PARADIGM SHIFT IN THE DIAGNOSIS AND THERAPY OF ACUTE APPENDICITIS

Mán Eszter M.D.

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UNIVERSITY OF SZEGED FACULTY OF MEDICINE

DEPARTMENT OF SURGERY

SUPERVISOR

Prof. Lázár György M.D., Ph.D., DSC

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II. Németh T, Géczi T, Markóth C, Mán E, Lázár G

Laparoscopos és nyitott appendectomia.

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A laparoscopos appendectomia gyors bevezetésének kockázata – előnyök, hátrányok a hagyományos technikával szemben, MAGYAR SEBÉSZET 65:(4) p. 259. 1 p. (2012)

V. Mán E, Lázár G

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VI. Mán E

Learning curve after rapid introduction of laparoscopic appendectomy: Are there any risks of surgical resident participation? MAGYAR SEBÉSZET 67:(4) p. 278. (2014), 14th World Congress of the European Association of Endoscopic Surgery. Paris: 2014.06.25 -2014.06.28.

VII. Mán E, Németh T, Géczi T, Simonka Z, Lázár G

Learning curve a laparoscopos appendectomia gyors bevezetése után: vannak-e a rizikófaktorai a rezidensek által végzett beavatkozásoknak? In: MAGYAR SEBÉSZ TÁRSASÁG SEBÉSZETI ENDOSZKÓPOS SZEKCIÓ XVI. KONGRESSZUSA SEBÉSZETI TOVÁBBKÉPZŐ TANFOLYAM: Eger, Hungary, 2015.11.12-2015.11.14. Eger: p. 29.

CONTENTS

Abbreviations

AA - Acute Appendicitis

APPAC - Antibiotic Therapy vs. Appendectomy for Treatment of Uncomplicated Acute Appendicitis

ASA - Adult Appendicitis Score

AIR - the Appendicitis Inflammatory Response Score

CT - Computed Tomography

IAA - Intra-Abdominal Abscess

LA - Laparoscopic Appendectomy

NAR - Negative Appendectomy Rate

OA - Open Appendectomy

PAS - Paediatric Appendicitis Score

RIPASA - Raja Isteri Pengiran Anak Saleha Appendicitis Score

RLQ Pain - Right Lower Quadrant Pain

US - Ultrasound

1. Introduction

Acute appendicitis is the most common urgent surgical condition. The first accurate description of appendicitis was made by Fitz in 1886, and the first appendectomy was performed by Claudius Amyand in England in 1735. Since then, appendectomy has become the preferred treatment of acute appendicitis. In New York in 1889, Charles McBurney described the pathogenesis of appendicitis and determined that the best treatment of the condition is appendectomy ***(1).*** Almost 200 years later, in 1980, Kurt Semm performed the first laparoscopic appendectomy, which became the new gold standard in the treatment of acute appendicitis.

Although appendicitis is a very common disease, it still has a poorly understood etiology, with a heterogeneous clinical pattern of presentation, varying from simple uncomplicated appendicitis to generalized peritonitis due to perforation. Nowadays it is the most common emergency surgical condition, with 7% of the population being affected ***(2).*** About 327,000 appendectomies were performed in the U.S. in 2011, according to a survey. This represents a rate of 10.5 procedures per 10,000 population and 2.5% of all operating-room procedures, which constitutes a huge financial burden ***(3).*** This is why cost-effectiveness has become very important nowadays in health care as well. In cases of acute appendicitis, correct diagnosis with new imaging technologies and scoring systems can reduce the negative appendectomy rate, lower the number of inadequate surgical procedures, and cut down needless health care costs. Furthermore, with the spread of minimal invasive procedures, hospital stay can be reduced, while earlier return to work represents an extra saving for the health care system.

1.1. Acute appendicitis: Pathogenesis, etiology and epidemiology

According to the leading theory, the initial event in the pathogenesis of acute appendicitis is obstruction of the lumen caused by fecaliths, foreign bodies, intestinal parasites, tumors, or lymphoid follicular enlargement due to viral infections. Due to high intraluminal pressure, the blood supply to the appendix mucosa is compromised, and bowel organisms invade the appendix wall, leading to inflammation. Risk factors for acute appendicitis are age, sex, and ethnic group/race. The most common symptom of appendicitis is abdominal pain, usually starting as periumbilical or epigastric pain migrating to the right lower quadrant (RLQ) of the abdomen, this sign is the most typical feature of the patient’s history, with a sensitivity and specificity of approximately 80% ***(4).*** Vomiting, nausea, anorexia, diarrhea or constipation, and fever can also occur. A differential diagnosis is extremely difficult, especially in the elderly, in children and in fertile-age women, where the disease can mimic numerous gynecological and urogenital conditions. A clinical classification is used to stratify management based on simple (non-perforated) and complex (gangrenous or perforated) inflammation. The current incidence of appendicitis is about 100 per 100,000 person-years in Europe/America ***(5).*** Whereas the appendectomy rate is still decreasing, the incidence of appendicitis is nearly stable. The variation of incidence is due to ethnicity, sex, age, obesity, and season of the year. In Hungary, the approximate rate of appendectomy is 100/1,000,000 inhabitants a year, of which rate of laparoscopic appendectomy is 30/1,000,000 inhabitants ***(6).*** The lethality of the condition is about 0.7%, which means that it causes the death of almost 100 patients in Hungary each year ***(7).***

1.2. Diagnosing acute appendicitis

It is challenging to diagnose acute appendicitis. It is based on a medical history, a physical examination and a laboratory analysis, but imaging techniques (ultrasound and CT scan) may also be helpful. Nevertheless, a differential diagnosis of AA is difficult. In addition, patients with right lower abdominal complaints, suspected to have appendicitis, are first assessed primarily by non-surgical residents or specialists in the growing number of emergency care centers (A&E Units). Although several studies have found that there is no significant difference in the accuracy of diagnosis by surgical and non-surgical residents, it would be necessary to help these young colleagues know when to ask for a consultation from a specialist surgeon for patients with suspected appendicitis. Laboratory tests are performed routinely in most patients. Besides the white blood cell count, a systematic review showed that C-reactive protein level provides the highest diagnostic accuracy ***(8).*** Non-invasive, inexpensive, and easy to perform, the ultrasound scan also avoids radiation, but its results are examiner- and patient-dependent. Its sensitivity rate is between 71 and 94% with a specificity rate of 81 and 94%. The number of negative appendectomies can be decreased by 10% with US ***(9).*** A CT scan provides an even more accurate picture of the lesion and reduces the number of negative appendectomies, but it is expensive and involves exposure to radiation. Its specificity rates are between 76 and 100%, and its sensitivity is between 81 and 98% ***(10).*** In past years, numerous clinical scoring systems have been created to make diagnosing the condition easier. The best known is the Alvarado score (MANTRELS score), which was created in 1986 by Alvarado, who processed data on appendectomy patients retrospectively. It includes eight diagnostic criteria (historical data, physical examination, and laboratory values). The therapy algorithm depends on the Alvarado score of the patient (1 to 4 points: discharge; 5 to 6 points: observation and repeated scoring in 12 hours; 7 to 10 points: urgent surgery) ***(11) (Table 1).*** The Paediatric Appendicitis Score (PAS), the Appendicitis Inflammatory Response Score (AIR), the Raja Isteri Pengiran Anak Saleha Appendicitis Score (RIPASA), and the Adult Appendicitis Score (ASA) are also well-known scoring systems. Since then, the reliability of scoring systems has been assessed by many studies, including numerous prospective ones; however, the number of randomized studies is low. These scores can be used as a diagnostic aid and can aid young surgeons and emergency physicians, but they are inferior when compared to the diagnostic accuracy of experienced specialist surgeons ***(12).***

Symptoms	**Score**
Migratory right iliac fossa pain	**1**
Anorexia	**1**
Nausea / Vomiting	**1**
Signs	
Tenderness in right iliac fossa	**2**
Rebound tenderness	**1**
Elevated temperature	**1**
Laboratory findings	
Leukocytosis	**2**
Shift of neutrophils to the left	**1**
Total score	**10**

Table 1. Alvarado score

1.3. Therapy of acute appendicitis

The treatment of acute appendicitis has undergone a paradigm shift in the last decade. There was a change in the gold standard for operative treatment. Nowadays laparoscopic appendectomy is the first choice in surgical therapy instead of the conventional open appendectomy. In the past decade, non-operative treatment of early appendicitis has become an alternative to surgery.

1.3.1. Non-surgical treatment

Clinically, AA has two main presentations: uncomplicated and complicated appendicitis. Anderson showed that not all patients with uncomplicated appendicitis will progress to perforation; spontaneous progression and resolution may occur ***(13).*** An APPAC (Antibiotic Therapy vs. Appendectomy for Treatment of Uncomplicated Acute Appendicitis) randomized trial has shown that most patients with non-complicated AA randomized to antibiotic treatment not requiring appendectomy during the 1-year follow-up period, and those who required appendectomy did not experience significant complications ***(14).*** A meta-analysis by Varadhan et al., including four randomized controlled trials, reported that antibiotic treatment of patients with early appendicitis had a 63% success rate in a 1-year period and a lower complication rate compared with the appendectomy group ***(15).*** According to these studies, antibiotic therapy (initial intravenous then conversion to oral antibiotics) may be an optional treatment for non-complicated appendicitis, but only in a tight and strictly selected patient group (who wish to avoid surgery or belong to a high-risk surgical group due to serious comorbidities) and only under careful observation in surgical departments with the opportunity for immediate surgical intervention if necessary.

1.3.2. Surgical treatment

Although a new trend has been observed in the non-operative treatment of early appendicitis, appendectomy is still considered the standard treatment of uncomplicated AA. Two main approaches exist to remove the inflamed appendix: the open approach (OA) and the laparoscopic approach (LA). Since Kurt Semm performed the first laparoscopic appendectomy in 1980, it has become the gold standard for the surgical treatment of AA instead of conventional open surgery. In recent years, the minimally invasive technique has been used in emergency surgery in ever increasing numbers ***(16).*** The most common urgent surgical condition to be treated with a laparoscopic method nowadays is acute appendicitis ***(17).*** LA has been proved to have numerous advantages over open surgery (more rapid recovery, less postoperative pain, a decrease in the need for medications and in complications from wound infections, reduced incidence of post-operative bowel obstruction, better cosmetic results, shorter hospital stay, and earlier return to work) ***(18).*** In addition, the procedure is reliable and safe for the treatment of this condition. On the other hand, disadvantages are: a possible higher incidence of intraabdominal abscess, longer operation time, and increased operation cost due to special devices needed for laparoscopy ***(19).***

In many Western countries, appendectomies outside the day-shift hours are performed by surgical residents under the supervision of a consultant ***(20).*** This is therefore the first type of laparoscopic surgery residents learn; they thus learn the basics of the minimally invasive surgical technique and may develop the basic skills they can use in later, more complex surgeries ***(21).***

2. Objectives

Acute appendicitis is the most common emergency surgical condition, with 7% of the population being affected and its lethality still around 0.7%. With the development of imaging technologies and surgical procedures and with the spread of minimal invasive surgery, there have been many changes in the diagnosis and treatment of AA; however, there is a lack of unequivocal international guidelines. In addition, a great emphasis is placed on financial outcomes nowadays in health care as well, and a great effort is being made to achieve optimal efficiency in surgical procedures with the aim of doing the best for the patients at a minimal cost. By reducing the number of negative appendectomies by refining diagnosis and using cost-effective minimal invasive techniques, these aims seem to be achieved. Furthermore, these days residency training has become an important topic in surgery as well. Surgical training is becoming more regulated and organized by recommendations made by surgical societies all around the world. In our clinical study, we intended to investigate the most important and up-to-date questions of this widely-debated condition: the use of scoring systems in diagnosing acute appendicitis, the question of open vs. laparoscopic appendectomies, and the learning curve of the surgical procedure in residency training.

I. One objective of our work was to investigate the impact of the Alvarado score on the diagnosis of acute appendicitis through a comparison of clinical judgment, Alvarado score, and a new modified score in suspected appendicitis (Study 1).

II. A further objective was to study the efficacy of surgical treatment through a comparison of open and laparoscopic appendectomies (Study 2).

III. Furthermore, we investigated the learning curve period after the rapid introduction of laparoscopic appendectomy, considering the risks of surgical residents' participation in the procedure (Study 3).

3. Patients and methods

3.1. The impact of the Alvarado score on the diagnosis of acute appendicitis as determined through a comparison of clinical judgment, Alvarado score, and a new modified score for suspected appendicitis (Study 1)

233 patients presenting with right lower abdominal complaints between September 1, 2011, and September 31, 2012, at the outpatient clinic of the Department of Surgery of the University of Szeged were enrolled in our prospective, randomized study. After signing a consent form, the patients were divided into two groups. In Group A, the treatment decision was based on the Alvarado score (1 to 4 points: discharge; 5 to 6 points: observation and repeated scoring in 12 hours; 7 to 10 points: urgent surgery) ***(Table 1)***. Further treatment of patients in Group B was based on the decision made by the head surgeon on duty. The head surgeon on duty did not know the Alvarado score of the patient and was not allowed to know the result of the ultrasound scan (if performed). In Week A, the head surgeon on duty had the opportunity to override the score. These patients were excluded from our study. The groups were alternated on a weekly basis. Following a surgery, the accuracy of the methods was assessed by evaluating the final histological results. After this, we assessed the value of the ultrasound scan performed routinely in the diagnosis of appendicitis at our clinic (specificity, sensitivity, and predictive value). With a statistical method, logistic regression, we first attempted to refine the score by weighting certain data, and then, after analyzing our own experience and the efficiency of the ultrasound scan, we amended the score with new aspects and discarded older ones. The new score was tested retrospectively on 131 patients outside the study. The data were analyzed with SPSS 20, with a significance level of $p<0.005$.

(The study was approved by the Ethics Committee of the University of Szeged and was registered under Current Controlled Trials under number ISRCTN56471.)

3.2. Efficient surgical treatment of acute appendicitis, open vs. laparoscopic appendectomy (Study 2)

3.2.1. Clinical data on open vs. laparoscopic appendectomy groups

The data on patients operated on at our institution using the traditional technique (Group I, n=298) and the laparoscopic procedure (Group II, n=430) over a seven-year period (between January 1, 2003, and December 31, 2009) were compared retrospectively. The diagnosis was made based on their medical history, a physical examination, their laboratory test results (white blood cell count), and an ultrasound scan. The ultrasound scan was performed at the radiology unit of our institution in every case. The scans were performed by 7 different radiologists using a GE Logiq7 ultrasound scanner. The specificity and sensitivity of the diagnostic method were assessed by comparing the final histological result with the ultrasound findings. The patients in both groups were given a "one-shot" antibiotic prophylaxis (1.5 g cefuroxime and 500 mg metronidazole) at the beginning of the procedure. Depending on the surgical picture (ulcero-phlegmonous appendicitis, abscess, or perforation), the antibiotic was continued in a therapeutic manner, or the therapy was adjusted based on the antibiogram. The two surgical techniques were compared based on the following clinical data: patient gender and age, surgical picture (including any other intraoperative diagnoses), duration of the procedure, blood loss during the procedure, presence of fever, time to first bowel movement, duration of the antibiotic treatment in days, length of hospital stay, and complications (minor complications and major complications that require reoperation, such as bleeding, postoperative ileus, abscess formation, appendix stump insufficiency, and thermal injury), histological results, and long-term complications (development of postoperative hernia or suture granuloma). Four groups were formed based on the laparoscopic and surgical experience of the surgeons who performed the procedures: residents (Group 1), candidate consultants (Group 2), young consultants (Group 3), and head surgeons on duty/consultants with at least 10 years of practice (Group 4). The surgeons in Groups 1 and 2 always performed the surgeries under the supervision of a consultant surgeon. During the surgeries, a condition other than acute appendicitis was found in 45 cases; these patients were excluded from the study. In both groups, the most frequent conditions were of gynecological origin, and the inflammation of Meckel's diverticle and small intestine intussusception were also common. The statistical analysis was performed using SigmaStat 3.1 and the Kruskal–Wallis test. The significance level was $p<0.05$.

3.2.2.1. Surgical technique for open appendectomy

Open appendectomy is usually performed from a transverse incision in the right lower quadrant, through the so-called McBurney incision. Vertical incisions (median laparotomy or pararectal incision) are rarely performed (e.g., in the case of peritonitis or if the diagnosis is not sufficiently certain for an exploration of the abdominal cavity). The abdominal muscles are dissected in the direction of their fibers to reach the peritoneum and to open the abdominal cavity. First, we identify the cecum and medially retract. After reaching the appendix, the mesoappendix is held between clamps, divided, and ligated. Then the appendix is clamped proximally, cut down, and then ligated. The appendix may be inverted into the cecum with a Z-stitch. The cecum is placed back into the abdomen, and the abdomen is irrigated. It is not necessary to place a tube; it depends on the severity of the inflammation.

3.2.2.2. Surgical technique for laparoscopic appendectomy

A Veress needle is placed into the abdominal cavity through an umbilical incision to perform a pneumoperitoneum with up to 10–14 mm Hg insufflation with carbon dioxide. After inserting the laparoscope to view the abdomen cavity, a 10 mm trocar is inserted in the left lower quadrant and another 5 mm trocar is inserted above the pubic symphysis. The appendix is grasped and retracted upward to divide and ligate the mesoappendix. The appendix can be transected with a linear endostapler, haemoclip, or endoloop, or, alternately, the base of the appendix may be suture-ligated. In our practice, an EndoGia stapler was required in four cases because of the thickness of the stump, whereas an endoloop was needed to secure the stump in two cases. The appendix is removed from the abdominal cavity through the 10 mm trocar. In the case of severe inflammation, it is packed into a laparoscopic pouch to prevent wound contamination. Peritoneal irrigation is performed to avoid formation of an intraabdominal abscess.

3.3. Learning curve after rapid introduction of laparoscopic appendectomy, considering the risks of surgical resident participation in the procedure (Study 3)

Laparoscopic appendectomy was introduced at our clinic in 2006 over a mere six months. In our retrospective study, we evaluated the results of surgeries performed by 5 residents (Group A – young resident colleagues with 2 to 3 years of surgical experience at the beginning of the study) and 5 consultants (Group B – consultant group, colleagues with 8 to 9 years of surgical experience) in the learning curve period (20 surgeries as recommended by the EAES) and in the period after that (up to December 31, 2009) during routine use. Therefore, subgroups were formed within Groups A and B: A1 – residents in the learning curve period, A2 – residents in the period of routine use, B1 – consultants in the learning curve period and B2 – consultants in the period of routine use. During emergency surgical care, the head surgeon on duty (with minimum surgical experience of 10 years) was responsible for care at the clinic, and it was that person who decided on the indication for surgery and, randomly, on the surgeon who would perform the operation. In all cases, the assistant surgeon scrubbed in, actually participated in the surgical intervention, supervised the procedure, and, naturally, advised the operating surgeon, if needed, but did not "take over" the procedure. Each resident had completed a two-week "Basic laparoscopic skills course" (training box with live animals) and had already assisted in other laparoscopic procedures (cholecystectomy, laparoscopic hernia repair, laparoscopic hiatal hernia repair, etc.). Each consultant was a more experienced laparoscopic surgeon who regularly performed other surgical procedures independently (cholecystectomy, hernia repair, etc.). Before the introduction of laparoscopic appendectomy, each surgeon was provided with theoretical training to learn the details of the technique. In both groups, the assistant was an older consultant on duty, who had the most experience in both conventional and laparoscopic procedures. Results were evaluated for a total of 600 patients (Group A, n=319 – A1: n=100, A2: n=219; Group B, n=281 – B1: n=100, B2: n=181). Patient selection and data collection occurred retrospectively through an analysis of our computer database (Medsolution System) and the documentation for the patients. All patients over the age of 18 who underwent laparoscopic appendectomy in the study period were included, and none of the patients were excluded from our study. The groups were compared based on general patient demographics (age, gender, comorbidities, and ASA score), duration of surgery, operation time depending on the severity of inflammation, intraoperative blood loss, conversion rate, hospital stay in days, negative appendectomy rate, and number of complications (early or late). SPSS 20 was used for the statistical analysis—the durations of surgery were compared with a two-sample t-test, the complications were compared with Fisher's exact test, and the effect of inflammation on the duration of surgery was determined by analysis of variance. A significance level of $p<0.05$ was used.

4. Results

4.1. The impact of the Alvarado score on the diagnosis of acute appendicitis as determined through a comparison of clinical judgment, Alvarado score, and a new modified score for suspected appendicitis (Study 1)

4.1.1. Patient characteristics

Over a period of one year, 233 patients were enrolled in our study (Group A, n=95; Group B, n=138). Their mean age was 34.6 years (17–87) (Group A: 33.3; Group B: 35.52; p=0.069). Gender distribution: women: Group A, n=67; Group B, n=88; men: Group A, n=28; Group B, n=50; p=0.326. The mean BMI was 24.6 (Group A: 23.7; Group B: 25.8; p=0.240), and the mean ASA score was 1.6 (1.7 in Group A and 1.5 in Group B). Thus, the demographics of the two groups can be considered homogeneous ***(Table 2)***.

Age	**Group A n=95**	**Group B n=138**	**P**
	33.3 (17–87)	35.52 (18–82)	0.69
Gender			
Female n	67	88	
%	70.5%	63.7%	0.32
Male n	28	50	
%	29.5%	36.3%	0.26
BMI	23.7	25.8	0.24
Mean ASA score	1.7	1.5	0.58

Table 2. Patient characteristics (p<0.05)

4.1.2. Specificity and sensitivity of Alvarado score vs. clinical judgment based on post-operative pathological findings

After surgery, the histological results were evaluated in both Groups A and B. Based on the cross-tabulation of the post-surgery histological results, the specificity of the Alvarado score and that of the conventional clinical judgment were calculated: Group A: 88.9%; Group B:

94.8% (p=0.320). (Sensitivity was not applicable because there were no patients who had been operated on but had no histological result.) In Group A, 8 (8.42%) negative appendectomies were performed, whereas this number was 5 (3.62%) in Group B (p=0.160) ***(Tables 3 and 4).***

surgery * pathology2 Crosstabulation

			Path2		Total
			.00	1.00	
surg	**0**	**Count**	64	0	64
		% within surg	100.0%	.0%	100.0%
		% within path2	**88.9%**	.0%	67.4%
	1	**Count**	8	23	31
		% within surg	25.8%	74.2%	100.0%
		% within path2	11.1%	100.0%	32.6%
Total		**Count**	72	23	95
		% within surg	75.8%	24.2%	100.0%
		% within path2	100.0%	100.0%	100.0%

Table 3. Surgery–pathology cross-tabulation in Group A (sensitivity: 88.9%)

surgery * pathology2 Crosstabulation

			Path2		Total
			.00	1.00	
surg	**0**	**Count**	92	0	92
		% within surg	100.0%	.0%	100.0%
		% within path2	**94.8%**	.0%	66.7%
	1	**Count**	5	41	46
		% within surg	10.9%	89.1%	100.0%
		% within path2	5.2%	100.0%	33.3%
Total		**Count**	97	41	138
		% within surg	70.3%	29.7%	100.0%
		% within path2	100.0%	100.0%	100.0%

Table 4. Surgery–pathology cross-tabulation in Group B (sensitivity: 94.8%)

Spearman's rank correlation was used to assess how true it was that a higher score is accompanied by more severe inflammation. Having assessed this in both groups, we can say that the correlation point is on the border, i.e., the correlation is not too close in this regard ***(Table 5).***

Correlations

			Pathology	Score
Spearman's rho	Pathology	Correlation Coefficient	1.000	.523**
		Sig. (2-tailed)	.	.000
		N	233	232
	score	Correlation Coefficient	.523**	1.000
		Sig. (2-tailed)	.000	.
		N	232	232

** Correlation is significant at the 0.01 level (2-tailed).

Table 5. Score–pathology rank correlation in both Groups A and B

Based on the ROC analysis, the clinical judgment shows a better discriminating capacity than the Alvarado scoring system: 0.933 vs. 0.749, p=0.120 (Table 6).

AUC	Std. Error	Asympt. Sig.
,749	,044	,000

AUC	Std. Error	Asympt. Sig.
,933	,027	,000

Table 6. ROC analysis of Group A and B

By estimating Youden's index, it can be established that the cut-off values produced by the scoring system as 5 to 6 are correct; for a score below 4, appendicitis is unlikely in the patient, whereas if the score is above 7, the inflammation is highly probable. Therefore, in the so-called "grey zone," between scores 5 and 6, it is necessary to observe the patients and, possibly, use another imaging procedure (urgent CT scan) ***(Figure 1).***

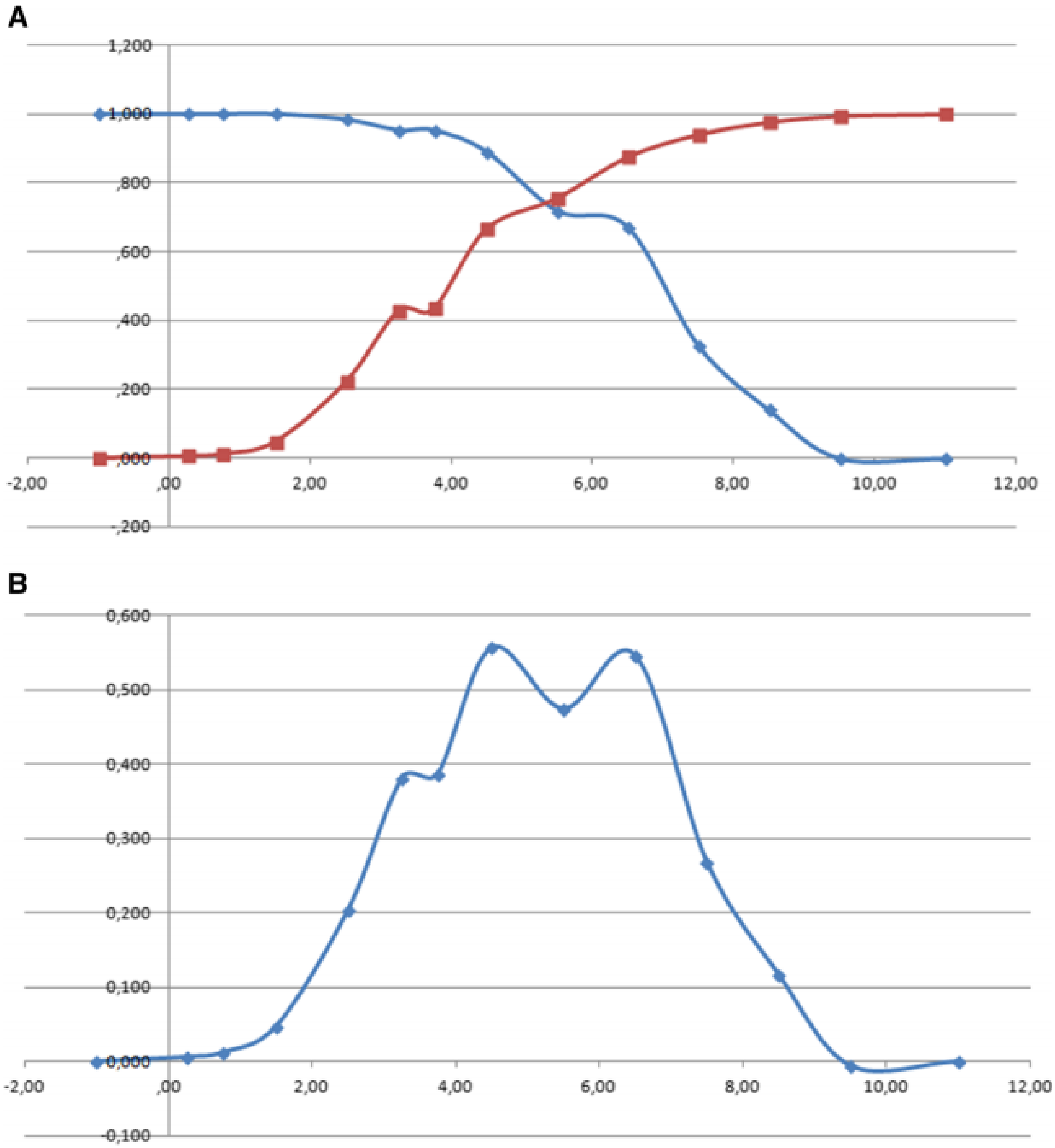

Figure 1. Specificity, sensitivity and Youden's index of Alvarado score

4.1.3 Creation of a new modified Alvarado score with linear regression

We attempted to create a new score using linear regression by weighting certain parameters. Parameters that had not been part of the score before but are important based on our clinical experience were included in the criteria system (rectal-axillary temperature difference, indirect signs). The AUC (area under curve) by ROC analysis increased (0.849); therefore, the original scoring system was successfully refined ***(Table 7).***

Symptoms	Modified score
RLQ pain	0.149
Nausea/vomiting	0.503
Anorexia	-4.927
Tenderness in right iliac fossa	1.788
Indirect sign positivity (1–2)	1.393
Indirect sign positivity (2 or more)	1.298
Elevated temperature	0.57
Rectal-axillar temp. difference >1°C	0.17
Leukocytosis >10G/l	-18.423
Leukocytosis >15G/l	1.888

AUC	Std. Error	Asympt. Sig.
,830	,027	,000

Table 7. New score calculated by logistic regression , ROC analysis

To further refine the score, certain predictors that had proved to be less significant were removed from the scoring system, and the result of the ultrasound scan was included instead. This resulted in a further increase in the AUC, and the score was successfully refined even further ***(Figure 2).*** The new modified scoring system is shown in ***Table 8.***

Symptoms	Modified score
Nausea/vomiting	0.645
RLQ tenderness	1.636
Indirect sign positivity (1–2)	1.059
Indirect sign positivity (2 or more)	0.985
Leukocytosis >10G/l	-17.841
Leukocytosis >15G/l	1.455
US examination	2.239

AUC	Std. Error	Asympt. Sig.
,899	,020	,000

Table 8. New modified score containing US examination and ROC analysis

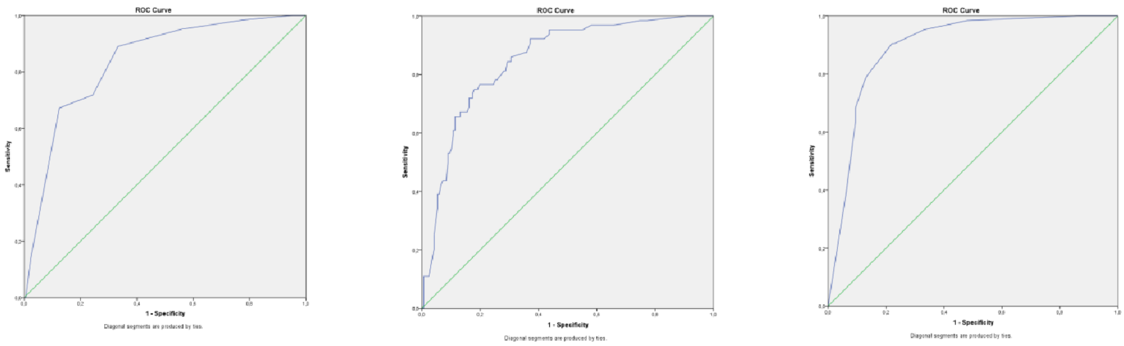

Figure 2. The changing ROC curves after modifying the Alvarado score (1. original score, 2. score arrived at by logistic regression, 3. modified score containing ultrasound investigation)

4.2. Efficient surgical treatment of acute appendicitis, open vs. laparoscopic appendectomy (Study 2)

4.2.1. Patient characteristics

The data on patients operated on at our institution using the traditional technique (Group I, n=298) and the laparoscopic procedure (Group II, n=430) over a seven-year period (between January 1, 2003, and December 31, 2009) were compared retrospectively. 46.1% of the patients were female (n=140) and 53.9% were male (n=158) in the open group, whereas the laparoscopic group consisted of 190 female (44.1%) and 232 male (55.9%) patients. The mean age was 41.1 (18–72) years in Group I and 32.9 (19–68) years in Group II. The mean BMI was 24.98 (20.02–33.1) in Group I and 23.87 (19.97–31.72) in Group II. The comorbidities and the distribution of the patients based on their ASA score were assessed in the groups ***(Table 9).***

Age	**OA n=298**	**LA n=430**	**P**
	38.9 (18–79)	32.9 (18–82)	0.64
Gender			
Female n	140	190	
%	46.90%	44.10%	0.77
Male n	158	232	
%	53.10%	55.90%	0.63
BMI	24.9 (20.2–33.1)	23.8 (19.9–31.72)	0.48
Comorbidity			
COPD	9 (3%)	12 (2.7%)	0.47
DM	15 (5%)	19 (4.4%)	0.67
Hypertension	32 (10.7%)	45 (10.46%)	0.24
IHD	6 (2%)	9 (2.09%)	0.14
ASA score			
I	203 (68%)	356 (83%)	0.43
II	87(29%)	69 (16%)	0.34
III	8 (3%)	5 (1%)	0.12

Table 9. Patient characteristics (p<0.05)

4.2.2. Surgical procedures: open vs. laparoscopic appendectomy – rapid introduction of laparoscopic appendectomy (number of procedures and operation time)

A total of 728 appendectomies were performed over the 7-year period ***(Table 10)***. Whereas the number of laparoscopic appendectomies was minimal compared to that of open surgeries in 2003 and 2004, the number of minimally invasive surgeries reached that of the traditional ones in 2005 thanks to the quick introduction of the laparoscopic technique, and, from 2006, the number of open appendectomies decreased to a minimum ***(Figure 3).***

	2003	2004	2005	2006	2007	2008	2009	Total
Lap. append.+drainage	9	7	7	6	8	6	5	48
Lap. appendectomy	7	6	42	83	74	86	84	382
Open appendectomy	93	96	52	12	15	9	8	285
Conversion	0	1	2	1	3	4	3	13
Conversion rate		7.6%	4.1%	1.1%	3.6%	4.3%	3.3%	3%

Table 10. Number of appendectomies between 2003 and 2009

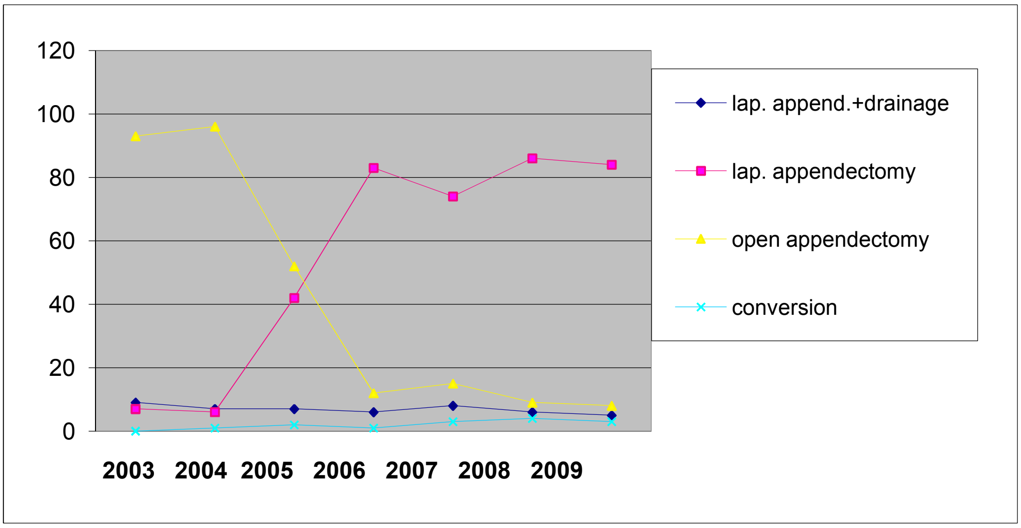

Figure 3. Changes in operation technique between 2003 and 2009

After the introduction of the laparoscopic technique, the indication for open surgery became limited. We decided to use the traditional technique to avoid the increase in abdominal pressure in 2 old patients with poor cardiorespiratory status, and we also chose the conventional technique in patients with a history of several abdominal surgeries. The severity of the inflammation had no influence on the decision made by our surgeons. Conversion was performed in 14 cases, thus representing an average conversion rate of 3%. The appendix was not visible because of adhesions due to prior surgery in 5 cases, whereas in 9 cases, the surgeon deemed that the stump of the appendix could not be secured safely with the laparoscopic procedure because of the severity of the inflammation.

The surgeons performing the procedures were divided into four groups based on their surgical experience (1 – resident, 2 – candidate consultant, 3 – young consultant, 4 – head surgeon on duty). For the number and type of procedures performed by each group, see ***Figure 4.***

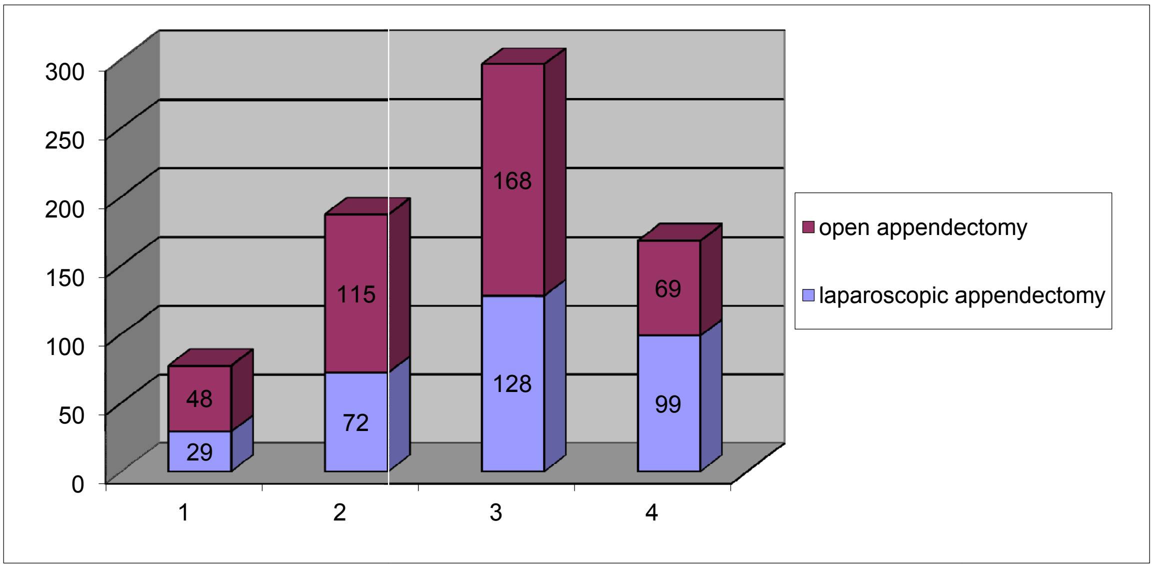

Figure 4: Number of open vs. laparoscopic appendectomies in Groups 1–4 (1 – resident, 2 – candidate consultant, 3 – young consultant, 4 – head surgeon on duty).

It is evident that almost half of the procedures were performed by young consultants in both the open and the laparoscopic group (296 cases out of a total of 728 surgeries, 43% of the open surgeries, 39% of the laparoscopic procedures). Candidate consultants and residents also performed a large number of appendectomies (Group 1: open – 9.7%, laparoscopic – 11.1%; Group 2: open – 24.1%, laparoscopic – 26.7%), naturally under the supervision of a consultant surgeon in every case (the assistant belonged to Group 4 and Group 3 in 82% and 18% of the cases, respectively).

We assessed the mean duration of the procedure for each surgical technique. The mean duration of the procedure was 62.41 (25–200) minutes in the laparoscopic group and 60.81 (20–160) minutes in the open group, and there was no significant difference between the groups in this regard (p=0.405) (***Figure 5).***

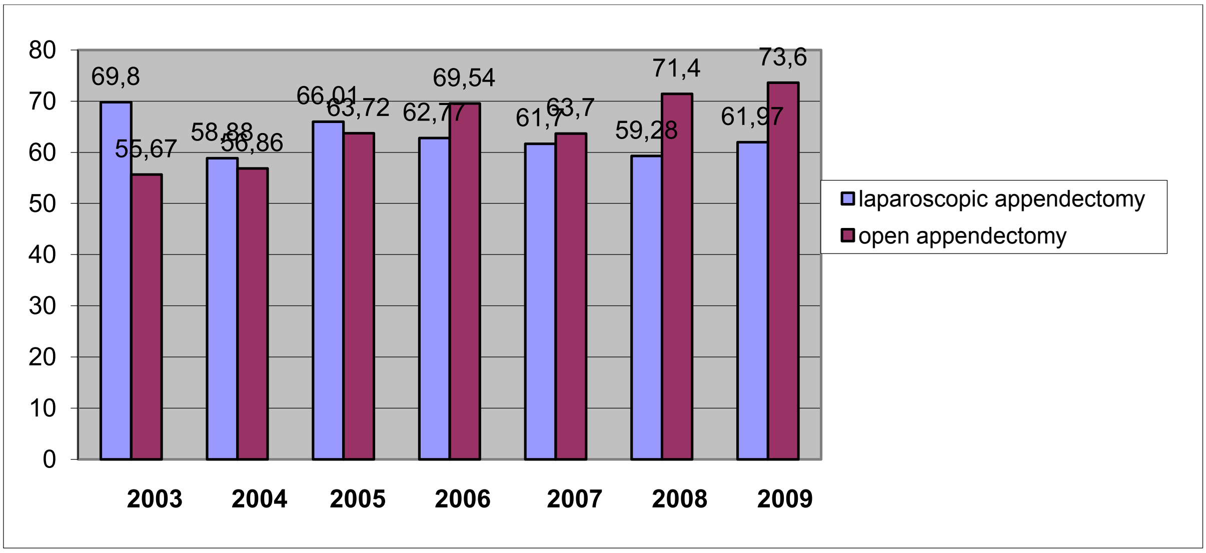

Figure 5: Operation time in LA (total: 62.41 min) and OA (total: 60.81 min) groups p=0.405 (p<0.05)

4.2.3. Histological findings

A histological result was available after every intervention. Based on the histological examination, the number of mild cases (simple/superficial acute appendicitis) was 84 (11.5%) in the open group and 107 (14.6%) in the laparoscopic group (p=0.72). Severe inflammation (ulcero-phlegmonous, gangrenous or perforated appendicitis) was found in 195 cases (26.7%) in the OA group, and 249 cases (34.2%) in the LA group (p=0.32). The histological examination revealed a non-inflamed appendix in 64 cases ***(Table 11).*** In the laparoscopic group, two-thirds of the positive histological results showed severe inflammation on histological examination. Perforation and peritonitis was found in 51 cases (7%) in the open group and in 43 cases (6%) in the laparoscopic group. In these cases, conversion from laparoscopy was required on 12 occasions (1.6%).

	OA	LA	P
Superficial inflammation	84 (11.5%)	107 (14.6%)	0.27
Severe inflammation	107 (14.6%	249 (34.2%)	0.12
Chr. appendicitis	4 (0.5%)	3 (0.4%)	0.62
Fibrosis, melanosis	6 (0.8%)	8 (1.1%)	0.27
carcinoma	3 (0.4 %)	5 (0.7%)	0.43
sine morbo	22 (3%)	42 (5.7%)	0.32

Table 11. Histopathological findings (p<0.05)

4.2.4. Clinical data in open vs. laparoscopic groups: intraoperative blood loss, duration of antibiotic therapy, length of hospital stay, time to first bowel movement, and fever

With regard to clinical data, we evaluated intraoperative blood loss, duration of antibiotic treatment, presence of fever, time to first bowel movement, and length of hospital stay in the two surgical groups. Intraoperative blood loss was 45 (20–150) mL for the open technique and 55 (25–145) mL in the laparoscopic group (p=0.505). In the open group, the patients were given antibiotics for an average of 3.96 (1–10) days, whereas the same parameter was 2.6 (1–6) days for the laparoscopic surgeries (p=0.01). Time to first bowel movement was 2.52 (1–5) days in the open group and 1.74 (1–4) days in the group that received the minimally invasive technique (p=0.02). The length of hospital stay was 5.64 (3–18) days in the OA group and 3.25 (2–7) days in the LA group (p=0.04) ***(Table 12).***

	OA	LA	P
Intraoperative blood loss (ml)	45	55	0.505
Length of AB use (days)	3.95	2.6	0.01
First bowel movement (days)	2.52	1.74	0.02
Hospital stay (days)	5.64	3.25	0.04

Table 12. Comparison of clinical outcomes (p<0.05)

4.2.5. Surgical complications in the open vs. laparoscopic groups

The surgical complications were classified into major and minor ones. The number of major complications that required reoperation was 20 (2.1%) in the open group and 8 (0.8%) in the laparoscopic group. Minor complications were observed in 20 patients (2.7%) in the OA group and in 8 patients (1.1%) in the LA group. On the whole, there was a significant difference between the two procedures with regard to the number of complications (p=0.034) ***(Table 13).*** With regard to minor complications, wound infection should be noted. It occurred in 15 cases in the open group, and in 6 cases in the laparoscopic group (p=0.025). These patients regularly attended our outpatient clinic for a dressing change for an average of 3 weeks. With regard to the procedures performed by surgeons in Group 1, major complications arose in 5 cases, whereas the number of major complications was 3 in the case of experienced surgeons. This ratio was 12 to 8 in the open group. No significant difference was found between the two groups of surgeons in terms of the complication rate (p=0.2). With regard to long-term complications (occurring >3 months after the procedure), surgery was required for hernia in 4 cases and for suture granuloma in 1 case in the open group, whereas postoperative hernia occurred in two patients, and intervention was needed for suture granuloma in 2 patients in the laparoscopic group. There was no significant difference between the groups with regard to late complications (p=0.664).

Major complications	**OA**	**LA**
Ileus	9	2
Postop. bleeding	6	3
Appendix stump insufficiency	3	0
Abscess	2	2
Thermic injury	0	1
Minor complications		
Subcutaneous hematoma	5	2
Wound infection	15	6
Total	40 (5.4%)	16 (2.1%)
		p=0.034

Table 13. Major and minor complications in OA and LA groups (p<0.05)

4.3. Learning curve period after rapid introduction of laparoscopic appendectomy, considering the risks of surgical resident participation in the procedure (Study 3)

4.3.1. Patient characteristics

Data was evaluated for 600 patients in total between 2006 and 2009. The mean age of the patients was 38.4 years (A1: 39.6, A2: 39.3, p=0.321; B1: 39.1, B2: 35.9, p=0.273). Gender distribution: A1 – female: n=53, male: n=47; A2 – female: n=119, male: n=100; B1 – female: n=65, male: n=35; B2 – female: n=98, male: n=83. With regard to comorbidities (ASA score III to IV, severe cardiac disease, COPD, DM, underlying tumor disease, and chronic renal failure): A1: n=10, A2: n=16, p=0.393; B1: n=12, B2: n=16, p=0.281. We may thus consider these patient groups homogeneous ***(Table 14).***

Demographics by subgroup				
		A1 (n=100)	**A2 (n=219)**	**p**
Gender (n)				
	female	53	119	0.283
	male	47	100	0.326
Age (years)		39.6	39.3	0.895
Comorbidities(n)		10	16	0.384
		B1 (n=100)	**B2 (n=181)**	**p**
Gender (n)				
	female	65	98	0.438
	male	35	83	0.245
Age (years)		39.1	35.9	0.263
Comorbidities(n)		12	16	0.654

A1: residents during the learning curve, A2: residents after the learning curve, B1: consultants during the learning curve, B2: consultants after the learning curve

Table 14. Patient characteristics (A1: resident learning curve period; A2: resident routine use period; B1: consultant learning curve period; B2: consultant routine use period)

4.3.2. Surgical procedures in Group A (residents) and Group B (consultants) in the learning curve and routine use periods: number of surgeries and operation time

As to duration of surgery, we evaluated whether there was a difference during the learning curve period between residents (A1) and consultants (B1), if there was a difference between the two groups after the learning curve (A2 vs. B2), and how duration of surgery changed over time for residents and consultants (A1 vs. A2, B1 vs. B2). We also investigated the effect of the severity of inflammation on operation time in each subgroup.

The mean duration of surgery was 74.6 min in Group A1 57.3 min in Group A2, 64.13 min in Group B1 and 53.38 min in Group B2 ***(Figure 6).***

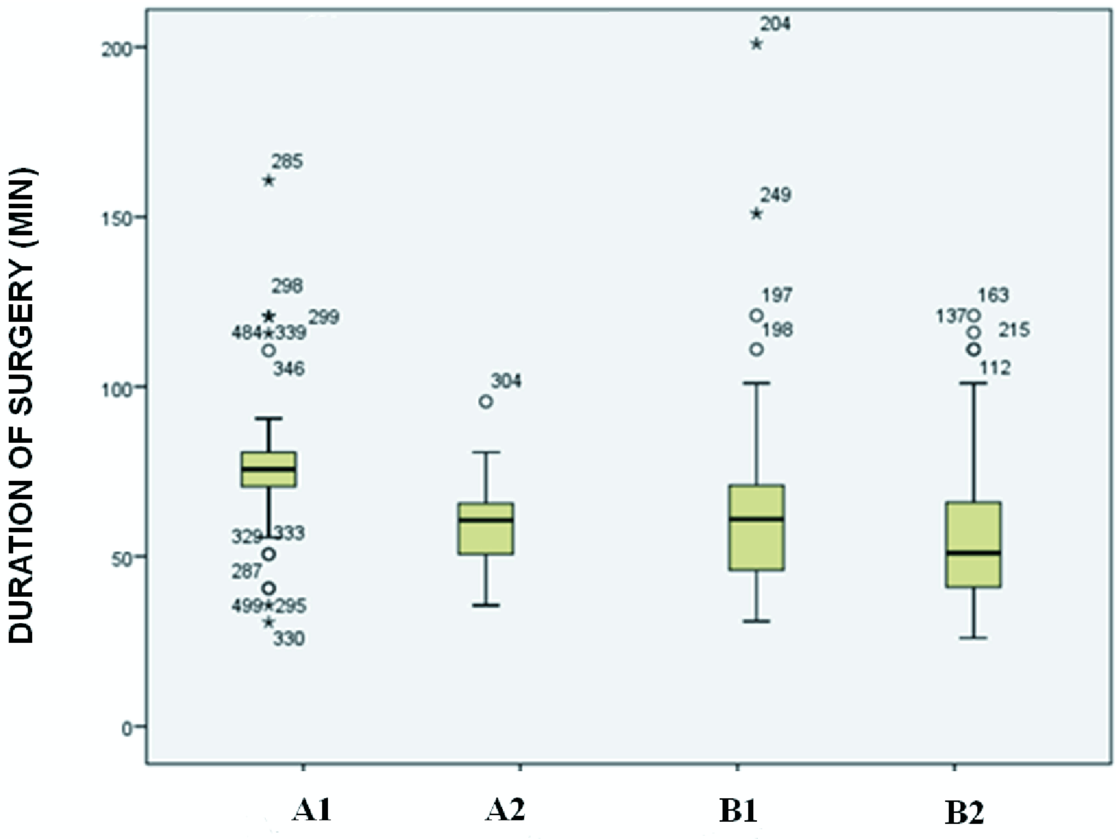

Figure 6. Duration of surgery by subgroup

When comparing the mean duration of surgery between residents and consultants in the learning curve period, we found a significant difference found between the groups (A1 – residents: 74.6 min vs. B1 – consultants: 64.13 min, $p<0.05$). The same was observed when we compared the groups after the learning curve period (A2 – residents: 57.3 min vs. B2 – consultants: 53.38 min, p<0.05).

In the two main groups, we compared the change in duration of surgery, the learning "dynamic": in Group A, the duration of surgery decreased from 74.6 minutes to 57.3 minutes (p<0.05), while a drop from 64.13 minutes to 53.38 minutes was observed in Group B (p<0.05) ***(Figure 7).***

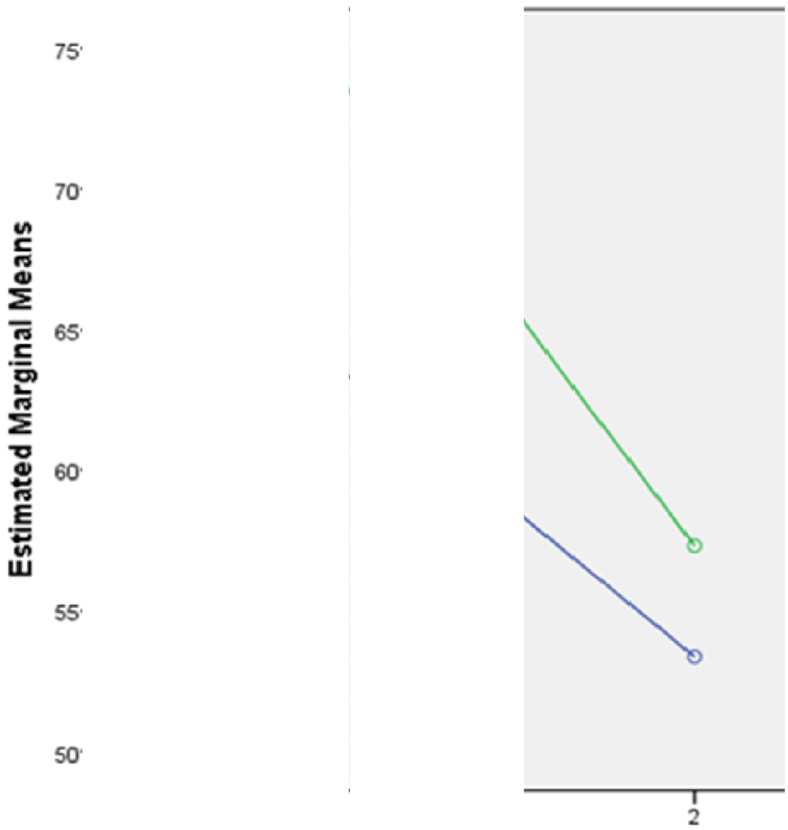

Figure 7. Dynamic for the duration of surgery in the learning curve period (1) and afterward (2) for residents (green line) and consultants (blue line).

When investigating the effect of the severity of inflammation on operation time, we found a significant difference between the subgroups. In Group A (residents), operation time was 61.4 min for early appendicitis with less severe inflammation (catarrhal, phlegmonous) vs. 74.8 min for severe inflammation (gangrenous, perforated) (p<0.05) ***(Figure 6).***

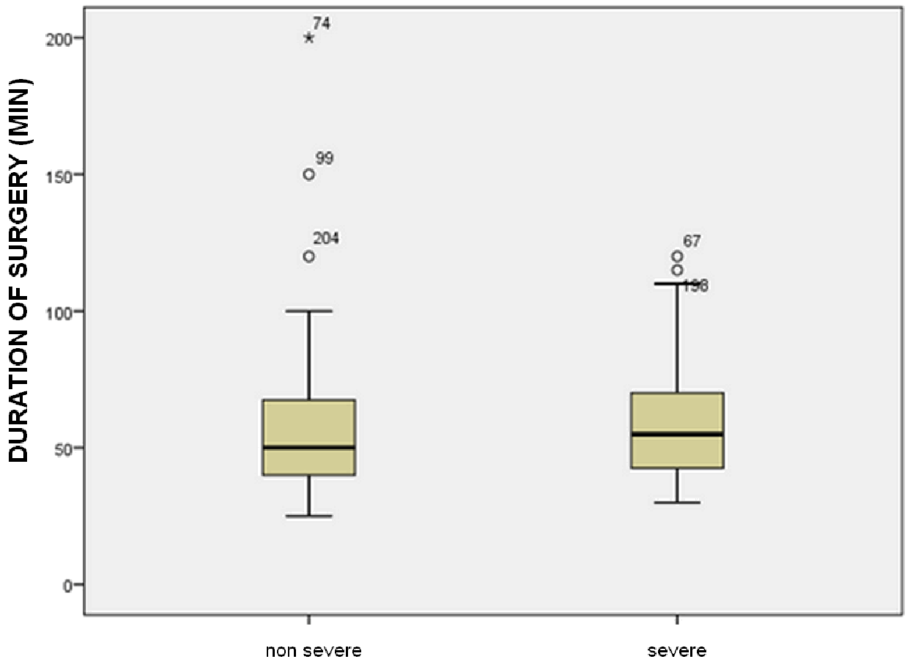

Figure 6. Duration of surgery depending on the severity of inflammation in Group A (residents)

This value was 53.4 min vs. 68.5 min for Group B (consultants) ($p<0.05$) ***(Figure 7).***

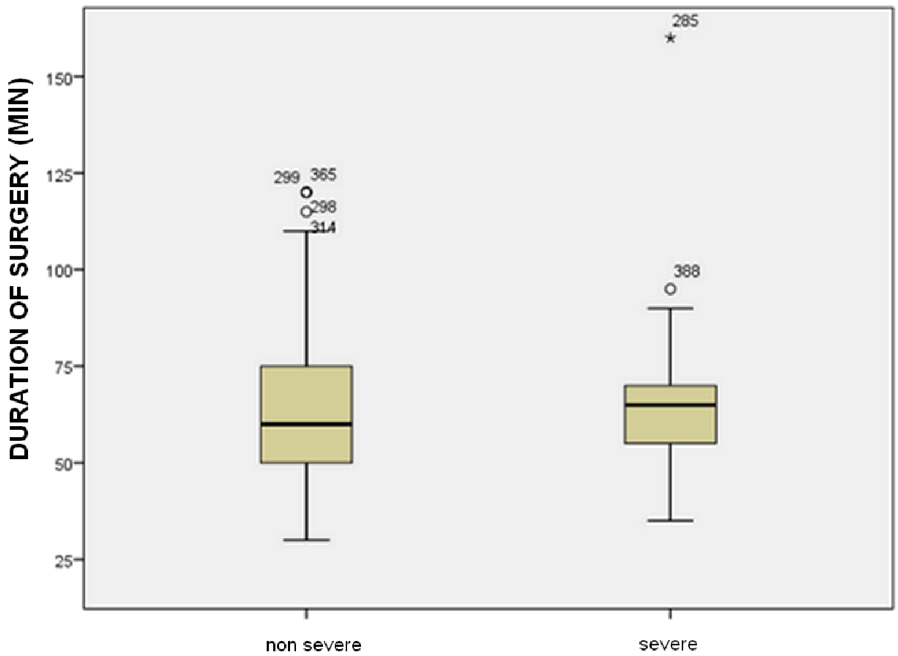

Figure 7. Duration of surgery depending on the severity of inflammation in Group B (consultants)

In the learning curve period, operation time was 58.49 min for early appendicitis and 70.12 min with severe inflammation; in the routine use period, it was 56.13min vs. 63.34 min. We found that the severity of the inflammation significantly affected the duration of the operation when comparing Groups A and B in the LC period vs. the routine use period.

4.3.3. Clinical data in Group A (residents) and Group B (consultants) in the learning curve and routine use periods: intraoperative blood loss, conversion rate, length of hospital stay, and negative appendectomy rate

We evaluated intraoperative blood loss in the two main groups: it was 55 mL in Group A and 45 mL in Group B, and there was no significant difference (p=0.664). In Group A, conversion was required in 18 cases (5.6%) (adhesions due to prior surgeries [n=6], perforated, gangrenous appendix, the stump of which could not be treated safely with laparoscopy [n=12]), while this number was 21 (7.4%) in Group B (adhesions [n=13], the stump could not be treated safely due to severe inflammation [n=6], extreme obesity [n=1], and mesenteric injury during insufflation [n=1]; p=0.321). We also assessed whether the conversion rate was higher in the learning curve period: conversion was required in 14 out of 200 surgeries (7%) in LC period subgroups A1 (residents) and B1 (consultants), while this number was 25 out of 400 (6.25%) in routine use subgroups A2 (residents) and B2 (consultants), without a significant difference between the early and late periods (p=0.522). In addition, there was no significant difference in hospital stay between the groups (3.21 vs. 3.84 days, p=0.391, non-perforated group: Group A: 2.34 days; Group B: 2.13 days. Perforated group: Group A: 4.78 days; Group B: 4.98 days). The two groups did not differ in negative appendectomy rate (NAR, 8.5% vs. 7.8%, p=0.835) either ***(Table 15).***

	A (n=200)	B (n=400)	P
Blood loss (ml)	55	45	0.664
Conversion rate (n [%])	18 (5.6%)	21 (7.4%)	0.321
Hospital stay (days)			
non-perforated appendicitis	2.34	2.13	0.812
perforated appendicitis	4.78	4.98	0.734
Negative appendectomy rate (NAR, %)	8.5%	7.8%	0.835

Table 15. Comparison of clinical data in Groups A and B

4.3.4. Surgical complications in Group A (residents) and Group B (consultants) in the learning curve and routine use periods

The groups were also compared in terms of complications during and after the learning curve period. Early (within 30 days) major complications (bleeding, ileus, abscess, and thermal injury, which require reoperation), minor complications (wound infection), and late (after 30 days) complications (postoperative hernia) were assessed. There were no mortalities. The types and occurrence of complications are shown in ***Table 16.*** In comparing the frequency of complications between subgroups A1 and B1 (5 vs. 9; 5% vs. 9%), it can be concluded that the occurrence of complications in the learning curve period was independent of surgical experience (p=0.238).

			A1 (n=100)	A2 (n=219)	B1 (n=100)	B2 (n=181)
Early						
	Major					
		Ileus	0	1	0	2
		abscess	1	1	2	1
		bleeding	1	1	2	2
	Minor	(wound infection)	3	5	3	9
	Late		–	2	2	2
	Total (n [%])		**5 (5%)**	**10 (4.6%)**	**9 (9%)**	**17 (9.3%)**

Table 16. Complications in Groups A and B (A1: residents during the learning curve; A2: residents after the learning curve; B1: consultants during the learning curve; B2: consultants after the learning curve)

5. Discussion

5.1. Challenges in diagnosing acute appendicitis with the growing number of A&E units

Despite advances in imaging procedures and laboratory analyses, diagnosing appendicitis is still a very difficult task, especially for candidate consultants and young colleagues. In addition, patients with right lower abdominal complaints suspected of having appendicitis are first assessed primarily by non-surgical residents or specialists in the growing number of emergency care centers (A&E Units). The failure of the initial examining physician to refer the patient for a surgical evaluation can lead to a delay in the treatment of acute appendicitis, which increases the risk of perforation and other complications. In the U.S., 6–8% of patients at the Emergency Department have abdominal pain. Although several studies have found that there is no significant difference in the accuracy of diagnosis by surgical and non-surgical residents, it would be necessary to assist these young colleagues in knowing when to request consultation from a specialist surgeon for patients with suspected appendicitis ***(11, 12).*** In past years, numerous clinical scoring systems have been created to make it easier to diagnose the condition. The best known is the Alvarado score (MANTRELS) score. The Paediatric Appendicitis Score (PAS), the Appendicitis Inflammatory Response Score (AIR), the Raja Isteri Pengiran Anak Saleha Appendicitis Score (RIPASA), and the Adult Appendicitis Score (ASA) are also well-known scoring systems. These scores can be used as a diagnostic tool, which can aid young surgeons and emergency physicians, but they are inferior when compared to the diagnostic accuracy of experienced specialist surgeons ***(13).***

Of course, imaging procedures may also assist us. Ultrasound scan is a quick, inexpensive, repeatable procedure. It is excellent for a differential diagnosis of gynecological conditions, but this modality is examiner-dependent ***(10).*** An abdominal ultrasound scan is also routinely performed at our clinic for suspected appendicitis. With the addition of the result from the abdominal ultrasound scan, the Alvarado score could be refined, thus increasing its reliability. A CT scan provides an even more accurate picture of the lesion and reduces the number of negative appendectomies, but it is expensive and involves exposure to radiation. Its specificity rates between 76 and 100%, and its sensitivity is between 81 and 98% ***(22).*** A recent American meta-analysis compared the costs of an ultrasound–CT protocol (on-demand CT) and a CT-only protocol for appendicitis evaluation. They found that an ultrasound–CT protocol for appendicitis evaluation offers potentially large saving over the standard CT-only protocol. Urgent surgery was performed without a CT scan when ultrasound ($88) confirmed acute appendicitis. In problematic cases, they requested a CT scan ($547). The cost savings for the total U.S. population was $24.9 million per year, and the ultrasound resulted in significantly less radiation exposure for the patient ***(23).***

5.2. The role of the Alvarado score in diagnosing acute appendicitis

In past years, numerous clinical scoring systems have been created to facilitate the diagnosis of the condition. The best known is the Alvarado score (MANTRELS score), which was created in 1986 by Alvarado, who processed data on appendectomy patients retrospectively. It contains eight diagnostic criteria (data from patient's history: migration of right iliac fossa pain, nausea/vomiting, and anorexia; physical examination: tenderness in the right iliac fossa, rebound tenderness in the right iliac fossa, and elevated temperature; and laboratory values: leucocytosis and shift of neutrophils to the left). The therapy algorithm depends on the Alvarado score of the patient (1 to 4 points: discharge; 5 to 6 points: observation and repeated scoring in 12 hours; 7 to 10 points: urgent surgery) ***(Table 1).*** The Paediatric Appendicitis Score (PAS), the Appendicitis Inflammatory Response Score (AIR), the Raja Isteri Pengiran Anak Saleha Appendicitis Score (RIPASA), and the Adult Appendicitis Score (ASA) are also well-known scoring systems. The role of these studies has been investigated in many retrospective and prospective studies. These scores can be used as a diagnostic aid and can assist young surgeons and emergency physicians, but they are inferior when compared to the diagnostic accuracy of experienced specialist surgeons ***(12).***

The Alvarado score is the most often used score in clinical settings. Numerous studies have confirmed the reliability of both the Alvarado score and the modified Alvarado score (MAS) in the diagnosis of appendicitis ***(24, 25, 26).*** According to a recent review, a cut-off value of 5 points in the scoring system is an excellent tool for deciding whether the patient should be discharged or provided with further treatment (observation and/or surgery). In the case of a higher score, consultation with a surgeon is required to make the decision on further therapy. When our sensitivity-specificity values were plotted with Youden's index, a similar result was reached. The so-called grey zone was between 5 and 6 points. In these cases, further observation or an imaging procedure (CT) is needed to confirm the diagnosis. According to some studies, a value above 7 points is the diagnostic criterion for an urgent surgery and the number of negative appendectomies decreases below 16% ***(27, 28, 29, 30).*** According to other studies, the conventional clinical judgment is more reliable with regard to the indication for surgery, and the number of negative appendectomies in these cases is about 12% ***(31, 32, 33).*** In our study, the specificity of the conventional clinical judgment was higher than that of the Alvarado scoring system, but the difference was not significant (94.8% vs. 88.9%, p=0.32). In Group A, 8 (8.42%) negative appendectomies were performed, whereas this number was 5 (3.62%) in Group B (p=0.16). According to the most recent systematic review, the Alvarado score over-predicts for women; however, no difference between the genders was found in our study.

We have found the score to be reliable in the diagnosis of the condition and that it assists the staff at the emergency outpatient clinic, primarily in the decision on admission/discharge and on consulting a specialist.

We attempted to refine the Alvarado score based on our own clinical experience. We created a new score using linear regression by weighting certain parameters from the conventional Alvarado score and opting in new parameters that had not been part of the score before but are important based on our clinical experience (rectal-axillary temperature difference and indirect signs). It has become easier to use the new scoring system; it involves fewer criteria, and an important and sensitive predictor, the result from the ultrasound scan, has been added.

5.3. The role of laparoscopic appendectomy in treating acute appendicitis

Appendicitis is the most common urgent surgical condition. Although 30 years have now passed since the introduction of the laparoscopic technique, numerous studies are still being conducted on the advantages and disadvantages of the procedure, compared with open appendectomy ***(34–37).*** Based on the studies published to date, laparoscopy has numerous advantages over the traditional procedure with regard to length of hospital stay, postoperative pain, and infectious complications ***(38–41).*** According to another author, the minimally invasive technique has no advantages over the open method, and its costs are higher than those of conventional appendectomy ***(42).***

In 2005, we managed to quickly introduce the laparoscopic technique into our clinical practice. Our conversion rate was 3%, which is lower than the average rate in the literature. Initially, the laparoscopic procedures were mainly performed by our experienced consultant surgeons, but our younger surgeons also began to use the minimally invasive technique more frequently after the so-called “learning curve” period. With regard to clinical data, significant differences were found between the two groups in the duration of the antibiotic treatment (3.95 and 2.6 days, p=0.01), time to first bowel movement (2.52 and 1.74 days, p=0.02), and the length of hospital stay (5.64 and 3.25 days, p=0.04). On the whole, there was a significant difference in the number of complications between the two procedures (open: 40; laparoscopic: 16; p=0.02).

According to the most recent meta-analyses, laparoscopy has several advantages over open surgery. B. Wei et al. evaluated data in 25 randomized studies conducted on a total of 4,694 patients between 1992 and 2010, and found that oral feeding can be introduced earlier, the hospital stay is shorter, and there were fewer postoperative complications after a laparoscopic procedure. The duration of the procedure, however, is longer in the case of the minimally invasive technique ***(43).*** A Chinese meta-analysis performed on data from 44 randomized studies with a total of 5,292 patients found similar results ***(44).*** When reviewing the clinical data, we found that there was a significant difference between the two surgical techniques with regard to the length of hospital stay (OA: 5.64 days; LA: 3.25 days; p=0.004), the duration of antibiotic treatment (OA: 3.95 days; LA: 2.5 days; p=0.001), and time to first bowel movement (OA: 2.52 days; LA: 1.74 days; p=0.02) as well. In the case of the minimally invasive intervention, therefore, patients can leave the hospital and return to their everyday routine earlier. Oral feeding can be started earlier because of the shorter time to bowel movements. The shorter duration of treatment and the lower need for medications decrease expenses for the health care provider. Contrary to the results of the meta-analyses, however, we did not find a significant difference in the duration of the procedure between the two techniques (LA: 62.41; OA: 60.81 minutes; p=0.405).

The laparoscopic technique was found to be more advantageous than the conventional procedure even with regard to the number of complications (OA: 40; LA: 13; p=0.001). When using the minimally invasive technique, the surgeon can remove the inflamed appendix with as little bowel manipulation as possible, thus preventing the development of postoperative ileus. The small incisions limit the possible pathways of infection, decreasing the risk of wound infections. In our study, the number of wound infections was 16 in the OA group (5%) and only 5 in the LA group (1,3%); we can consider this difference significant (p<0.01). Another centrally debated question regarding the role of laparoscopy is the problem of intra-abdominal abscesses (IAA). Some studies have shown that the formation of IAA is significantly higher in LA ***(45),*** but recent studies have proved that peritoneal irrigation is shown to be a risk factor for the development of postoperative IAA after LA in the case of abdomen contamination and that it can be performed thoroughly in LA as well. When peritoneal irrigation is performed, surgeons should consider using peritoneal drainage and postoperative antibiotics (including anti-anaerobic antibiotics) to prevent postoperative IAA formation ***(46).***

In 2005, the year in which the procedure was introduced, complications occurred in 4.5% of the annual number of laparoscopic surgeries, whereas this figure was 4.2% in 2009. Based on this, we can conclude that the technique can already be used safely in the learning curve period. When assessing the duration of the procedure and the surgical complications in relation to surgical experience, we found no difference between the data from 2005 and those from 2008 and 2009 (2 complications in 2005, mean duration of the procedure: 66 minutes; 2 and 4 complications in 2008 and 2009, respectively, mean duration of the procedure: 59.28 and 61.97 minutes, respectively). The minimally invasive technique, therefore, can be used safely by surgeons with less experience, naturally under the appropriate supervision of a consultant.

Another great advantage of laparoscopy is the possibility of exploration. Through small incisions, the entire abdominal cavity and the lesser pelvis can be explored, and other lesions causing complaints (most commonly, gynecological conditions) can also be treated with this method. Diagnostic laparoscopy, though invasive, can be both diagnostic and therapeutic. Laparoscopy has also been found to be useful in childbearing women with RLQ pain. In a prospective study by Larsson et al., 110 childbearing women with suspected appendicitis were randomized into open or laparoscopic groups. In 73% of the LA group, a gynecological diagnosis was found instead of appendicitis, while this number was only 17% in the OA group ***(47).***

The question is frequently raised whether cases with severe inflammation and perforation can be treated safely with the minimally invasive technique. Massoomi et al. assessed the NIS (Nationwide Inpatient Samples, USA) data from the period between 2006 and 2008, comparing the results of the two surgical techniques in cases of appendicitis with mild and severe inflammation (causing even perforation). They found that, in both groups, the number of complications was smaller, the hospital mortality was lower, and the hospital stay was shorter in the laparoscopic cases ***(48).*** We found a similar result when assessing the data on our patients: in the laparoscopic group, two-thirds of the positive histological results showed severe inflammation on histological examination. Perforation and peritonitis were found in 51 cases (7%) in the open group, and in 43 cases (6%) in the laparoscopic group. In these cases, conversion from laparoscopy was required on 12 occasions (1.6%). It must be noted that 57% of all wound infections occurred in those open surgeries where perforation of the appendix and peritonitis were observed. Significantly fewer complications were observed when the cases with severe inflammation were treated with the minimally invasive technique (compared to the open group); therefore, this procedure can also be used safely in cases of severe inflammation and complicated appendicitis.

We should note here that our mean conversion rate was 3% in the study period, which is lower than the average value in the literature (8.6%) ***(34).*** In nine cases (64%), we decided on conversion because of the severity of the inflammation, whereas in 5 cases (36%), the appendix could not be removed with the laparoscopic technique because of adhesions due to prior surgery. The surgeons in Groups 1 and 2 performed conversion on 8 occasions, whereas it was required on 6 occasions in Groups 3 and 4. Conversion, therefore, was determined by the severity of the inflammation and the technical difficulties (e.g., adhesions); the experience of the surgeon had no influence on it.

In conclusion, our results confirm that the quick introduction of laparoscopy poses no risks. We have shown numerous advantages of the method, such as shorter hospital stay, less need for antibiotics, shorter time to first bowel movement, and fewer major complications (requiring reoperation) and minor complications (the lower rate of wound infections should be noted here). This surgical technique can also be used by younger surgeons, since better results were achieved in this group than with the traditional method with regard to the duration of the procedure and the number of complications as well. Furthermore, LA is a valuable opportunity for young residents to safely master basic laparoscopic skills.

5.4. Resident participation in laparoscopic appendectomy – are there any disadvantages?

The minimally invasive technique was also introduced rapidly at our clinic, over a period of six months in 2006, and it completely superseded the open method. Considering the fact that appendicitis is an urgent surgical condition, it is frequently treated by young resident surgeons outside the day-shift hours under the supervision of a consultant. Initially, the "new technique" was mainly used by consultant surgeons (in 2005, 75% of the interventions were performed by them), whereas in 2008 and 2009, candidate consultants and residents performed an increasing number of laparoscopic surgeries under the supervision of consultant surgeons and head surgeons on duty (40% and 32%, respectively). The laparoscopic-to-open ratio in Group A was 0.22 before 2006 and 10.21 between 2006 and 2009. In Group B, the same ratio was 0.37 before 2006 and 4.8 after 2006. Therefore, it is also increasingly important to develop laparoscopic skills and learn basic minimally invasive procedures in training young surgeons at our clinic. This trend can be observed in the training program at foreign universities as well. In 2009, a multicenter study conducted in the United States and based on an international database showed that younger surgeons (from the second–third postgraduate years) perform significantly more laparoscopic interventions ***(49).*** Another multicenter study in the United States investigated the effect of resident participation in appendectomies on postoperative patient outcomes. This study contained patient data for more than 250,000 surgical procedures performed at more than 250 hospitals across the United States. They found that resident participation was an independent risk factor for major complications and that increasing the seniority of the participating resident increased the operating time and the number of postoperative complications ***(50).*** The spread of minimally invasive surgery is thought to be the reason; surgeons can develop basic laparoscopic skills earlier in the learning phase ***(51).*** However, there is still no clear evidence for the minimum number of laparoscopic cases to achieve proficiency. The EAES consensus guideline recommends a minimum of 20 operations ***(52).*** Some other retrospective studies also recommend 20–30 operations during the learning curve period ***(53–55).*** Numerous studies have analyzed the results of laparoscopic appendectomies performed by resident surgeons. The factors evaluated were duration of surgery, hospital stay in days, complications, and conversion rate.

In our study, we also evaluated these data, comparing the surgery results achieved by residents with those by consultants. In addition, the results of laparoscopic appendectomies performed by the two groups were compared in the learning curve period and thereafter.

Several studies have focused on the learning curve, that is, how many laparoscopic interventions under supervision are required for a resident to be able to perform surgeries independently. The learning curve period for laparoscopic appendectomy is short; a working group has found that 2.5 procedures on average are sufficient for independent practice ***(49).*** Other studies recommend 30 surgeries ***(56).*** Based on the 1994 EAES recommendation, in the case of laparoscopic appendectomy, 20 surgeries are to be performed under supervision in the learning curve period for independent practice, and this is supported by several studies ***(57, 58).*** Based on our own experience, this number of surgeries is necessary for a resident to be able to perform appendectomy independently. After the learning curve period (20 surgeries), there was a significant difference in mean duration of surgery both in the consultant group and the resident group (64.13 vs. 53.38 min and 74.6 vs. 57.3 min, respectively, $p<0.05$). According to our results, the severity of the inflammation affected operation time significantly.

The mean hospital stay in days is a good measure of laparoscopic experience, as this period is longer in the case of a prolonged, complicated surgery. A similar objective parameter is conversion rate. In our study, there was no significant difference between the learning curve period and the period after that either in hospital stay or conversion rate, nor was there any difference when comparing young surgeons with consultants. Conversion rate, therefore, was independent of laparoscopic experience. It was determined by the severity of the inflammation. Similarly to reports from other studies, conversion was required when the stump could not be treated safely because of the severity of the inflammation ***(50).***

Since, according to our results, there was no difference in the frequency of complications between subgroups A1 and B1 (5 vs. 9; 5% vs. 9%), the occurrence of complications in the learning curve period was independent of surgical experience ($p=0.238$). Based on the comparison between subgroups A2 and B2, after the learning curve period (10 vs. 17; 4.5% vs. 9.3%), the number of complications was lower in the case of the younger group; however, this drop was not statistically significant. In a recent multicentre study from the USA, the data for 54,467 appendectomies performed between 2005 and 2009 was analyzed. It was found that the duration of surgery is significantly longer and the number of major postoperative complications significantly higher in the case of surgeries performed by residents ***(56).*** Our sample size was much smaller, but we only observed a difference between the groups in duration of surgery. In the learning curve period, it was 74.6 min in subgroup A1 and 64.13 min in subgroup B1 ($p<0.05$), while it was 57.3 min in subgroup A2 and 53.38 min in B2 after the learning curve period ($p<0.05$). In the two main groups, we compared the change in duration of surgery, the learning "dynamic": in Group A, duration of surgery decreased from 74.6 minutes to 57.3 minutes ($p<0.05$), while in Group B, a drop from 64.13 minutes to 53.38 minutes was found ($p<0.05$). It is interesting that the decrease in duration of surgery after the learning curve period was greater among residents. As they performed an increasing number of surgeries, they used the laparoscopic instruments with ever greater confidence, and both the surgeon performing the surgery and the surgical staff felt more confident in the laparoscopic situation ***(51, 52).*** The more rapid improvement observed in the case of residents may be caused by the fact that, for many of them, laparoscopy was the primary surgical technique for appendectomy, as they had begun working in a period when the number of open appendectomies performed was small.

5.5. Laparoscopy training in the residency years

In Hungary, residents must complete a two-week "Basic laparoscopic skills course", where they learn the basics of laparoscopy in training boxes and have the opportunity to practice on live animals (splenectomy, appendectomy, cholecystectomy, and bowel sutures). However, the real training starts when they assist in basic (cholecystectomy, laparoscopic hernia repair, and appendectomy) and advanced (colorectal surgery, hiatal hernia repair, splenectomy, etc.) laparoscopic surgeries. The first laparoscopic procedure that they perform individually with the help of a supervisor (consultant) is mostly laparoscopic appendectomy. Through the six years of surgical residency training, each candidate must perform a fixed number of basic laparoscopic procedures (25 appendectomies and 20 cholecystectomies).

Learning these basic techniques is very important, as it may be of great assistance during their training to prepare them for subsequent, more complex laparoscopic surgeries. In many countries, residents must participate in laparoscopic training first, with the basic surgery types practiced on simulators. Furthermore, there is a need for an apprenticeship that involves courses using animal models. However, training with animal models remains limited because of the low number of such facilities and financial considerations. According to some studies, this training decreases subsequent intraoperative complications ***(53, 54).*** Others suggest that real procedures performed in the OR are required for the actual development of skills and for the resident to become a skilled surgeon ***(55).***

According to a U.S. survey, a large proportion of residents feel that they did not perform a sufficient number of laparoscopic procedures during their residency and therefore do not feel secure when they have to perform surgery independently ***(59, 60).*** As a result, in 2007–2008, the Accreditation Council of Graduate Medical Education increased the mandatory number of laparoscopic surgeries to be performed during residency training: from 25 to 60 for simpler, so-called basic procedures, and from 9 to 25 for more complex, advanced procedures ***(60).***

With the spread of laparoscopy, increased attention must be paid to the training of residents, and there is a need to implement standardized training models, as it is clear that, in our case, laparoscopic appendectomy is a technique that can also be used safely by residents in the learning curve period—naturally under the supervision of a consultant. Learning this technique provides residents with a valuable opportunity to perform more difficult, more complex laparoscopic surgeries with adequate safety in the future.

Summary and key results

1. *Based on our prospective, randomized clinical trial, the Alvarado score is a reliable tool in diagnosing acute appendicitis, and it aids the staff at the emergency outpatient clinic, primarily in the decision on admission/discharge and on consulting a specialist.*
2. *Furthermore, in our prospective randomized clinical trial, we created a new score using linear regression, by weighting certain parameters from the conventional Alvarado score and opting in new parameters we have found important based on our clinical experience (rectal-axillary temperature difference, indirect signs, and US investigation). It has become easier to use the new scoring system, as it involves fewer criteria.*
3. *Our results confirm that the quick introduction of laparoscopic appendectomy poses no risks. We have shown numerous advantages of the method compared to the traditional, open technique, such as shorter hospital stay, less need for antibiotics, shorter time to first bowel movement, and fewer major and minor complications. This surgical technique can also be used by young surgeons, since better results were achieved in this group than with the traditional method with regard to the duration of the procedure and the number of complications as well.*
4. *Laparoscopic appendectomy is a technique that can also be used safely by residents in the learning curve period—naturally under the supervision of a consultant. Learning this technique provides residents with a valuable opportunity to perform more difficult, more complex laparoscopic surgeries with adequate safety in the future.*

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