of flawed anastomosis decreased with training: 26.6%, 21.8%, 17.1%, 17%, 16.1%, and 10.5% after 20, 40, 60, 80, 100, and 120 h, respectively. Bearing in mind reduction in both performance time and flawed anastomosis rate, it appears that after 70 h of training the learning curve reaches a plateau zone.

**Conclusions:** Intestinal anastomosis (either JJA or GJA) performed in "endotrainer" is a suitable model for laparoscopic training, without the need of live animals. After a training period of 70 hours, the improvement seems of little benefit.

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## Evaluación del entrenamiento de residentes en cirugía laparoscópica en el laboratorio basado en un modelo de anastomosis digestivas

### R E S U M E N

#### Palabras clave:

Entrenamiento laparoscópico  
Endotrainer  
Anastomosis intestinales

**Introducción:** La complejidad de la cirugía laparoscópica hace necesario un entrenamiento específico fuera del quirófano para acortar la curva de aprendizaje y reducir la morbilidad. El objetivo del estudio es analizar la progresión en habilidades laparoscópicas tras un programa de entrenamiento en laboratorio.

**Material y métodos:** Estudio prospectivo de un programa de entrenamiento de residentes de 4 semanas anuales (20 h semanales) basado en anastomosis en endotrainer, realizado entre 2004 y 2007. Los parámetros principales fueron tiempo y número de anastomosis necesarias hasta llegar a una correcta ejecución. Una vez completada, la anastomosis se revisó conjuntamente mediante un residente y un monitor. Se registraron tiempo de ejecución y fallos anastomóticos (sutura floja, eversión de bordes y fuga).

**Resultados:** Doce residentes realizaron 189 anastomosis yeyunoyeyunales (AYY) (media: 15,8) y 197 anastomosis gastroyeyunales (AGY) (media: 16,4). El tiempo medio de las AYY fue de 72,7 min y el de las AGY fue de 87,2 min. Se observó una gran reducción en el tiempo de ejecución desde el comienzo al final del programa. El porcentaje de anastomosis incorrectas disminuyó en función del tiempo de entrenamiento: el 26,6; el 21,8; el 17,1; el 17; el 16,1 y el 10,5% después de 20; 40; 60; 80; 100 y 120 h, respectivamente. Considerando la reducción, tanto en tiempo de ejecución como en el índice de anastomosis incorrectas, después de 70 h de entrenamiento la curva de aprendizaje alcanzaba una meseta.

**Conclusiones:** El entrenamiento en endotrainer basado en anastomosis intestinales (tanto AYY o AGY) constituye un método útil de entrenamiento laparoscópico. Después de un entrenamiento de 70 h se aprecia poca progresión.

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## Introduction

Until recently, learning any surgical procedure was based on performance, initially supervised, over the patients themselves. This implies a long learning curve with higher morbidity and, possibly, mortality rates, as well as worse outcomes in the long term. Laparoscopic procedures require longer and more prolonged training, because sense of touch is absent and because this technique is thus based on a 2 dimensional image. Furthermore, learning increases surgical costs due to more prolonged surgical times.<sup>1</sup> Such training acquires still more significance for residents, who are naturally less surgically experienced.

In order to accelerate learning and not to start on patients directly, training laboratories have been designed. In these laboratories, practice can be carried out using virtual reality systems<sup>2,3</sup> or physical simulators.<sup>4,5</sup> With both systems, basic surgical techniques can be developed, such as dissection, incision, and sutures. Physical simulators also make training possible using animal organs. Together with this type of simulation there is another that consists in using living animals and even cadavers. All these techniques have shown technical progress for the trainees.<sup>3,5-8</sup> Some studies even state that intestinal anastomosis performed in *endotrainer* is possible.<sup>9</sup>

However, neither the appropriate method nor training times has been clearly established yet. This work aims at assessing a training strategy in laparoscopic surgery consisting in anastomosis performance in *endotrainer*, and then measure its technical progress. Especially, the main objective was to analyse time and number of necessary anastomoses to achieve an appropriate degree of performance. Secondary to this objective, some influencing factors were analysed, such as specialty and year of residence.

## Material and methods

Prospective study assessing the results from laparoscopic training of residents in surgical specialties to be acquired in a skill-promoting laboratory. This study was carried out at the training centre of laparoscopic and endoscopic surgery of Hospital Universitario Marqués de Valdecilla of Santander.

The participating residents were 7 from general surgery (2 residents of 4th year [R4] and 5 residents of 5th year [R5]), 3 from gynaecology (3R4), and 2 from urology (1R4-1R5). The training programme took place between 2004 and 2007 and consisted of 1 week (20 h) quarterly training during their time of residence. This training was carried out using equipment consisting of *endotrainer*, 10 mm optics anchored

with support (which allowed training without assistant), and a laparoscopic tower with monitor, insufflator and camera control. The programme started with basic exercises of spatial orientation, elementary dissection, and laparoscopic suture and knotting. Simultaneously, surgical techniques in anaesthetised living pigs were performed—cholecystectomy, antireflux, gastrectomy or colectomy—. All the participants were familiarised with intestinal anastomosis in open surgery technique. The parameters to be assessed were established first: time employed in performing a proper anastomosis, being such defined by no edge eversion, adequate suture tension, and no leakages. For its evaluation, the suture was instrumentally examined and a hydrostatic test was performed by filling the organ with saline serum, prior to closing the edges. Jejunojejunal anastomoses (JJA) and gastro-jejunal anastomoses (GJA) were performed over segments of pig's jejunum and stomach, obtained from other experiments carried out in the same training centre. The technique consisted in a posterior face seroserosal suture with 7 loose silk stitches, followed by a whole-thickness continuous suture with monofilament Monosyn 0000 (Braun), departing from one half of the posterior face and forming 2 semi-circumferences ending up in one half of the anterior face. Anastomosis size was of 5 cm. Study parameters were recorded for each practice. The evaluators (surgeons with over 15 years of experience in surgery and experienced in advanced laparoscopic procedures) supervised the training. Upon completion of each anastomosis, a joint revision by resident and evaluator was performed to check for technical failures.

The statistical analysis consisted in descriptive statistics of numerical variables by mean and standard deviation, or median and interquartile range (IQR) when the variable did not follow a normal distribution (for example, the time employed in performing the anastomoses). Student t test was used to compare 2 means and Fisher's exact test to assess the association of 2 qualitative variables. A model of polynomial regression was used to describe the time employed in performing the anastomosis depending on learning hours:

$$Y = \beta_0 + \beta_1 X + \beta_2 X^2 + \beta_3 X^3 + \dots + \beta_k X^k, i=1,2,\dots,k$$

Dependent variable (Y) is the time employed in the anastomosis and independent variable (X) represents the learning hours. Of the possible values for k (polynomial degree) the minimum that best explained the variability observed was chosen. The importance of a factor is described by the odds ratio and its confidence interval. The ratio between anastomosis duration and resident specialty was evaluated by a multiple regression analysis. The ratio between quality of anastomosis and different independent factors was studied by multiple regression analysis. Signification level was set at  $P < .05$ .

## Results

Twelve residents performed 189 JJA, mean 15.8 per resident, SD 4.07 (interval, 9–21), of which general surgery residents

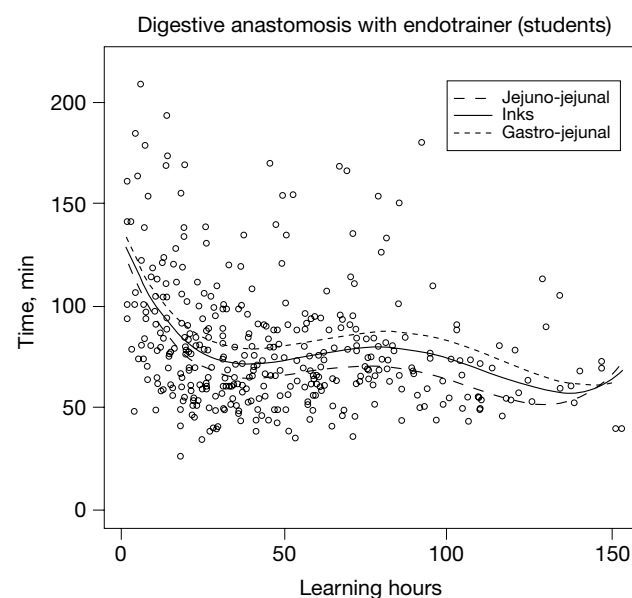
performed 114, gynaecology residents 54, and urology residents 21. They also performed 197 GJA, mean 16.4 per resident, SD 3.55 (interval, 10–21), of which general surgery residents performed 120, gynaecology residents 50, and urology residents 27.

The mean time for performing JJA was 72.7 min (median, 65; IQR, 32) and for GJA, 87.2 min (median, 80; IQR, 35).

Anastomosis performance time is graphically shown against total hours of training (Figure 1), and a dot cloud is obtained, that may indicate whether there is certain progressive tendency, as the initial hypothesis was that a rapid reduction should be observed at onset to move onto a more gradual reduction as training progresses. It can be seen how performance time decreases as training time increases ( $P < .0001$ ). The adjustment degree, although significant ( $r = 0.39$ ), is not very good, as the model only explains 15% of data variability. Figure 1 also shows the curves for each one of the 2 types of anastomoses. It can be observed that they are practically parallel, so that they can be summarised in the curve globally representing the 2 types of anastomosis.

In any case, it can be observed how the general surgery residents performed their anastomosis employing less time ( $r = 0.22$ ), and urology residents took more time at first to reduce it later on ( $r = 0.73$ ), whereas the learning speed of gynaecology residents was intermediate ( $r = 0.51$ ). However, the size of the groups is too small to draw conclusions.

With relation to quality of anastomosis (Table), it can be seen that 18.4% showed technical failures. The percentage of technical failures in GJA (22.8%) was higher than in JJA (13.8%), although differences did not become significant. This

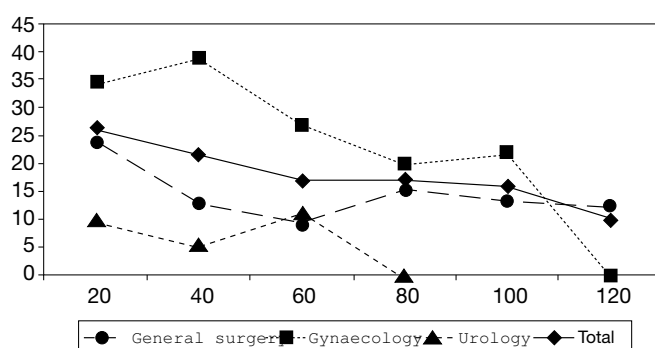


**Figure 1 – Time (ordinates) taken by residents to perform anastomosis is represented graphically against total training hours (axis) and a dot cloud is obtained. It can be observed how surgical time decreases as learning time increases ( $P < .0001$ ).**

**Table – Number, percentage, and 95% confidence interval of technical failures observed in different classes of anastomosis performed**

Variable	Gastro-jejunal anastomoses			Jejuno-jejunal anastomoses			Other type of anastomosis		
	No.	%	95% CI	No.	%	95% CI	No.	%	95% CI
Eversion	7	3.6	1.7–7.2	5	2.6	1.1–6.0	12	3.1	1.8–5.4
Loose suture	12	6.1	3.5–10.3	5	2.6	1.1–6.0	17	4.4	2.8–6.9
Leakage	34	17.3	12.6–23.1	19	10.1	6.5–15.2	53	13.7	10.7–17.5
Outcome	45	22.8	17.5–29.2	26	13.8	9.6–19.4	71	18.4	14.8–22.6

CI indicates confidence interval.



**Figure 2 – Percentage of anastomosis with technical failures at different moments during training (in hours). Global rate is shown, as well as rates according to resident specialty.**

proportion gradually decreased as training hours increased (Figure 2).

Several factors were observed to have influenced for a better quality of anastomosis, such as longer training time, the trainee being a urology resident, and type of anastomosis being JJA. The highest coefficient (besides it is the most significant one) and, therefore, the most influential, was the year of residence, with an odds ratio of 0.23 (95% confidence interval, 0.103–0.522).

Bearing in mind reduction curves of time employed in one anastomosis performance and technical failure reduction, a plateau is observed after 70 h of training, so much so that it could be stated that, after such period, progress is scant.

## Discussion

The long learning curve of laparoscopic procedures, with higher morbidity and, possibly, mortality rates involved in teaching directly over patients, favours training in laboratory against training over patients.<sup>10</sup> Furthermore, the new legal norms increasingly restrain weekly time of medical work and, therefore, physicians' possibilities of learning. The number of cases that a resident should operate on laparoscopically, to

reach a plateau in his/her learning curve, has been estimated in 100.<sup>11</sup> Moreover, developing effective and reproducible training methods may serve to evaluate residents and detect training deficits.<sup>12</sup>

It is important to note that there are various publications on resident training but few that measure and prove learning results.<sup>4,8,13</sup> In this study we have been able to document the technical progression of residents. Together with other works,<sup>9,10,13</sup> our training method is based on anastomosis performance. We employ the anastomosis technique over a single layer of continuous suture, which has been broadly accepted.<sup>9</sup> Apart from instructing over anastomosis learning in itself, it also involves training in several basic technical aspects: spatial orientation, instrument handling, suture, and knotting.

We have observed that performing enteroenteric or gastroenteric anastomosis is an adequate technique for laparoscopic training, if we base this statement on various aspects. Firstly, it can be measured how surgical time diminishes as training time increases. Secondly, technical failure occurrence diminishes as practice hours increase. However, this ratio does not improve after 70 h, either because the number of anastomosis is small or because residents specialising in general surgery or urology have achieved acceptable levels of technical failures. Nevertheless, as the number of anastomosis after 70 h is small, this observation should be taken with caution.

It is worthy of note the importance of supervision by the evaluator and the joint analysis of each experience, as this allows learning from mistakes.<sup>14</sup> Beyond doubt, this strategy accelerates learning. However, it is also to be taken into account that, in our study, progression did not only depend on anastomosis performance, as the residents were simultaneously being trained in laparoscopic techniques on living animals and continued with their habitual clinical practice, where they carried out laparoscopic techniques of increasing complexity as they made progress in their internship. A not measured variable was that not all the residents departed from the same level of skills.

GJA and JJA are comparable as a means of training, although GJA associates a slightly higher proportion of technical failures. Furthermore, some differences in learning have been observed. Despite the small number of residents participating

in this study and difference in years of residence between some of them, it can be seen that general surgery residents achieved shorter performance times at the end of the training programme than gynaecology and urology residents, presumably because their daily work involves more surgical practice. Urology residents make progress more rapidly than the others and achieve better results in quality, although their minimum time does not match that of general surgery residents. A tendency to achieve better results on the part of general surgery residents has been observed in other works carried out in non-laparoscopic anastomosis.<sup>15</sup> However, the small sample size prevents drawing conclusions regarding learning and resident specialty ratio.

The number necessary to acquire competence has been established at 40 anastomoses,<sup>9</sup> although this has been defined for trained specialists and not for residents.

Basic-surgical-technique simulators have shown their usefulness to improve surgical performance,<sup>4</sup> as well as anastomosis performed with synthetic materials.<sup>15</sup> Intestinal anastomosis using animal organs, as we have done in our study and in others,<sup>13</sup> appears to be a training method resembling clinical scenarios, and has advantages over other alternatives, such as surgery with living animals, virtual reality, cadavers, and other simulators. Training with living animals re-creates to the maximum real surgical scenarios. However, it has various drawbacks, such as high cost, due to the need for infrastructure and monitors, or the need to sacrifice animals. It is worthy of note that, although in our study the anastomoses were performed over organs from animals employed in other training experiences, it would be possible to use organs from industrial slaughter houses, which would avoid sacrificing animals and also save up on costs. Surgery over cadavers also adequately re-creates real conditions,<sup>16</sup> but its availability is very restrained. Virtual reality training re-creates less faithfully real surgical scenarios, and evidence validating effectiveness of most systems is still scant, except for the system "minimally invasive surgical trainer" in virtual reality (MIST-VR).<sup>2</sup> Models based on virtual reality could be a useful first step in laparoscopic training, as it is understood from conclusions to systematic revisions, although advantages over *endotrainer* for residents with certain laparoscopic experience are not as yet clear.<sup>16,17</sup> In any case, simulation systems are expensive, although not as much as direct teaching over patients.<sup>1</sup>

To conclude, according to the present study, it appears that enteroenteric or gastroenteric anastomosis is an adequate technique for laparoscopic training: standardisable and feasible without living animals. JJA and GJA are equally valid. Using this model progress is barely significant after 70 h of training.

It is still to be demonstrated that learning in a training laboratory translate into real surgery progress, although there are already some data indicating this to be so.<sup>3,8,18</sup>

### Conflict of interest

The authors affirm that they have no conflicts of interest.

### REFERENCES

- Harrington DT, Roye GD, Ryder BA, Miner TJ, Richardson P, Cioffi WG. A time-cost analysis of teaching a laparoscopic entero-enterostomy. *J Surg Educ.* 2007;64:342-5.
- Carter FJ, Schijven MP, Aggarwal R, Grantcharov T, Francis NK, Hanna GB, et al. Consensus guidelines for validation of virtual reality surgical simulators. *Surg Endosc.* 2005;19:1523-32.
- Seymour NE, Gallagher AG, Roman SA, O'Brien MK, Bansal VK, Andersen DK, et al. Virtual reality training improves operating room performance: Results of a randomized, double-blinded study. *Ann Surg.* 2002;236:458-63.
- Stefanidis D, Sierra R, Korndorffer JR, Dunne JB, Markley S, Touchard CL, et al. Intensive continuing medical education course training on simulators results in proficiency for laparoscopic suturing. *Am J Surg.* 2006;191:23-7.
- van Sickle KR, Ritter EM, Baghai M, Goldenberg AE, Huang IP, Gallagher AG, et al. Prospective, randomized, double-blind trial of curriculum-based training for intracorporeal suturing and knot tying. *J Am Coll Surg.* 2008;207:560-8.
- Korndorffer Jr JR, Dunne JB, Sierra R, Stefanidis D, Touchard CL, Scott DJ. Simulator training for laparoscopic suturing using performance goals translates to the operating room. *J Am Coll Surg.* 2005;201:23-9.
- Verdaasdonk EG, Dankelman J, Lange JF, Stassen LP. Transfer validity of laparoscopic knot-tying training on a VR simulator to a realistic environment: A randomized controlled trial. *Surg Endosc.* 2008;22:1636-42.
- Scott DJ, Bergen PC, Rege RV, Laycock R, Tesfay ST, Valentine RJ, et al. Laparoscopic training on bench models: Better and more cost effective than operating room experience. *J Am Coll Surg.* 2000;191:272-83.
- Hamad MA, Mentges B, Buess G. Laparoscopic sutured anastomosis of the bowel. Technique and learning curve. *Surg Endosc.* 2003;17:1840-4.
- MacFadyen Jr BV. Teaching, training, and clinical surgery. *Surg Endosc.* 2004;18:361-2.
- Black M, Gould JC. Measuring laparoscopic operative skill in a video trainer. *Surg Endosc.* 2006;20:1069-71.
- Datta V, Bann S, Aggarwal R, Mandalia M, Hance J, Darzi A. Technical skills examination for general surgical trainees. *Br J Surg.* 2006;93:1139-46.
- Jensen AR, Wright AS, McIntyre LK, Levy AE, Foy HM, Anastakis DJ, et al. Laboratory-based instruction for skin closure and bowel anastomosis for surgical residents. *Arch Surg.* 2008;143:852-9.
- O'Connor A, Schwaitzberg SD, Cao CGL. How much feedback is necessary for learning to suture?. *Surg Endosc.* 2008;22:1614-9.
- Shah J, Munz Y, Manson J, Moorthy K, Darzi A. Objective assessment of small bowel anastomosis skill in trainee general surgeons and urologists. *World J Surg.* 2006;30:248-51.
- Sutherland LM, Middleton PF, Anthony A, Hamdorf J, Cregan P, Scott D, et al. Surgical simulation: A systematic review. *Ann Surg.* 2006;243:291-300.

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17. Gurusamy K, Aggarwal R, Palanivelu L, Davidson BR. Systematic review of randomized controlled trials on the effectiveness of virtual reality training for laparoscopic surgery. *Br J Surg*. 2008;95:1088–97.
  18. Schijven MP, Jakimowicz JJ, Broeders IA, Tseng LN. The Eindhoven laparoscopic cholecystectomy training course – improving operating room performance using virtual reality training: Results from the first E.A.E.S. accredited virtual reality trainings curriculum. *Surg Endosc*. 2005;19: 1220–6.