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Original articles

Surgical resident training program in minimally invasive surgery experimental laboratory (CENDOS)

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ARTICLE INFORMATION

Article history:
Received May 16, 2008
Accepted July 7, 2008

Keywords:
Training and formation
Experimental laboratory
Laparoscopic surgery

A B S T R A C T

Introduction: The rapid development of laparoscopic surgery makes resident training programmes necessary.
Objective: To analyse the results of a structured programme of laparoscopic training in an experimental laboratory.
Material and method: From 2003 until 2007, we trained 11 general surgery residents for 20 h every 3 months, for 3 years. The practice consisted of suture and anastomosis in Endo-Trainer with animal organs, as well as laparoscopic techniques in live animals. In the Endo-Trainer practice we evaluated the time and quality of anastomosis performance. In laparoscopic techniques (cholecystectomy and anti-reflux surgery) a task table was evaluated, from 0 (no errors) to 100 (severe lesion).
Results: In total, 314 anastomosis were performed by the 11 residents, with a median of 28.5 per resident (24-42). The mean time for the first gastro-jejunal anastomosis was 135 min (100-140) and 65 min (57.5-105) for the first jejunal-jejunal anastomosis. Maximum learning was achieved after 45 training hours. There were no appreciable differences between both types of anastomosis. There was inadequate anastomosis quality due to leakage in 17.1% during the learning period and 13.7% during the consolidation period. In the animal, 172 procedures were performed. In cholecystectomy and anti-reflux surgery the mean scores were 2.4 and 5.6 points, respectively. In the remaining procedures, subjectively evaluated by the monitors, the quality was adequate in 65%, deficient in 22% and highly deficient in 13%.
Conclusions: This structured programme of laparoscopic skills based on intestinal anastomosis allows for quicker resident training.

CENDOS: Centre for Training and Research into Endoscopic Surgery and Minimally Invasive Image-Assisted Procedures (Centro de Formación e Investigación en Cirugía Endoscópica y Procedimientos Mínimamente Invasivos Asistidos por Imagen); IFIMAV: Marqués de Valdecilla Institute of Training and Research (Instituto de Formación e Investigación Marqués Valdecilla), Marqués de Valdecilla foundation, Cantabria, Spain.

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0009-739X/$ - see front matter

Programa de formación del residente de cirugía en un laboratorio experimental de cirugía minimamente invasiva (CENDOS)

Palabras clave:
Entrenamiento y formación
Laboratorio experimental
Cirugía laparoscópica

R E S U M E N

Introducción: El rápido avance de la cirugía laparoscópica obliga a cambiar los métodos de enseñanza de residentes.
Objetivo: Analizar los resultados de un programa estructurado de formación laparoscópica en laboratorio experimental.
Material y método: Entre 2003 y 2007, entrenamos a 11 residentes de cirugía general 20 h por trimestre durante 3 años. Incluimos habilidades en suturas y anastomosis en endotrainer con órganos animales y técnicas laparoscópicas en animales vivos. En la práctica en cajas, se registraron tiempo y calidad anastomótica. En la laparoscopia realizada al animal (colecistectomía y antirreflujo), se puntuó una tabla de tareas de 0 (ningú n error) a 100 (lesión grave).
Resultados: Los 11 residentes realizaron 314 anastomosis, con una media de 28,5 (24-42) anastomosis/residente. La mediana de tiempo para la primera anastomosis gastroyeyunal fue 135 (100-140) min y para la yeyunoyeyunal, 65 (57,5-105) min. El máximo aprendizaje se produjo transcurridas 45 h de entrenamiento. No se apreciaron diferencias en la ejecución de ambas anastomosis. Se registró deficiente calidad anastomótica, determinada por existencia de fuga, en el 17,1% durante el período de aprendizaje y el 13,7% durante el de consolidación. En el animal realizaron 172 procedimientos. En colecistectomía y antirreflujo hubo una media de 2,4 y 5,6 puntos. En el resto de procedimientos, valorados subjetivamente por el monitor, la calidad de la técnica fue correcta en el 65%, mejorable en el 22% y muy mejorable en el 13%.
Conclusiones: Este programa estructurado de habilidades laparoscópicas basado en la ejecución de anastomosis intestinales permite acelerar la formación de los residentes.

Introduction

Endoscopic surgery is one of the most important surgical advances of the 20th century. It is a new therapeutic method that differs from conventional surgery largely due to the loss of the third dimension and most of the touch sensation.[1]

All the above require a different method of executing this surgery, a method that requires time to learn it and is no longer based on the principles of Halsted[2] with respect to participation and progressive responsibility with experienced surgeons, but is assisted by new training techniques such as procedure drills, virtual reality simulators, and new information technologies.

The laparoscopic surgical technique has been used for 20 years and, at the present time, it is possible to carry out surgery using the laparoscopic technique in more than 60% of all surgical operations. In addition to requiring new techniques and expertise, technology now forms part of our daily surgical procedures and the number of hours dedicated to work is falling, which requires new teaching methods in experimental laboratories.[3]

The training programme for residents in Hospital Valdecilla, Santander, was set up in 2003; it covers all surgical residents and the purpose is to offer them the largest number of surgical and non-surgical skills. The aim of this study is to analyse the results of a programme structured on endoscopic training in an experimental laboratory.

Material and method

A prospective study of the endoscopic surgical training parameters used from September 2003 to September 2007 in the experimental facilities (CENDOS) of Hospital Valdecilla, forming part of the IFIMAV. Eleven general surgery residents developed a continuous surgical training process for 1 week (20 h) each quarter.

During the residency, the programme included the use of an endotrainer and animals for different surgical techniques structured each year, as shown in Table 1. As each practice was executed, the resident was guided by a surgeon with expertise in minimally invasive techniques.

The entire programme contained 3 fundamental sections which we will consider in this study: performing of intestinal anastomoses as a technical basis for learning, development of procedures in experimental animals and evaluation by the resident of the programme itself.

Table 1 – CENDOS Training Programme for General Surgery Residents at Valdecilla Hospital. The Total Programme Lasted for 420 h

Year 1 of residency
Material and laparoscopic equipment
Eye-hand coordination techniques (in endotrainer and in virtual simulator)
Execution of continuous and discontinuous sutures and intra and extra-corporeal knots (endotrainer)
Experimental animal:

- Pneumoperitoneal. Trochars
- Dissection, cutting, and suture
- Anatomy, anaesthesia, and site
- In animal, at least 5 cholecystectomies

Practical sessions: problems in laparoscopic equipment and material
Audiovisual techniques: cholecystectomy, problems, and solutions
Manual with techniques, literature, and evaluation tests

Year 2 of residency
Training in knots and sutures
Gastroenteric anastomoses in endotrainer
Cholecystectomy and cholangiography in animals

Year 3 of residency
Intestinal anastomoses endotrainer
Approach in animals:

- Different oesophagogastric valvuloplastia techniques
- Gastroenteric and enteroenteric anastomoses

Video sessions in patients:

- Emergency cholecystectomy
- Appendicectomy
- Oesophageal hiatus pathology

Course in microsurgery (25 h): vascular and nervous anastomoses and free flaps in rat
Course in endoscopy (25 h): endoscopic treatment in endotrainer on preserved animal organs and on animals

Year 4 of residency
Intestinal anastomoses endotrainer
Animal: abdominal wall, enteric anastomoses, cholectomies, and gastrectomies
Audiovisual sessions: emergencies (perforation, obstruction, and diagnosis)
Course on polytrauma lasting 30 h
Course on clinical safety lasting 30 h

Year 5 of residency
Endotrainer: gastric bypass, B II
Animal: gastrectomy and rectal amputation, gastric bypass, oesophagectomy
Audiovisual sessions: rectal tumours, morbid obesity, suprarenalectomy
Communication course and teamwork (30 h)

The execution of intestinal anastomoses starts during the second week of study at the centre with gastrojejunal anastomosis and from the fourth anastomosis of this type, the course continues with jejunojejunal anastomosis. The parameters to be measured in each anastomosis are: execution time and quality of the anastomosis, determining whether it is correct (with no dehiscence) or incorrect (dehiscence, suture or eversion of edges). For evaluating progression in the training, 2 parameters were evaluated: quality of the anastomosis and learning time, in hours.

With respect to the section on surgical techniques performed on animals, cholecystectomies and anti-reflux techniques are evaluated by measuring the time of execution, but also by means of structuring of the practice into tasks and sub-tasks and evaluating correct actions and errors to achieve a final score in which 0 represents perfect execution and 100 a serious error (lesion of the bile duct, oesophageal rupture), (Table 2).

Laparoscopic surgery performed on animals has a subjective evolution in the eyes of the surgeon who acts as residents' supervisor. This evolution is included during the technical execution and on its conclusion, firstly by monitoring the resident and then performing the necropsy on the animal together. After completing the practice, the monitor indicates the execution of the technique on a surgical protocol sheet and evaluates it as being correct, improvable, or manifestly improvable.

The resident him/herself evaluates the programme by means of a survey at the end of each year, giving a rating for the technical equipment, teachers, audiovisual, and teaching material. The survey is repeated in greater depth at the end of the residency period.

All these parameters are collected prospectively and entered in a database.

The statistical analysis was done using SPSS 14 software for Windows. In describing the qualitative variables, the frequencies distribution was used and the confidence intervals were calculated, with an alpha error = .05, using the Wilson's method. To check proportions, the Fisher's exact test was used.

The quantitative variables are described using the average (standard deviation); when a normal law was not followed (checked by means of the Shapiro-Wilks' test), the mean was used [interquartile range.] To check the means, the ANOVA or Kruskal-Wallis test was used.

The ratio between the length of the anastomosis (min) and the learning time (h) was described by polynomic regression. The ratio between the quality of the anastomosis and different independent factors was studied using a multiple regression analysis. The level of significance was set at $P<.05$.

Results

Of the multiple results obtained from the programme, we are interested in emphasising the following 3 in this study: intestinal anastomoses in the endotrainer, number of procedures and quality of those performed on the experimental animals, and an evaluation of the programme by the resident him/herself.

Table 2 – Tasks, Sub-tasks, and Errors in the Nissen Fundoplication Via the Laparoscopic Route

1. Task: Preparation of the animal abdomen and equipment
Subtasks: Position of the animal, preparation of the abdomen, instruments, and laparoscopic equipment
Error: Incorrect positioning of the animal (1); alteration of the consecutive order for positioning the laparoscopic equipment (1)
2. Task: Creation of the pneumoperitoneum with CO2
Sub-task: Closed technique with insertion of Veres needle into the left hypochondrium; insufflation of the abdomen with CO_2
Error: Pneumoperitonium not created (2)
3. Task: Insertion of trochars
Sub-task: Insertion of 10 mm trochar into the epigastrium; insertion of right sub-costal trochar of 10 mm; insertion of left subcostal trochar of 10 mm; insertion of 10 mm subxyphoid trochar; insertion of left empty 5 mm trochar
Error: Trochars not inserted in the right order (1); trochars inserted at non-predetermined points (2); bleeding of abdominal wall on inserting trochars (2); lesion of abdominal viscera (25)
4. Task: Examination of the abdominal cavity and hiatus
Sub-task: Positioning of hepatic retractor; positioning of the optical in subxyphoid trochar; opening of the Hiss angle with a grasping pincer located on the left subcostal trochar; search for and dissection of aberrant hepatic vessels
Error: Lesion in hepatic parenchyma with controllable (2) deep (10) bleeding
5. Task: Release of hiatal adherences, exposure of right and left diaphragmatic pillars
Sub-task: Opening of phreno-oesophageal membrane; identification of the anterior vagus nerve; release of the right pillar until the V forming the left pillar is found; dissection of adherences in the Hiss angle and left pillar; passage of the oesophageal retractor from the right side in front of the left pillar and behind the cardiae; identification of the posterior vagus nerve; lateral, anterior and posterior release of the oesophagus by about 6 cm
Error: Minor bleeding during the dissection of the adherences (2); incorrect exposure of the hiatus (5); opening of the left or right pleura (10); section of the anterior or posterior vagus nerve (15); oesophageal perforation (50); tearing out of the oesophagus (100)
6. Task: Anaesthetic complications
Sub-task: Rectification of insufflations parameters; conversion to laparotomy
Error: Laparoscopic method continues despite the severe complication (15)
7. Task: Closing of diaphragmatic pillars
Sub-task: Positioning of 2-3 stitches covering both pillars; positioning of 56 Fr oesophageal calibration probe
Error: Error in positioning the stitches (1); loose or poorly knotted stitches (1); oesophageal perforation during calibration (50)
8. Task: Execution of the fundoplication
Sub-task: Passage of the fundus from left to right behind the oesophagus; stable position of the fundus tie loosely in front of the pillars; section of the short vessels if the fundus is pulled to the left; positioning of the three stitches forming the gastric scarf
Error: Passing through the gastric body to form the scarf (5); gastric bruising caused by the stitching (5); gastric perforation caused by a stitch (25); repositioning of a stitch (2); fundoplication not well positioned or in tension (10); bleeding of short vessel or splenic laceration (5)
9. Task: Washing of upper half of abdomen
Sub-task: Checking of the looseness of the fundoplication and the permanence of the pillar stitches; checking of haemostasis (short vessels)
Error: Positioning of the drainage (1)
10. Task: Completion of the laparoscopic method
Sub-task: Positioning of the optical in the epigastric trochar; removal of the lateral trochars; removal of the maximum quantity of intra-abdominal CO_2; removal of the subxyphoid trochar and epigastric trochar; closing of trochars with diameter >10 mm
Error: Failure to control potential bleeding of trochars (2)

The points that are added up in each error for obtaining the final score are shown in brackets.

In the first section, anastomoses, the 11 residents performed 159 gastrojejunal anastomoses and 155 jejunojejunal anastomoses. The average times for performing the first anastomosis were 135 [100-140] min and 65 [57.5-105] min respectively. The average number of anastomoses per student was 28.5 (6.51) (24-42).

Progress in learning the anastomotic technique is shown in Figure 1, where it is observed that the surgical time in performing each anastomosis is reduced as the learning time increases ($P<.0001$). In this Figure the curves for each of the 2 types of anastomosis are shown and it can be seen that they are practically parallel, meaning that they can be summarized in the curve that shows them globally, although in this graph it is seen that the time for performing a gastrojejunal anastomosis is 15 min more than for a jejunojeunal one. However, we can also see that the improvement in the times is increased until 45 h of training have elapsed, when it becomes stable at 70 h, and slowly falls again from then on.

The quality of the anastomosis was not appropriate in 18.4% (95% confidence interval [CI], 14.8-22.6) and was worse in the gastrojejunal anastomosis (22.8%; 95% CI, 17.5-29.2) than in the jejunojejunal one (13.8%; 95% CI, 9.6-19.4.)

If we measure this quality over the training period up to 45 h, up to 70 h and from 70 h on, we observe that in the first period, it was 17.1%; in the second, 13.7%; and in the third, 2%.

The factors that could have influenced the quality of the results were analysed using a logistic regression model; the result is the dependent variable and the learning time, with the independent variable controlled by sex, year of residency, type of anastomosis, and size of the anastomosis. It was shown that only 2 factors had an effect: the learning time and the type of anastomosis.

We also intended to ascertain the number of anastomoses that the resident had to perform to equal the times of the laparoscopist (this referring to a person who has performed at least 200 advanced procedures and 50 intestinal anastomoses) and we observed (Figure 2) that during the current period of consolidating the technique, the students still take 40 min more than the experts. On extrapolating these data with the number of anastomoses performed every week (5) and the reduction in the average time for each anastomosis (5 min), both curves would be similar in a total of 70 anastomoses.

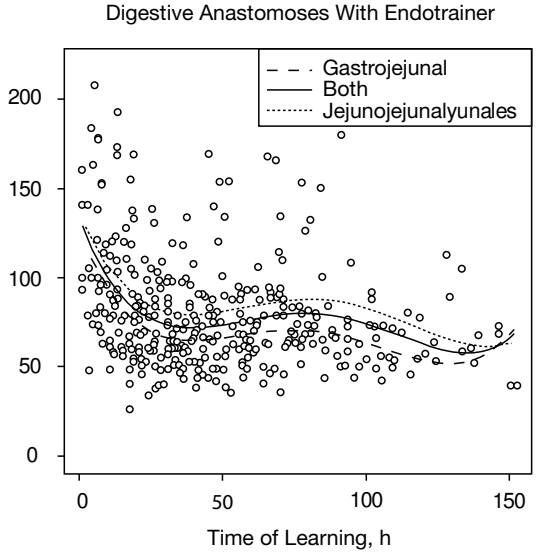

Figure 1 – Graph of the cloud of points formed by the operating time and start of learning the technique. The data are shown for 314 digestive anastomoses performed in the surgical laboratory using an endotrainer by 11 Resident Trainee Surgeons (MIR surgeons).

The second result we decided to measure in the programme was the number of surgical procedures carried out on the animals and their quality. There were 172 procedures (130 animals), which, broken down, corresponded to: 35 cholecystectomies, 39 gastroenteroanastomoses, 65 anti-oesophageal reflux, 16 subtotal – total gastrectomies, 6 left colectomies, and 8 right colectomies shown in Table 3 for each year of internship and in Table 4, for each student.

The quality of the cholecystectomies performed, measured based on the sum of the scores obtained in the tasks, subtasks, and errors (0-100) during execution, was correct, with an average of 2.4 points. In the anti-reflux techniques (Table 2) the quality was also correct and the sum gave an average of 5.6 points. In the rest of the surgical techniques, the monitor evaluated the quality in a subjective manner: correct execution, 65%; improvable, 22%; and manifestly improvable, 13%.

The third parameter of the programme measured by the students themselves in the form of satisfaction survey at the end of each year and at the end of the programme showed the following data at the end of the 2006–2007 course (very good evaluation, 5 and good, 4). Facilities, 86.6%; teachers, 85.1%; laparoscopy equipment, 90%; theoretical sessions, 47.8%; explaining of audiovisual techniques, 60.6%; and surgical sessions with animals, 93.6%. Eighty-three percent said they had not participated in a similar course and 97% said it responded to their expectations. All believed that training should be compulsory during their residency.

On completing the programme, these data were very positive for 72% and positive for 28%. Regarding the lecturers, the ratings were 45.5% and 36.4%. Regarding the facilities, the ratings were 63.4% and 36.6%.

Eighty-one point eight percent were of the opinion that most of the programme would be accompanied by the use of virtual simulators and 72.7% thought that human corpses would be used for teaching purposes.

When asked about the number of courses foreseen in the new surgery internship programme, they all said they were insufficient, with 72.7% saying they would study the first year of the resident-2 course and 54.5% saying they would study the advanced resident-4 course.

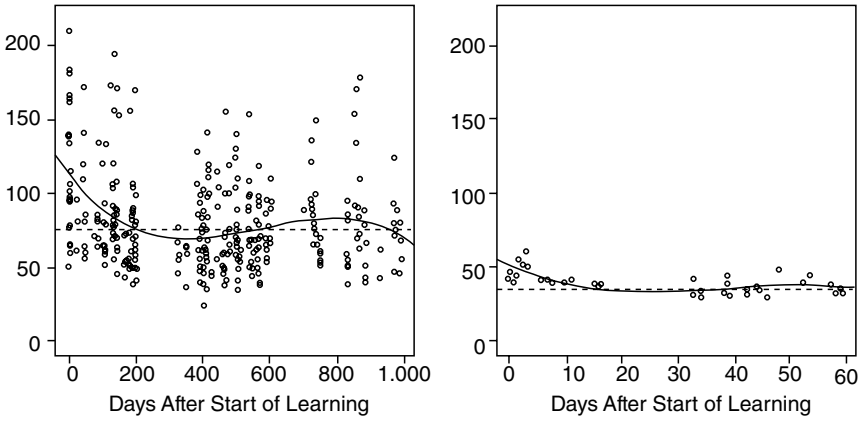

Figure 2 – Comparison of the learning curve of students (on the left) with that of lecturers (on the right). It can be seen that the stabilization of the students is at around 76 min, whereas that of the lecturers is at around 36 min.

Table 3 – Surgical Procedures and Average Times per Procedure Performed During Each Year of Internship on Experimental Animals

Residents 1 (6 residents)	
19 Cholecystectomies (in 3 cases, with cholangiography)	
Cholecystectomy	61.8 min
Cholecystectomy+intraoperative cholangiography	95 min
3 Nissen-type anti-reflux	143.3 min
Residents 2 (8 residents)	
16 Cholecystectomies (3 cases with cholangiography)	
Cholecystectomy	57.3 min
Cholecystectomy + intraoperative cholangiography	98.3 min
18 Nissen	123.3 min
2 Toupet	87.5 min
2 Gastroenteric anastomoses	155 min
1 Left colectomy	120 min
Residents 3 (9 residents)	
18 Nissen	105.5 min
4 Toupet	92.5 min
4 Dor	87.5 min
1 Collis-Nissen	130 min
1 Heller+Toupet	135 min
2 Heller+Dor	105 min
1 Heller+Thal	65 min
16 Gastroenteroanastomoses	73.1 min
1 Subtotal gastrectomy (without reconstruction)	105 min
2 Total gastrectomies (without reconstruction)	75 min
Residents 4 (7 residents)	
8 Nissen	73.12 min
1 Dor	60 min
1 Toupet	60 min
5 Gastroenteroanastomoses	114 min
3 Subtotal gastrectomies with BII reconstruction	192 min
2 Total gastrectomies with Roux Y reconstruction	95 min
1 Total gastrectomy with distal oesophagectomy and Roux Y reconstruction	180 min
1 Ileohepatic+cholecystectomy dissection	90 min
4 Left colectomy	162.5 min
3 Right colectomy	163.3 min
Residents 5 (5 residents)	
1 Nissen	60 min
1 Left colectomy	150 min
5 Right colectomy	162 min
16 gastroenteroanastomoses	73.12 min
5 Total gastrectomy with Roux Y	173.75 min
2 Total gastrectomies+distal oesophagectomy +Roux Y	155 min
1 Gastric bypass	110 min

A total of 130 animals were used.

The skills provided by the programme were, for 100%, greater dexterity and self-confidence in executing the technique. Ninety-one percent thought it also added to their knowledge on the technique.

The average number of basic laparoscopies performed on patients during the residency was 120.4 (22-320) cases/resident and in advanced laparoscopic procedures 16.5 (60-2) cases/resident. Of the 5 students terminating their residency, 4 said the programme had facilitated their incorporation as staff in another hospital.

Discussion

The surgeon variable in the quality of the surgical procedure has great specific weight.[1] They must be trained and their skills acquired must be so high that this variable can reduce the weight.

These skills have been evaluated using subjective techniques in the presence of expert surgeons and in others, fewer in number and not as widely developed today, through objective techniques.[4]

With the arrival of minimally invasive surgery, surgeons who are experts in advanced techniques are few in number, and operating theatres are used to develop the learning curve. However, this must not be the case, based on the high cost and iatrogenic damage they may cause to patients. For this reason, there are experimental laboratories or centres for training and learning.

The current training strategy is based on 3 educational models: procedure drills,[2] that are correlated with achieving task related to clinical practice, surgical simulators, and new communication technologies, multimedia techniques, and remote-surgery techniques.

But, how is this training being implemented at present? Feliu et al,[5] in Spain, and Chiasson et al,[6] in Canada, include in their surveys responses that indicate there are no guidelines defined in the training, that it is not regulated, that it lacks criteria that are previously established by universities or professional associations, and today, the greatest tutelage is through surgeons with wide experience.

Some countries such as Sweden and the Netherlands start up national training courses based on virtual surgical simulators and it is obligatory to be accredited in them before performing a laparoscopic cholecystectomy,[7,8] but in other European countries and the US, the programmes are specific for each centre and not carried out in all of them.[9-11] In Latin America, the FELAC, Federación Latinoamericana de Cirugía Endoscópica (Latin American Federation of Endoscopic Surgery) has started up a programme based on training in laparoscopic surgery which it sponsors, and which is given by experts from different countries for the training of residents through specific courses.

Among all these programmes that are structured by year of internship, there are—as we have mentioned—some that base all their laparoscopic teaching on simulation. Others perform all the surgical practices in an endotrainer and without animals.[11] Some, like Valentine, increase the number of skills to be acquired including the handling of ultrasound, endoscopy and the advanced trauma life support (ATLS) and execute all the procedures in booths or virtual environments. Yale University[12] developed an entire programme based on executing using simulation and a powerful multimedia programme with monitoring through the network. Others even go further and apart from all the above, develop skills with animals and human corpses.[13]

In our hospital we transfer initial learning of minimally invasive techniques in the operating theatre to the experimental centre lab, where, through a structured programme, 11 residents have developed skills in basic

Table 4 – Techniques Performed by Each Resident on Experimental Animal (Pig)

Year Initials	R5 FCS	R5 SRD	R5 MLD	R5 MSC	R5 MGN	R5 JRG	R5 SNG	R4 APN	R4 MPC	R3 AAO	R3 LSM
Cholecystectomy	2	3	3	4	–	–	–	6	8	6	5
Gastrojejunal anastomoses	2	1	4	5	7	7	7	2	2	1	1
Anti-reflux	7	6	8	10	5	5	5	9	4	3	3
Subtotal gastrectomy	–	–	–	–	1	1	1	–	1	–	–
Total gastrectomy	3	–	–	3	1	1	2	2	–	–	–
Left colectomy	1	1	1	–	1	1	1	–	–	–	–
Right colectomy	1	2	1	1	1	1	1	–	–	–	–
Gastric bypass	–	–	–	1	–	–	–	–	–	–	–

laparoscopic procedures, in performing 314 intestinal anastomoses in an endotrainer and 172 surgical procedures on experimental animals, adding these to other microsurgical and endoscopic techniques. It is a mixed programme that uses booths with the ex vivo viscera of animals and sometimes, virtual simulators, but currently without structuring.

We think the time has come for the evaluation of these skills to be converted into part of the evaluation of professional competence and in addition, we should learn to measure these skills and their implementation in clinical practice. For this reason, teachers such as Darzi, Hwang, and Buess[14-16] have developed objective methods for measuring both in the laboratory and in the operating theatre. We have objectively studied the times and qualities of the intestinal anastomoses and technical execution with final scores in cholecystectomy and anti-reflux surgery. We have observed that residents must undergo at least 70 h of training to dominate the execution of an intestinal anastomosis, which is close to the figures for laparoscopists in performing 70 anastomoses, and that clinical implementation is shown through executing a high number of laparoscopic procedures during their residency.

For many authors (Valentine et al,[17] Yule et al,[18] and Undre et al[19]), the future curriculum of surgical residents must—in addition to solid theoretical knowledge—include dedicated and efficient care of patients, fluid interpersonal communications, and professional competence; we must give them an opportunity to face difficult situations in a simulated environment, by offering specific courses, including our programme, from 2008 onwards.

But this project that we have developed is not sufficient if we want to extend training outside our community scope; we need institutional backing in committees and associations in the specialty and a sufficient number of centres to train[20] and at least comply with the requirements established in the new specialty training programme (Spanish Official Journal BOE8/05/07).

In conclusion, we can affirm that our programme for surgical residents is structured and permits the development of basic and advanced laparoscopic skills with high level of qualification.

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