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ORIGINAL ARTICLE

Multivariate logistic model of hospital length of stay after appendectomy

Krstina Doklestić [1,2], Zlatibor Lončar [1,2], Zoran Bukumirić [1,3]

[1]Faculty of Medicine, University of Belgrade, Serbia
[2]University Clinical Center of Serbia, Clinic for Emergency Surgery
[3]Institute for Medical Statistics, and Informatics - Belgrade, Serbia

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Correspondence to:
Krstina Doklestić
University of Belgrade, Faculty of Medicine, Belgrade, Serbia
University Clinical Center of Serbia
Clinic for Emergency Surgery, Pasterova 2, Belgrade, Serbia
krstinadoklestic @gmail.com

Summary

Background: Appendectomies are interesting because they are the most common emergency abdominal operations, they are considered simple procedures, and the imperative is a quick recovery measured by hospital length of stay (LOS). However, this is not always the case in clinical practice, hospitalization can be prolonged, and the question is what factors affect it.

Methods: A multivariant logistic model of LOS predictors analyzed from the clinical data of 446 patients who underwent appendectomy at the Clinic for Emergency Surgery, Belgrade. The patients were divided into Short LOS group (SLOS hospital stay ≤3 days, 157 patients) and Long LOS group (LLOS hospital stay >3 days, 289 patients).

Results: Significant differences were found between SLOS and LLOS groups in age ($p<0.001$), comorbidities ($p=0.001$), preoperative WBC ($p = 0.004$); preoperative CRP ($p < 0.001$); peritonitis ($p < 0.001$), using ≥ 2 antibiotics ($p < 0.001$), complicated appendicitis ($p < 0.001$), surgical time ($P < 0.001$). No significant difference was found concerning gender, postoperative WBC, CRP, and complications ($p>0.05$). Patients who underwent laparoscopic appendectomy (LAP) had a statistically significantly shorter hospitalization time compared to those who underwent Mini-Incision Open Appendectomy (MIOA) ($p < 0.001$). The multivariate logistic model found three statistically significant predictors of longer hospitalization: CRP preoperatively ($B=0.006$, $p=0.047$), $OR=1.006$, the type of surgery ($B=1.199$; $p<0.001$), $OR=3.3$ complicated appendicitis ($B=0.762$; $p=0.003$), $OR=2.142$.

Conclusion: Surgical approach has statistically the most significant impact on LOS. Laparoscopic appendectomy is superior to Mini-Incision Open Appendectomy concerning the hospital LOS.

Key words: Hospital Length of Stay (LOS), Laparoscopic Appendectomy (LAP), Mini-Incision Open appendectomy (MIOA)

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INTRODUCTION

Despite advances in non-operative management of appendicitis, modern antibiotic therapy and precise imaging for monitoring patients, the standard of care for acute appendicitis is appendectomy (1) Appendicitis is one of the most common abdominal emergencies and appendectomy is one of the most common abdominal surgeries (2,3). The advantages of laparoscopic appendectomy (LA) over the open one have made it the gold standard today (4). Open appendectomy (OA) is still an option for cases of severe abdominal inflammation with a presentation of an acute abdomen, for patients with previous multiple abdominal operations due to adhesions, in cases of severe respiratory disorders, in case of technical deficiencies of the hospital, a lack of intensive perioperative care and an inexperienced surgical team. Two important indicators of the success of the treatment are the rate of postoperative complications and the length of hospital stay (LOS). The most common complications after appendectomy are wound infection, intra-abdominal abscess, ileus. Although appendectomy is considered a simple procedure and both LAP and OA are safe and effective techniques, the patient's recovery and the occurrence of postoperative complications depend on various factors (5). Recent studies indicate that laparoscopic surgery vs open appendectomy brings about a quick recovery and a shorter LOS (6).

We designed a study to reassess the treatment quality analyzing the LOS in patients who underwent appendectomy at the University Clinic for Emergency Surgery, considering hospitalization shorter than 3 days as a favorable outcome.

METHODS

This retrospective study analyses the clinical data that could have a significant impact on the hospital LOS of patients with acute appendicitis who underwent appendectomy between April 2020 and June 2022. at the Clinic for Emergency Surgery, University Clinical Center of Serbia, Belgrade. The study was approved by the Ethical committee of the University Clinical Center of Serbia, Belgrade (878/9). LOS was defined as the period of time from hospital admission to patient's discharge. The patients were divided into Short LOS group (SLOS, hospital stay ≤3 days) and Long LOS group (LLOS hospital stay, >3 days). We included 446 adult patients diagnosed with acute appendicitis which was indicative of emergency appendectomy. Diagnostic procedures and treatment protocols were standardized for all the patients including antibiotic therapy, premedication, surgical treatment, analgesia, nutrition. Depending on the admission time, operations were performed at any time during regular 24-hour shifts by surgical teams at the Clinic for Emergency Surgery. Two surgical approaches were used, laparoscopic and open appendectomy. Three Port Laparoscopic Appendectomy (LAP) was performed through one umbilical port (10 mm), suprapubic (5mm) and low left lateral port (10 mm) **(Figure 1 a, b; Figure 2 a, b, c)**. For managing the base of the appendix, we used titanium or polymer ligating clips **(Figure 1 a, b; Figure 2 a, b, c)**. LAP was the first option, but the definite decision about the type of operation was based on surgeons' assessment depending on the local findings of the severity of inflammation, the patient's condition, the status of Covid infection. Mini-Incision Open appendectomy (MIOA) was defined as the right lower quadrant incision, up to 3cm diameter.

The exclusion criteria were the following:

- Patients who were treated by nonoperative management, antibiotics, or percutaneous drainage as the first choice according to guidelines (3, 6).
- Patient who underwent medial laparotomy.

The diagnostic algorithm for acute appendicitis was as follows: clinical finding of abdominal pain, followed by nausea and vomiting, abdominal tenderness with maxi-

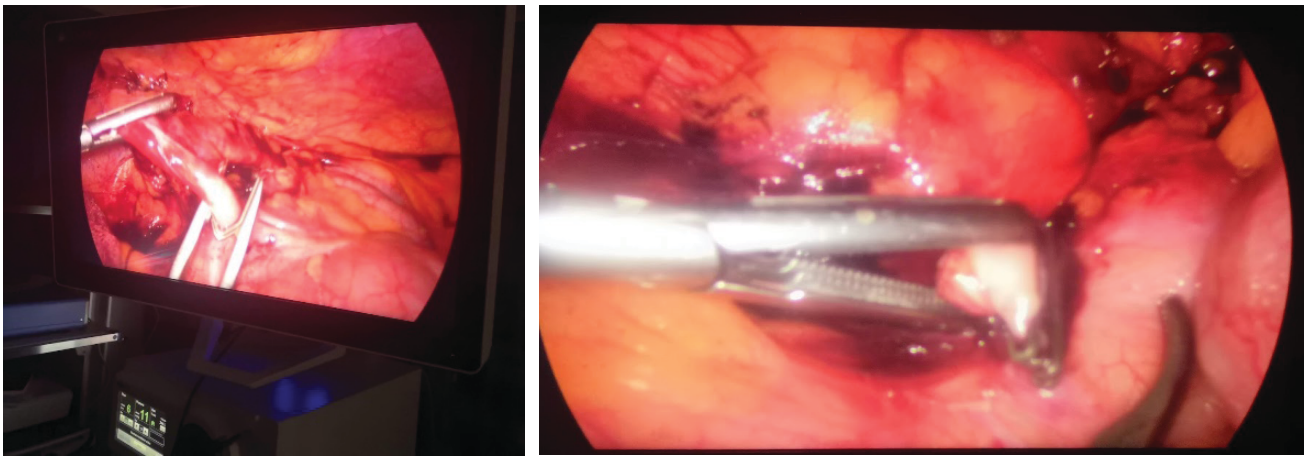

Figure 1. A. LAP-After vascular dissection, holding appendix near the base using a forceps introduced through 5 mm suprapubic port, before appendiceal stump treatment by titanium ligating clips. **B.** LAP- Management of the base of the appendix was completed, the appendiceal stump closure by titanium ligating clips through left lateral port was performed.

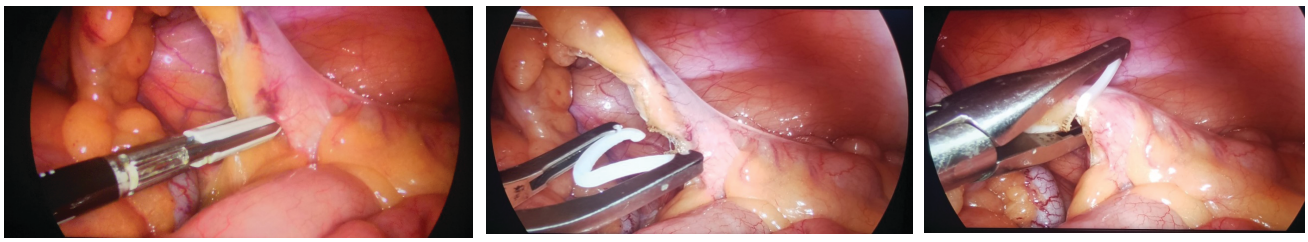

Figure 2.A. LAP -Vascular dissection of appendix. Figure 2. **B.** LAP - After vascular dissection, holding appendix before the appendiceal stump closure by polymer ligating clips. Figure 2. **C.** LAP – The appendiceal stump closure by polymer ligating clips.

mum pain in McBurney point, increased white blood cell (WBC) count, increased C-reactive protein (CRP) and positive ultrasound or abdominal Computed Tomography (CT) suggesting acute appendicitis. All procedures during the treatment were performed in accordance with the current medical and ethical standards. The multivariant logistic model predictors were patients' anonymous clinical data: sex, age, comorbidity, preoperative imaging diagnostics, preoperative laboratory value of WBC and CRP, intraoperative finding of peritonitis, pathological type of acute appendicitis, surgical time, postoperative complications, mono/dual antibiotic treatment. Surgical time represents the duration of the operation from the moment of surgical incision to the end of operation, measured in minutes. Acute appendicitis was defined as uncomplicated or complicated, which was determined by the presence of gangrenous appendicitis or perforated appendix with peritonitis, with or without an abscess. In all the cases of complicated appendicitis, we placed intrabdominal drainage, as the final step after appendectomy. Minor (Clavien-Dindo I, II) complications were postoperative nausea, wound infections, minor stump fistula, abscesses, all treated by non-operative management. Major complication defined as Clavien-Dindo III-IV needed re-intervention or ICU after appendectomy and included the following: postoperative bleeding, ileus, peritonitis (7).

STATISTICAL ANALYSIS.

Depending on the type of variables and the normality of distribution, data description is shown as n (%), mean±sd or median (min-max). Among the methods for testing statistical hypotheses, the following were used: t-test, Mann-Whitney test, chi-square test and Fisher's exact probability test. Univariate and multivariate logistic regressions were used to analyze the relationship between binary outcomes (hospitalization up to and over 3 days) and potential predictors. Multivariate regression models included predictors from univariate models that were statistically significant at the 0.05 significance level. Statistical hypotheses were tested at the statistical significance level of 0.05. The results are presented tabularly and graphically. All the data were processed in the IBM SPSS Statistics 22 (SPSS Inc., Chicago, IL, USA) software package.

RESULTS

Significant differences were detected between SLOS and LLOS groups in age (30.62 ± 11.09 years vs 35.92 ± 13.60, p<0.001), comorbidities (11.5% vs 24.2, p=0.001), preoperative WBC (12.57 ± 3.23 × 109/L vs 13.63 ± 4.31 × 109/L, p = 0.004); preoperative CRP (31.16 ± 36.88 mg/L vs 53.13 ± 54.11 mg/L, p < 0.001), peritonitis (37.6% vs 60.6%, p < 0.001), using ≥ 2 antibiotics (37.6% vs 60.6%, p < 0.001), complicated appendicitis (55.4% vs 73.7%, p < 0.001), surgical time (45.0 min vs 55.0 min, p < 0.01), type of surgery (p < 0.001) (Table 1). It this study 238 (53.4%) patients underwent LAP and 208 (46.6%) patients underwent MIOA. Patients who underwent laparoscopic surgery had a statistically significantly shorter hospitalization time compared to those who underwent an open surgery (p < 0.001) (Table 1; Figure 1a, b; Figure 2a, b, c). No significant difference was found concerning gender (p=0.432), preoperative imaging (p=0.316), postoperative CRP (p=0.082) and minor or major postoperative complications (p=0.655, p=0.167) **(Table 1)**.

In the multivariate logistic model with the LOS longer than 3 days, those predictors from the univariate models that were statistically significant at the significance level of 0.05 were included. The model contains 8 predictors that were compared to 446 respondents, 289 of which had the outcome of interest. The entire model with all predictors was statistically significant (p<0.001) **(Table 2)**.

In the multivariate logistic model, statistically significant predictors of hospitalization longer than 3 days were:

- CRP preoperatively (B=0.006, p=0.047), OR=1.006, which means that with an increase in CRP for a unit of measure, the chance of hospitalization longer than 3 days increases by 0.6%, while controlling all other predictors in the model.
- Type of surgery (open versus laparoscopic), (B=1.199; p<0.001), OR=3.3 shows that respondents who underwent MIOA had almost 3 times higher chance of hospitalization longer than 3 days, while controlling all other predictors in the model.
- Complicated appendicitis (B=0.762; p=0.003), OR=2.142, respondents who had complicated appendicitis had more than 2 times higher chance of being hospitalized longer than 3 days, with all other predictors in the model controlled.

Table 1. Comparison of characteristics between the two groups.

Characteristic	SLOS group n=157	LLOS group n=289	p
Age (year, mean ± SD)	30.62 ± 11.09	35.92 ± 13.60	<0.001
Sex, male (*n*, %)	80 (51.0%)	136 (47.1%)	0.432
Comorbidities (*n*, %)	18 (11.5%)	70 (24.2%)	<0.001
Preoperative WBC count (10^9/L, mean ± SD)	12.57 ± 3.23	13.63 ± 4.31	0.004
Preoperative CRP level median (range)	18.1 (0.6-240.5)	38.5 (0.6-292.5)	< 0.001
Preoperative US	139 (88.5%)	246 (85.1%)	0.316
Preoperative CT	18 (11.5%)	43 (14.9%)	
LAP	108 (68.8%)	130(45.0%)	< 0.001
MIOA	49 (31.2%)	159 (55.0%)	
Surgical time median (range)	45 (30-110)	55 (30-120)	< 0.001
Peritonitis (*n*, %)	59 (37.6%)	175(60.6%)	< 0.001
Complicated appendicitis (*n*, %)	87 (55.4%)	213 (73.7%)	< 0.001
Dual antibiotic therapy (*n*, %)	59 (37.6%)	175(60.6%)	< 0.001
WBC on the second postoperative day (10^9/L, mean ± SD)	8.016 ±2.09	7.492±2.25	0.016
CRP level on the second postoperative day median (range)	30.6 (0.6-195.0)	35.2 (0.6-210.9)	0.082
Clavien-Dindo I, II complications	10 (6.4%)	23 (8.0%)	0.655
Clavien-Dindo III-V complications	0 (0.0%)	5(1.7%)	0.167

Table 2. The multivariate logistic model for LOS.

Variables	B	p	OR	95% C. I.	
				Lower	Upper
Age	0.017	0.109	1.017	0.996	1.038
Comorbidity	0.225	0.508	1.253	0.643	2.440
Preoperative WBC count	0.008	0.793	1.008	0.951	1.069
Preoperative CRL level	0.006	0.047	1.006	1.000	1.012
Type of surgery	1.199	< 0.001	3.316	2.074	5.300
Peritonitis	0.463	0.053	1.589	0.991	2.547
Complicated appendicitis	0.762	0.003	2.142	1.302	3.526
Surgical time	0.011	0.223	1.011	0.993	1.030

DISCUSSION

Appendectomy is one of the most common interventions in emergency surgery (8,9). Experience from our clinic has confirmed that patients with acute appendicitis are most frequently hospitalized among emergency surgical patients. It is most often a disease of younger adults and an adequate treatment enables their quick recovery and early return to normal life. Elderly patients with appendicitis have a lower rate of complications if the diagnosis is made on time and adequate treatment is carried out (9).

Regardless of the severity of abdominal inflammation or the presence of comorbidity, the goal is always to make the patient's recovery as short as possible and without complications. LOS measured in days is the time elapsed from hospital admission to discharge. In clinical practice, we can expect that a patient's recovery and length of hospitalization may depend on the severity of the diagnosis itself. However, statistical analysis can provide a more accurate insight into the relationship between several clinical parameters and their outcome. LOS is considered as an adequate indicator of the effectiveness of the treatment, the quality of hospital treatment, including both the patient outcome and the cost of treatment (10-12).

In this study three factors were identified as significant predictors of LOS after emergency appendectomy. We made a predictive model based on multivariate regression factors of SLOS and LLOS for 446 patients undergoing appendectomy (Figure 1, 2). Study analyzed the influence of seventeen clinical parameters on the duration of hospital stay, as one of the indicators of the quality of treatment in patients who underwent emergency LAP or MIOA. During the two-year study time, it was not always possible to perform laparoscopy for objective reasons or to perform open surgery in conditions of Covid infection due to Covid protocol. Eight clinical parameters showed

a statistically significant influence on the LOS. Between different variables such as demographic data, laboratory data, pathohistological data, we found that the three most important predictors are: CRP preoperatively, type of surgery and severity of appendicitis. Finally, this statistical model showed that the type of surgery is the most important predictor of the LOS. Patients who underwent laparoscopic appendectomy had a statistically significantly shorter hospitalization time compared to those who underwent an open surgery ($p < 0.001$) **(Table 1, 2)**.

Laparoscopic appendectomy has become a gold standard owing to the results of randomized trials based on the comparison between LAP and open appendectomy (4-6). LAP is associated with lower morbidity, shorter operative time, less postoperative pain, and shorter hospitalization (4-6). However, in not so rare cases of severe neglected abdominal infection and peritonitis-ileus syndrome that occur as a consequence of complicated appendicitis, open appendectomy is still the conventional approach (5).

Although it is considered a simple procedure, it is obvious that in patients who underwent appendectomy, many factors could affect the outcome and LOS.

A large multicenter cohort study of 4618 patients identifies complicated appendicitis, morbidity, conversion, and reinterventions as significant risk factors for longer hospital stay after laparoscopic appendectomy, assuming that the median LOS was 3 days (13). Trunfio et al. showed that complications, severe diagnosis, and patients' age influenced LOS after LAP (14). Crandall et al. excluded a complicated case and the study of variables affecting LOS showed that LOS was significantly influenced by the operative time of day (15). In the study containing 636 patients who underwent LAP, Zhang et al. showed that LOS increased with patients' age, higher preoperative inflammatory markers, operation delay and the rate of complicated appendicitis with appendicolith (16). We also found that patients who underwent complicated appendicitis had more than a two times higher chance of being hospitalized longer than 3 days (Table 2). Similar to our results, but in the pediatric population, Cheong et al. found an association of the length of hospitalization with open appendectomy (17). In patients who underwent appendectomy, some authors have found that patients' demographic characteristics could have an influence on LOS (18).

According to different authors, the length of hospital stay after appendectomy can be influenced by complicated appendicitis, a surgery delay, the time of day when the surgery is performed, the skills of the surgeon or resident, the patient's age, the type of surgery (open vs. laparoscopic) (13-17). This study showed that older age, comorbidities, higher preoperative WBC and CRP, peritonitis, using ≥ 2 antibiotics, complicated appendicitis, longer surgical time, and open surgical approach significantly affect the length of hospitalization. It is important to mention that those predictors are measurable so their identification would help about a better clinical decision-making process.

CONCLUSION

This study was designed with the idea of improving the treatment of many patients hospitalized for emergency surgery due to acute appendicitis. Out of the seventeen analyzed parameters that can influence LOS, multivariant logistic model identified three predictors: CRP preoperatively, the type of surgery and the severity of appendicitis. This result is very close to our clinical experience. Finally, the statistical analysis showed that surgical approach has the greatest impact on LOS. Laparoscopic appendectomy is superior to Mini-incision Open appendectomy concerning the hospital LOS.

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MULTIVARIJANTNI LOGISTIČKI MODEL DUŽINE HOSPITALIZACIJE NAKON APENDEKTOMIJE

Krstina Doklestić[1,2], Zlatibor Lončar[1,2], Zoran Bukumirić[1,3]

Sažetak

Uvod: Apendektomije su zanimljive jer su najčešće hitne abdominalne operacije, smatraju se jednostavnom procedurom, a imperativ je brz oporavak meren dužinom boravka u bolnici (DBB). Ali to nije uvek slučaj u kliničkoj praksi, hospitalizacija se može produžiti, a pitanje je koji faktori na to utiču.

Metode: Multivarijantni logistički model prediktora DBB analiziran je na osnovu kliničkih podataka 446 pacijenata koji su podvrgnuti operaciji slepog creva na Klinici za urgentnu hirurgiju u Beogradu. Pacijenti su podeljeni u kratku DBB grupu (KDBB, ≤3 dana, 157 pacijenata) i u dugu DBB grupu (DDBB, >3 dana, 289 pacijenata).

Rezultati: Utvrđene su značajne razlike između grupa u pogledu starosti (p<0,001), komorbiditeta (p<0,01), preoperativoj vrednosti leukocita (p = 0,04); preoperativnom CRP (p < 0,001); peritonitisu (p < 0,001), primeni ≥ 2 antibiotika (p < 0,001), komplikovane upale slepog creva (p < 0,001), dužini trajanja operacije (P < 0,01). Nije nađena značajna razlika u odnosu na pol, postoperativne vrednosti leukocita, CRP i komplikacije (p>0,05). Pacijenti koji su bili podvrgnuti laparoskopskoj apendektomiji (LAP) imali su statistički značajno kraće vreme hospitalizacije u poređenju sa onima koji su bili podvrgnuti otvorenoj apendektomiji sa minimalnim rezom (OAMR) (p < 0,001). Multivarijantni logistički model je pronašao tri statistički značajna prediktora duže hospitalizacije: CRP preoperativno (B=0,006, p=0,047), OR=1,006, 95% CI (1,000-1,012), tip operacije (B=1,199; p<0,001), OR=3,3 95% CI (2,074-5,300), komplikovanu upala slepog creva (B=0,762; p=0,003), OR=2,142, 95% CI (0,284-0,768).

Zaključak: Hirurški pristup ima statistički najznačajniji uticaj na DBB. Laparoskopska apendektomija je superiornija od otvorene apendektomije sa minimalnim rezom u pogledu DBB.

Ključne reči: Dužinom boravka u bolnici (DBB), Laparoskopska apendektomija (LAP) Otvorena apendektomija sa minimalnim rezom (OAMR)

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